Coronavirus Accelerates Across Africa

The virus was slow to start in many African countries, but epidemiologists say the number of confirmed cases on the continent is now rising fast.

Health workers disinfecting a market in Toamasina, Madagascar, this month. Public health experts have warned that Africa could become the next epicenter of the Covid-19 pandemic. Rijasolo/Agence France-Presse — Getty Images

By Ruth Maclean

June 16, 2020

DAKAR, Senegal — When Daniel Khan Mbuh died in a hospital in northern Cameroon, the hospital declared the cause of death to be Covid-19 — then released the body to the family instead of arranging for a safe burial, his daughter Stella said.

Ms. Mbuh said she was told the house where she had been caring for her father in the city of Bamenda would be disinfected. Nobody came. When she tried to get tested, the hospital refused, saying there were not enough test kits. And she was never advised to self-isolate, so she simply imposed her own two-week quarantine on herself and her siblings.

“They said they are following contacts,” Ms. Mbuh said of health officials, “but I am one of the contacts. And I am not being followed.”

The spread of the new coronavirus is now accelerating in many countries in Africa, where medical resources are stretched, rumors are rife and efforts to stop the pandemic are sometimes haphazard.

Public health experts have warned that Africa could become the next epicenter of the Covid-19 pandemic.

The World Health Organization said last week that confirmed cases in Africa had doubled in 18 days to reach 200,000; the first 100,000 took 98 days.

“Even though these cases in Africa account for less than 3 percent of the global total, it’s clear that this pandemic is accelerating,” Dr. Matshidiso Moeti, the W.H.O.’s regional director for Africa, said in a video briefing last week.

She said that until there was a vaccine available, the continent would have to live with a steady increase of cases.

Workers disinfecting a gravesite before burying a man believed to have died from the coronavirus, at a cemetery in Nairobi, Kenya, last month. Brian Inganga/Associated Press

Most African nations staved off the initial spread of the virus for several months, partly by closing borders early, banning public gatherings and, in some countries, effectively tracing contacts using past experience of infectious diseases.

But the extra time this bought was not enough to bolster weak health care systems and to prepare for the predicted explosion of cases.

And now that many African countries, like others across the globe, are lifting their restrictions in order to restart their economies, the virus has new opportunity to spread and potentially, to overwhelm health care systems.

Nigerian doctors announced a nationwide strike starting on Monday over the lack of personal protective equipment in government hospitals and hazard pay for treating Covid-19 patients. Dozens of Nigerian health care workers have been infected, partly because they had no protective gear.

Epidemiologists at the Africa Centers for Disease Control and Prevention warned of a “catastrophic shortage” of health care professionals, and a drastic reduction of medical supplies because of border closures, price increases and restrictions on exports imposed during the pandemic.

“Africa needs to intensify its efforts to slow the spread of the pandemic,” they said in an article published last week in the journal Nature. They said that the continent needed financial support to stop the pandemic and tackle its economic and humanitarian effects.

A flight with humanitarian aid headed to Bangui, Central African Republic, being loaded by workers near Lyon, France, last month. Jeff Pachoud/Agence France-Presse — Getty Images

The early spread of the pandemic in many African countries was driven by foreigners and the economic elite: people from Europe, and those with the means to travel there.

It has continued to spread among elites. Ghana’s health minister caught the virus “in the line of duty,” the country’s president, Nana Akufo-Addo, said on Sunday. Four people in the Kenyan president’s office tested positive and have been taken to the hospital, according to a statement from the office.

However, what has often been perceived in Africa as a foreigners’ disease is increasingly reaching all sections of society. Testing is still extremely limited in most countries, so it is impossible to know how widely the pandemic has taken hold. But a month ago, the W.H.O. predicted that between 29 and 44 million Africans could become infected in the first year.

Truckers are carrying the coronavirus across borders, just as truckers had also spread H.I.V., the virus that causes AIDS. Countries now have set up border controls, which can intensify the points of contact and possible spread of infection.

In the border town of Garoua-Boulaï in the Central African Republic, dozens of truck drivers jostled outside a tarpaulin tent waiting to get tested for the coronavirus. Some wore masks, but many did not, or had pulled them down below their chins.

The Coronavirus Outbreak

- ## Frequently Asked Questions and Advice

  Updated June 16, 2020

  - **I've heard about a treatment called dexamethasone. Does it work?**

    The steroid, dexamethasone, is the first treatment shown to reduce mortality in severely ill patients, according to scientists in Britain. The drug appears to reduce inflammation caused by the immune system, protecting the tissues. In the study,

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They had to wait for many days for results until their samples could be driven 370 miles across the country to the capital, Bangui. But as they waited, other citizens crossed back and forth at the border without being checked. No truck, no problem.

Rumors and lack of information have also contributed to the spread. In Tanzania, President John Magufuli said that the country had eradicated coronavirus "by the grace of God." His government stopped releasing any data on cases after April 29.

In Madagascar, the president touted an unproven herbal drink as a cure.

In Nigeria, most of the public health messages have been released in English, which many Hausa speakers in the north do not understand.

Students at a high school in Antananarivo, Madagascar, preparing to drink bottles of Covid Organics, an herbal tea, in April. The tea has been touted by the country's president, Andry Rajoelina, as a powerful remedy for the coronavirus. Rijasolo/Agence France-Presse — Getty Images

In some countries, many say that hospitals, health authorities and governments are inflating their Covid-19 numbers in an attempt to attract extra funding, though there is little evidence to support such a claim.

In several cases, patients have run away from hospitals and quarantine centers; some believed themselves to be perfectly healthy, others objected to the conditions.

One man said he pulled into Bangui, two weeks ago when the bus he was on was stopped by police working with health authorities. He was tired and “felt malarial,” he said, and was pulled off the bus.

He tested positive and was hospitalized, but he said that the conditions were so bad that he ran away. He spoke on condition of anonymity, scared that the police would track him down.

“There was not enough water and very bad food,” he said. “They are still looking for me and I think that they would like to punish me, but they will never get me.”

Ruth Maclean reported from Dakar, Moussa Abdoulaye from Garoua-Boulaï, Central African Republic and Brenda Kiven from Douala, Cameroon.

Could Statins Reduce the Severity of COVID-19?

The cholesterol-lowering drugs quell inflammation and reverse endothelial tissue damage, hints that they might curb the body's excessive immune response to SARS-CoV-2 infection.

Ashley Yeager
Jun 12, 2020

ABOVE: © ISTOCK.COM, GANNET77

On March 21, epidemiologist Haleema Shakur-Still got a WhatsApp message from Temitayo Shokunbi, a colleague at the University of Ibadan in Nigeria. He asked about starting a trial for treating COVID-19 patients with the drug hydroxychloroquine. At the time, several trials were already in the works to investigate the effectiveness of the antimalarial to counter SARS-CoV-2, the virus that causes COVID-19, so Shakur-Still didn't think starting another one on the antimalarial would add much new information. She offered Shokunbi an alternative: test aspirin, statins, and anti-hypertensive drugs instead. These medications, Shakur-Still reasoned, could counter the intense inflammation and other tissue damage associated with COVID-19.

A growing amount of data shows that intense inflammation, blood clots, and stroke are some of the most severe symptoms of COVID-19. Decades of research have also shown that aside from lowering cholesterol, statins decrease inflammation, reduce blood clots, and prevent damage to endothelial tissue—the thin layer of cells that line blood vessels and other organs. That tissue also appears to be affected by COVID-19. There's also some evidence that statins act as antivirals. Because of those effects, epidemiologists such as Shakur-Still and other researchers want to see if statins could be a readily available treatment for COVID-19, a disease that has, so far, sickened more than 7.3 million people worldwide and killed 416,000.

Shakur-Still says Shokunbi told her: "Low- and middle-income countries are in for a potential catastrophe because of weak health infrastructure. Whatever can help needs to be done."

With Shokunbi on board, Shakur-Still, who works at the London School of Hygiene and Tropical Medicine, and her collaborators got to work devising a trial that will begin in the next few weeks. In it, COVID-19 patients coming to a treatment center either in Pakistan or Nigeria will be randomly assigned to receive aspirin, the cholesterol-lowering drug simvastatin, the anti-hypertensive losartan, a combination of the drugs, or standard of care. Another trial in Cambridge, Massachusetts, will test a similar cholesterol-lowering drug called atorvastatin, and there are a few other clinical trials underway that will look at the effects of statins on COVID-19.

"Effective treatments are needed urgently," Shakur-Still writes in an email to *The Scientist*. "Even a modest reduction in mortality from an inexpensive and widely available and practicable treatment that adds little

Data to suggest that statins may reduce the severity of COVID-19 or prevent death from it are limited. A small, observational study of 150 individuals in their 80s published on *medRxiv* in mid-May shows that those who took statins for cardiovascular disease before coming down with COVID-19 fared better than individuals of a similar age who were not on statins. From the results, "it seems like statins are beneficial in this population, and we know they are safe and cheap," says study coauthor Anton De Spiegeleer of Ghent University in Belgium. "And it's all that we have."

The results of that study also suggest that a combination of a statin and an antihypertensive drug could have even more benefit than statins alone, but more work needs to be done to confirm that link, De Spiegeleer says. David Kass, a cardiologist at Johns Hopkins School of Medicine who was not involved in the work, is more reserved about the conclusions and says there could be other reasons, such as overall health, lifestyle, or genetics, that could account for why participants on statins fared better after they became infected with SARS-CoV-2.

> **We have known for a long time that statins do more than lower cholesterol. It's those other effects, the ones they weren't designed to have but do have, that could affect the coronavirus.**
>
> —David Kass, Johns Hopkins School of Medicine

One of the consequences of severe SARS-CoV-2 infection is widespread inflammation in the lungs—also called acute respiratory distress syndrome, or ARDS. Research has shown statins can ameliorate ARDS, Shakur-Still says. Simvastatin, for example, reduced lung inflammation and lung injury in mice with ARDS. It also quelled lung inflammation in healthy human volunteers who had inhaled an endotoxin. That's one reason she and her colleagues are testing simvastatin in their clinical trial to treat COVID-19.

How exactly statins reduce the inflammation of ARDS isn't clear, though studies have shown that the drugs can suppress inflammatory cytokines, such as interleukin-6, and target the cell signaling molecules so that they are broken down before entering endothelial tissue. Acting in those ways, statins could shore up the integrity of the barrier that separates the lungs' endothelial tissue, which lines blood vessels, from their epithelial tissue, which surrounds the air sacs, or alveoli, that help us breathe. Maintaining that barrier between the tissue types would keep inflammatory molecules out of the lungs, explains David Fedson, a retired physician and former director of medical affairs at the European vaccine company Aventis Pasteur MSD. Other drugs, such as antihypertensives, might have a similar effect. This type of treatment protocol is an example of an emerging concept in infectious disease research called disease tolerance, in which treatments target the host's response to infection, rather the virus itself.

See "Could Tolerating Disease Be Better than Fighting It?"

Along with reducing inflammation, statins might also prevent blood clots, another consequence of SARS-CoV-2 infection. A small study of 21 patients admitted to intensive care at Baylor St. Luke's Medical Center in Houston found that more than half developed blood clots while being treated for COVID-19. In a separate study, patients who died of COVID-19 had nine times as many blood clots in their lungs as patients who died of the H1N1 flu, a team of doctors reported May 21 in the *New England Journal of Medicine*. Experimental studies and clinical trials have shown that statins can lower levels of thrombin, an enzyme in blood plasma that assists in blood clotting, and increase levels of thrombomodulin, a protein expressed on endothelial cells that reduces blood coagulation.

"We have known for a long time that statins do more than lower cholesterol," Kass says. "It's those other effects, the ones they weren't designed to have but do have, that could affect the coronavirus."

Statins' interference with SARS-CoV-2

Statins might not only target inflammation and blood clots, but interact with viruses directly as well. The drugs reduce the amount of cholesterol in the membranes of cells, and lower levels of cholesterol can prevent viruses from successfully entering cells. A study published May 10 on *bioRxiv* showed that added cholesterol in the cell membrane makes it easier for SARS-CoV-2 to get inside.

When the cholesterol level in the cell membrane is high, ACE2—the receptor the virus uses to invade cells—sits at a spot on the cell surface primed for endocytosis, the process by which extracellular material (including viruses) is brought into the cell. When cholesterol is low, ACE2 is present in a region that isn't primed for endocytosis. SARS-CoV-2 can still gain entry through a less efficient cell surface mechanism using the protein TMPRSS2, but the new work shows the endocytic pathway is the more infectious one, study coauthor Scott Hansen of the Scripps Research Institute in Jupiter, Florida, writes in an email to *The Scientist*. Lowering cell membrane cholesterol levels, which statins could do if taken in advance of infection, led to less virus getting into the cell, he says.

A recent computer simulation study also found that several statins could inhibit SARS-CoV-2's main protease—an enzyme essential for viral replication and transcription. The results, the authors write in the paper describing them, indicate that statins could "directly affect the virus particle," though there hasn't been a study in cells to show this yet.

That effect is probably less important than statins' role in fixing endothelial damage, says Fedson, who was not involved in the modeling study. "But we shouldn't overlook it."

Statins' performance in clinical trials for infections

Although the data on COVID-19 and statins are scant, evidence from other infections, such as influenza, indicate that the drugs could have some benefit. For instance, individuals who were already taking a moderate dose of statins before coming down with the flu had a reduced risk of dying from the infection compared with those who did not take statins, and patients who took statins before or during a hospital visit for flu also appeared to have a lower risk of dying from the infection.

In addition to flu, statins have also been suggested as a treatment for Ebola. In a small study in Sierra Leone in 2014, approximately 100 individuals infected with the virus were treated with a combination of a statin called atorvastatin and an antihypertensive called irbesartan for five to six days. Some of the patients also received clomiphene, which was thought to have antiviral effects against Ebola, for two to three days. Data from the study weren't released publicly, but individual health records, letters, and memoranda shared by clinicians who treated these patients showed that dozens of them survived the Ebola infection and were released from care. Typically, half of patients who are infected with Ebola die, according to the World Health Organization (WHO).

> **If we can prevent even a small number of patients getting to the stage of needing mechanical ventilation and dying, I think it will help.**
>
> —Haleema Shakur-Still, London School of Hygiene and Tropical Medicine

Together, statins and antihypertensives seemed to improve survival in the patients with Ebola, Fedson says. Still, even with these seemingly promising preliminary findings, the WHO chose not to set up any additional clinical trials or other studies to follow up on the results, he notes.

There have also been randomized clinical trials using statins to treat sepsis and ARDS. In three of those trials, patients were already mechanically ventilated by the time they received statins; the drugs did not appear to reduce mortality. A small trial using statins to treat patients hospitalized with sepsis showed more promise, as a large percentage of cases did not develop into severe sepsis with multi-organ failure. There weren't enough study participants for the team to draw statistical significance from the findings.

The WHO has turned down requests from Fedson to include statins in trials to treat patients infected with SARS-CoV-2. Letters Fedson shared with *The Scientist* reveal the organization's hesitancy to support the drug treatment because of the lack of evidence showing statins will be successful against COVID-19. The Gates Foundation has also turned down a request by John Costello of First Group Healthcare in France to start a trial in several Central African countries with a combination of statins and antihypertensive drugs called ARBs. The reason, according to a letter to Costello from the Gates Foundation, is because one trial on ARBs alone is already underway and because statins didn't work for sepsis and ARDS in previous studies of mechanically ventilated patients.

See "Blood Pressure Meds Point the Way to Possible COVID-19 Treatment"

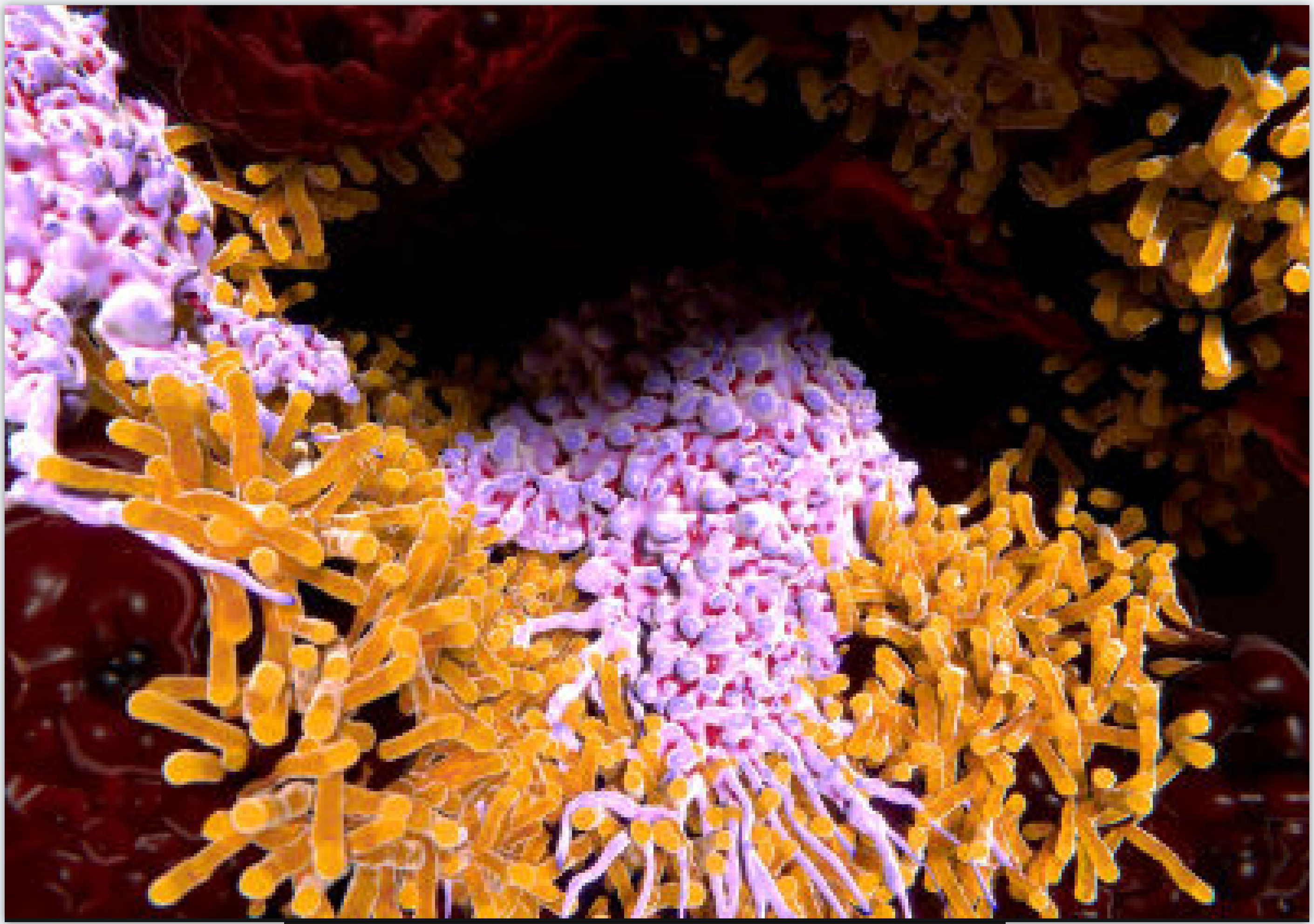
Kass says the use of statins to treat COVID-19 could go either way. "It could be that even though it's a good thing it is not enough of a good thing to make a dent into COVID-19. It's like putting on a rain jacket when it's drizzling, you're going to stay dry, but if you go out with the same rain jacket in a class four hurricane, you're going to get soaked," he explains. "So if COVID-19 is more like a class four hurricane for the blood vessels, then even though statins help to protect them, it may not be enough. That's why we need to do the study."

Shakur-Still and colleagues' trial in Pakistan and Nigeria is a small step in that direction. But more could be done right now with statins to save lives, especially in less-developed countries, Fedson says.

Shakur-Still shares a similar sentiment. When thinking about her trial, she says, she can't decide if she's excited for it to start or terrified. "Speaking to colleagues in Islamabad, Pakistan, last weekend, there were no ICU beds for COVID-19 patients. This terrifies me," she says. "However, if we can prevent even a small number of patients getting to the stage of needing mechanical ventilation and dying, I think it will help."

Keywords:

Africa, blood clot, cardiovascular disease, cell & molecular biology, cell membrane, cholesterol, clinical trials, coronavirus, COVID-19, cytokines, disease & medicine, endothelial cells, epithelial cells, immunology, inflammation, interleukin, lung, Pakistan, pandemic, statins, stroke, thrombosis, WHO



Experimental TB Vaccine Partially Effective: Study

Tested in patients with the latent form of tuberculosis, the vaccine prevented the development of the active form of infection in 50 percent more individuals compared with unvaccinated patients.

Ashley Yeager
Oct 30, 2019

An experimental vaccine continues to show promise in preventing active tuberculosis infections in patients with the latent form of the disease, researchers reported yesterday (October 29) in *The New England Journal of Medicine* and at the 50th Union World Conference on Lung Health conference.

ABOVE: Macrophages consume *M. tuberculosis* in the lung in this illustration.
©ISTOCK.COM, SELVANEGRA

"The vaccine looks promising, and likely better than our century-old BCG [bacille Calmette-Guerin] vaccine," Mario Raviglione, a global health expert at the University of Milan who headed the World Health Organization's (WHO) global tuberculosis program from 2003 to 2017, tells *The New York Times*.

The BCG vaccine is typically given to children in countries where the prevalence of TB is high. It is rarely given to adults because it varies in effectiveness in preventing *Mycobacterium tuberculosis*, the bacterium that causes the illness, from multiplying and causing disease in the lungs.

Tuberculosis is now one of the deadliest infectious diseases worldwide. It sickened an estimated 10 million people and killed 1.5 million individuals in 2018, according to the WHO. Tuberculosis typically affects patients in two ways: an active infection in which *M. tuberculosis* multiplies in the lungs and causes illness or death, or a latent form in which the bacterium is present in the body, causes an immune response, but does not lead to any symptoms. Latent TB can develop into active TB, which is contagious and can spread through the air, but the risk of latent TB reactivating is only 5–10 percent.

See "Tuberculosis Can Emerge After Cancer Immunotherapy"

In the latest study, researchers reported updated results on patients with the latent form of TB who were either given the experimental vaccine, called M72/AS01E, or a placebo shot. Nearly 3,300 individuals from Kenya, South Africa, and Zambia participated in the experiment in 2014 or 2015, with 1,626 individuals getting two shots of the vaccine and 1,663 getting placebo shots. When the team reported results on the vaccine last year, 10 of the vaccinated individuals and 22 of the unvaccinated study participants had developed active TB; that number increased to 13 vaccinated and 26 unvaccinated individuals reported in the latest paper.

The results, which show a roughly 50 percent efficacy, suggest "the vaccine is holding up" over time, Paula Fujiwara, the scientific director of the International Union Against Tuberculosis and Lung Disease, the group hosting the conference in Hyderabad, India, tells the *Associated Press*. It's a small step, she says, toward a preventive tool against TB that scientists have wanted to develop for a century.

See "Triage Test for Tuberculosis Spots Infections Within an Hour" and "First New Tuberculosis Drug Approved in 50 Years"

Still, the results don't clarify who would benefit most from the vaccine. Roughly a quarter of the global population carries the latent form of TB, but not all of those people develop the active form of the infection—some never do, so it would not make sense to vaccinate every person with latent TB. It's also not clear how well the vaccine works in those who don't have latent TB.

"These results need confirmation in larger and longer studies conducted in a broader range of populations," the study authors conclude. Because of the uncertainties, the vaccine will probably only be ready to use in those who need it most by 2028, *BBC* reports.

Ashley Yeager is an associate editor at The Scientist. *Email her at ayeager@the-scientist.com.*

Keywords:

cell & molecular biology, disease & medicine, latent infection, mycobacteria, nutshell, TB, tuberculosis, vaccine, WHO, World Health Organization

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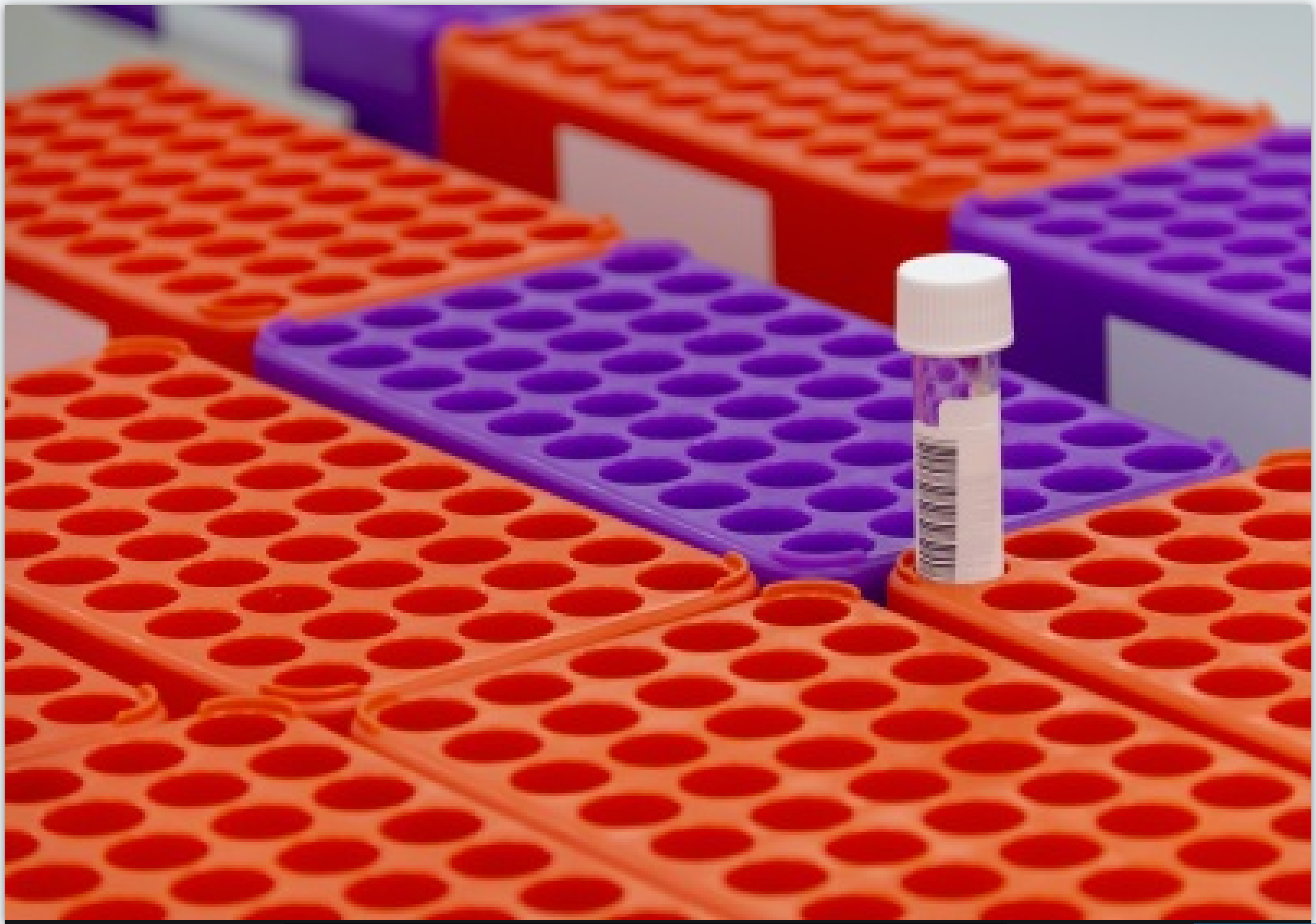


Governments Must Ramp Up COVID-19 Testing, Says WHO

The World Health Organization warns that a lack of data on how many people have the disease could undermine containment and mitigation efforts in many countries.

Catherine Offord
Mar 18, 2020

ABOVE: © ISTOCK.COM, PRILL

The World Health Organization is urging governments to perform more tests for COVID-19 following concerns about underreporting of cases in many countries around the globe. As the number of confirmed deaths due to infections with SARS-CoV-2 passed 8,000 this week, more and more nations have introduced strict measures to attempt to delay the virus's spread, but the organization warns that assessing the impact of these measures will only be possible with accurate data on the disease.

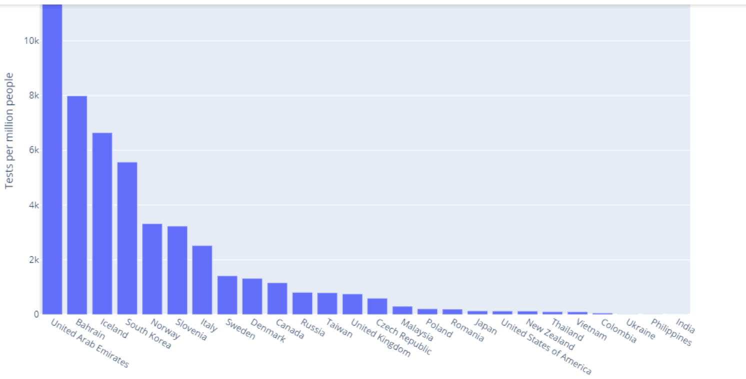
The message to every government and health authority on the planet right now is "get the capacity, and test, test, test," Margaret Harris of the WHO coronavirus response team tells *Sky News*. "If you don't know you've got a fire, you can't put it out."

See "How SARS-CoV-2 Tests Work and What's Next in COVID-19 Diagnostics"

Some countries have been taking a proactive approach to testing. South Korea, which has a population of more than 51 million people, rapidly implemented the largest testing program in the world after cases began soaring in February, screening people who had any contact with infected individuals as well as anyone with symptoms, and setting up drive-through testing sites.

According to Our World in Data, a project run by researchers at the University of Oxford in the UK, South Korea has so far carried out more than 285,000 tests—the equivalent of 5,500 tests for every million people in the population. With the national number of COVID-19 cases stabilizing at around 8,400, South Korea's experience shows that "diagnostic capacity at scale is key to epidemic control," Raina MacIntyre, an emerging infectious disease scholar at the University of New South Wales, Sydney, tells *Science*.

South Korea is now sending testing kits to other parts of the world. The *Korea Times* reported yesterday (March 17) that more than 50,000 tests had been exported to the United Arab Emirates (UAE), a country of around 9.5 million people that is overseeing a largescale testing operation for COVID-19 among its population. Bahrain and Iceland, which have popu[...]king on screening large numbers of people.

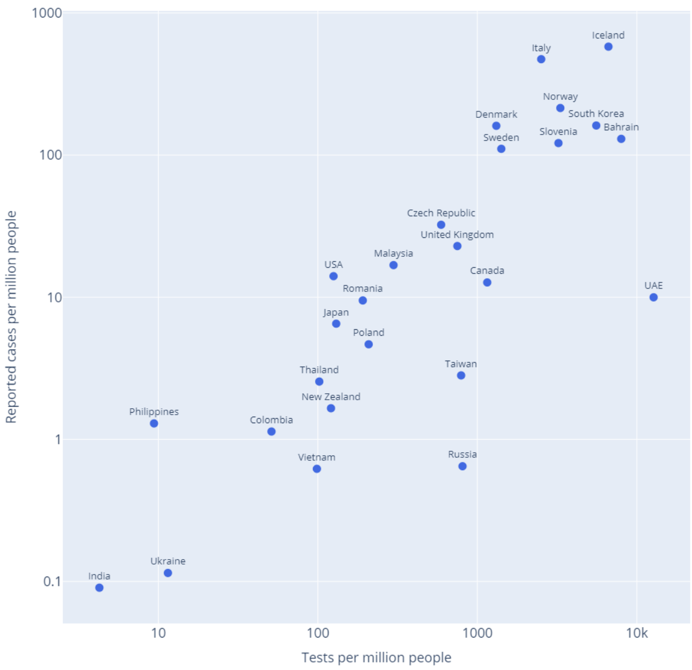


Estimates of the number of tests carried out in each country are based on reports from March 16 or March 17 for all countries except India, which last updated its test numbers on March 13.
DATA FROM OUR WORLD IN DATA

Many other countries have taken a less exhaustive approach. The UK, for example, announced at a press conference last week that it would only test people who were admitted to hospitals—a move criticized by many researchers and health workers, *The Guardian* reports. As of Tuesday, the country had carried out around 50,000 tests—fewer than 750 tests per million people in the population. Doctors and other staff working at National Health Service hospitals are not being tested even if they have symptoms, according to *The Guardian*.

Tim Colbourn, a global health epidemiologist at University College London, told the *Financial Times* earlier this week that the UK should "follow World Health Organization advice and do massive testing and tracing, as well as social distancing." Restricting tests to hospitalized patients would make it "difficult to understand how many people are infected and what the likely burden on the health system will be in the coming week."

Health workers in the US have also raised concerns about undertesting. According to Our World in Data, state health organizations and the United States Centers for Disease Control and Prevention (CDC) have collectively tested about 41,500 people, or around 125 per million people in the population.



Estimates of the number of tests carried out in each country are based on reports from March 16 or March 17 for all countries except India, which last updated its test numbers on March 13.
TESTING DATA FROM OUR WORLD IN DATA, CASE DATA FROM ECDC

The total number of tests carried out in the US when private companies are taken into account is likely to be larger, although that's impossible to know for sure, because private companies are only required to report positive COVID-19 tests; the number of tests that came back negative is unavailable in many US states.

A statement from the WHO on March 16 noted that a total of 1.5 million tests had been sent out to 120 countries. Those countries do not include the US, which has chosen to pursue its own testing technologies, according to *CNN*. Several states are currently reporting shortages of testing kits and supplies.

See "RNA Extraction Kits for COVID-19 Tests Are In Short Supply In US"

India, which is reporting fewer than 150 cases of COVID-19, has refused to scale up its testing programs on the grounds that spread of disease has been less severe there than elsewhere. By the end of last week, the country had carried out fewer than 6,000 tests for COVID-19, a testing rate equivalent to just 4.3 tests per million people in the population. The WHO guidance is "premature" for India, Balaram Bharghava, who heads the Indian Council of Medical Research, tells *Al Jazeera*, adding that there hadn't yet been reports of community transmission. The call for widespread testing "creates more fear, more paranoia, and more hype."

But researchers in India, which has a population of 1.34 billion, have expressed skepticism about the claims. "Given the pattern of disease in other places, and given our low level of testing," Gagandeep Kang, director of the Translational Health Science and Technology Institute, tells *Al Jazeera*, "then I do think that community transmission is happening."

Catherine Offord is an associate editor at The Scientist*. Email her at cofford@the-scientist.com.*

Keywords:

Centers for Disease Control and Prevention, COVID-19, diagnostics, disease & medicine, epidemiology, medical testing, nutshell, outbreak, policy, SARS-CoV-2, science policy, techniques, united kingdom, World Health Organization

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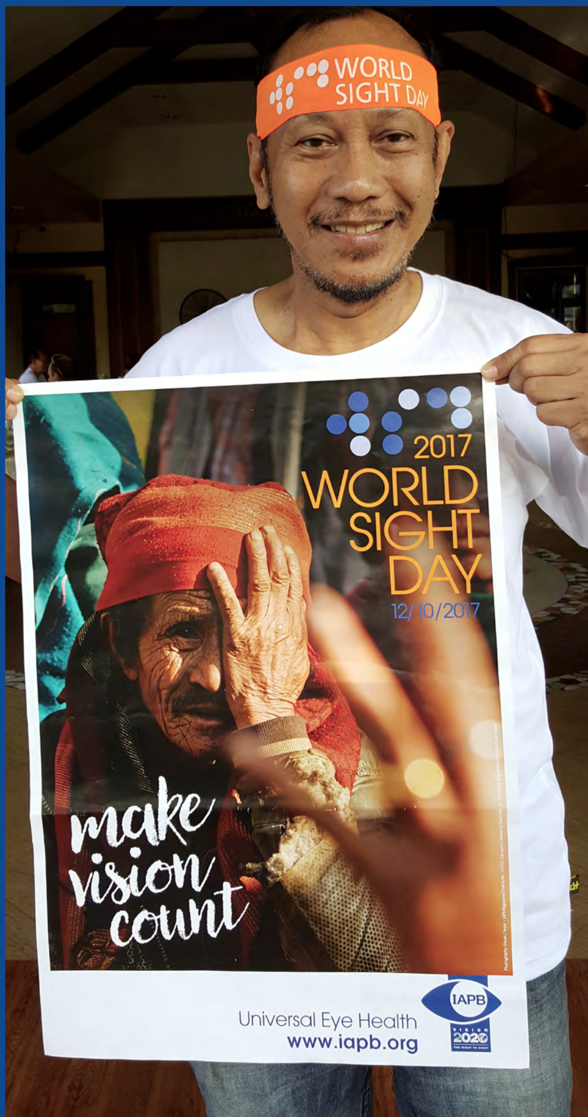
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WORLD REPORT ON VISION

LAUNCH PACK - MESSAGES

On 9 October 2019, ahead of World Sight Day, the WHO launched its first World Report on Vision.

The World Report on Vision seeks to generate greater awareness and increased political will and investment to strengthen eye care globally. The report sets out concrete proposals to address significant challenges in delivering eye care. Its key proposal is to integrate and scale up 'people-centred eye care', embedded in health systems and based on strong primary health care.

" It is unacceptable that more than a billion people are affected by treatable or avoidable sight loss. And this number is projected to balloon in the coming years—**we need to act now**. I congratulate the WHO and partners for launching this crucial document on the eve of World Sight Day. In the coming months, we will work with the WHO and IAPB member organisations to advocate for and deliver the World Report's priorities across the world.

-Peter Holland, CEO, IAPB

This document provides IAPB's key messages on the World Report on Vision, including the key findings and recommendations of report and a social media and communications toolkit.

The Key findings of the report

Global magnitude

- Globally more than 2.2 billion people have a vision impairment.
- Of those at least 1 billion people have a vision impairment that could have been prevented or has yet to be treated.

One of the greatest challenges is that we still don't know the magnitude of the problem. For the first time, the World Report on Vision begins to capture the global need - including the backlog of people who have yet to be helped, those whose needs have been met, for instance with glasses and contact lenses, and those who still need to interact with the health system and could benefit from rehabilitation.

Inequity in eye health

The burden of most eye conditions and vision impairment is not borne equally. It weighs more heavily on low- and middle-income countries, on rural communities, on older people, women, people with disabilities, ethnic minorities and indigenous populations.

Increasing global demand

Global demand for eye care is set to triple by 2050 because of population growth, ageing, and changes in lifestyle. This poses a considerable challenge to health systems.

Universal Health Coverage and the Sustainable Development Goals

The World Report recognises that people-centred eye care can advance UHC (SDG3.8) and will be key to achieving SDG3 on good health and well-being, but eye health also has a significant impact on SDG1, SDG4, SDG5, SDG8 and SDG10 and SDG13.

The Report recommendations

- **Integration**: The key proposal of the Report is to integrate and scale up eye care within national health services, based on strong primary health. Eye care needs to be part of overall health strategy – not planned separately or developed in parallel to overall health plans.

- **Integrated people-centred eye care**: Eye care needs to be 'people-centred' so services are managed and delivered so that people receive a continuum of promotive, preventive, treatment and rehabilitative interventions to address the full spectrum of eye conditions.

- **Data**: We need to address the gaps in data, particularly regarding met and unmet eye care needs, so that we can plan services and monitor progress effectively.

- **Financial hardship**: Protection against financial hardship involves ensuring that the costs of eye care do not expose the user to catastrophic spending on health.

- **Coordination**: There needs to be greater coordination of eye care across all sectors, including social services, finance, education, labour, and the private sector.

IAPB COMMUNICATIONS TOOLKIT

The World Health Organization (WHO) launches this crucial framework for eye health delivery on the eve of World Sight Day 2019

Hashtags and key accounts

- #VisionFirst! #HealthforAll #UniversalHealthCoverage #CHMM #UHC #WorldSightDay
- World Health Organization (@WHO); Dr Tedros, Director General WHO (@DrTedros); Etienne Krug @etiennekrug; IAPB (@IAPB1)

#VisionFirst! #HealthforAll #UniversalHealthCoverage #UHC #WorldSightDay #CHMM

IAPB Social Messages

TEXT	SUGGESTED ARTWORK	COMMENTS
It is time to make sure that as many people as possible in all countries can see as well as current health technologies and health systems allow." - @DrTedros Released today by the World Health Organization, the report sets out concrete proposals to address challenges in eye care. Learn more at: *https://www.iapb.org/news/who-launches-the-world-report-on-vision/*	*https://flic.kr/p/2azo6jv*	

The much-anticipated World Report on Vision is out, this #WorldSightDay!		
After much anticipation, 'World Report on Vision' is HERE! Read all about it—and download the report here: *https://www.iapb.org/news/who-launches-the-world-report-on-vision/*	*https://www.iapb.org/wp-content/uploads/Alarcos_WHO_WRV.jpg*	
"More than a billion people are effected by treatable or avoidable sight loss. And this number is projected to balloon in the coming years—we need to act now", said Peter Holland, CEO, IAPB. Read more: *https://www.iapb.org/news/who-launches-the-world-report-on-vision/*		
"Our hope is that, building on past efforts, we can successfully take on this challenge and help countries prevent eye conditions and vision impairment more effectively and provide quality eye care services." - @DrTedros World Health Organization releases 'World Report on Vision'. *https://www.iapb.org/news/who-launches-the-world-report-on-vision/*	*https://flic.kr/p/29dmbGc*	
We are excited to announce the release of 'World Report on Vision'. This principal report, published by WHO, aims to galvanise actions required to address a multitude of eye care challenges. Download your copy today! *https://www.iapb.org/news/who-launches-the-world-report-on-vision/*		

Investing in vision offers a good return on investment" – WHO. The 'World Report on Vision' will help shape the global agenda on vision. Member States can use it to: 1. Reduce the burden of vision loss, 2. Improve the lives of people with vision impairment, and 3. Achieve the #SDGs.	*https://flic.kr/p/27Exprc*	
FIVE actions from 'World Report on Vision': 1. Make eye care an integral part of #UHC 2. Implement integrated people-centred eye care 3. Promote high-quality implementation and research 4. Monitor trends and evaluate progress 5. Raise awareness, engage and empower people Learn more at: *https://www.iapb.org/news/who-launches-the-world-report-on-vision/*	*https://flic.kr/p/W53vjS*	
If you are a policy-maker, practitioner, public health specialist, researcher, academic, or work for a ministry of health, in civil society, or a development agency the 'World Report on Vision' is for you! Download it NOW! *https://www.iapb.org/news/who-launches-the-world-report-on-vision/*	*https://flic.kr/p/PN6321*	

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WHO SOCIAL MEDIA TOOLKIT

WHO Social Media Toolkit

- At least 2.2 billion people have vision impairment or blindness

- Over 1 billion could have been prevented or have still to be addressed: @WHO's first ever World Report on Vision https://bit.ly/35gpK20

- Ahead of #WorldSightDay on 10 October, @WHO launches its first World report on vision https://bit.ly/35gpK20

- More than 1 billion people worldwide are living with vision impairment because they do not get the care they need for conditions like (https://bit.ly/35gpK20) :

    - Short and Far sightedness

    - Glaucoma

    - Cataract

- The burden of eye conditions and vision impairment is often far greater in:

    - People living in rural areas

    - People with low incomes

    - Women

    - Older people

    - People with disabilities

    - Ethnic minorities

    - Indigenous populations

- The proportion of the population living with distance eye impairment, such as near-sightedness, in many low- and middle-income regions is estimated to be 4X higher than in high-income regions https://bit.ly/35gpK20

- Low- and middle-income regions of western and eastern sub-Saharan Africa and South Asia have rates of blindness that are eight times higher than in all high-income countries https://bit.ly/35gpK20

- Rates of cataract and trachomatous trichiasis are higher among women, particularly in low- and middle-income countries https://bit.ly/35gpK20

- Some eye conditions are linked to lifestyle. For example, spending little time outdoor can lead to near-sightedness glasses https://bit.ly/35gpK20

- Diabetes can impact vision if not detected and treated. Most people with diabetes will have some form of retinopathy in their lifetimes.

- Routine checks and good diabetes control can protect people's vision from this condition.

- Due to weak or poorly integrated eye care services, many people lack access to routine checks that can detect conditions and lead to the delivery of appropriate preventive care or treatment

- People living with blindness and severe vision impairment who cannot be treated are still able to lead independent lives if they access rehabilitation services, such as optical magnifiers, Braille, smartphone wayfinders and orientation and mobility training with white canes


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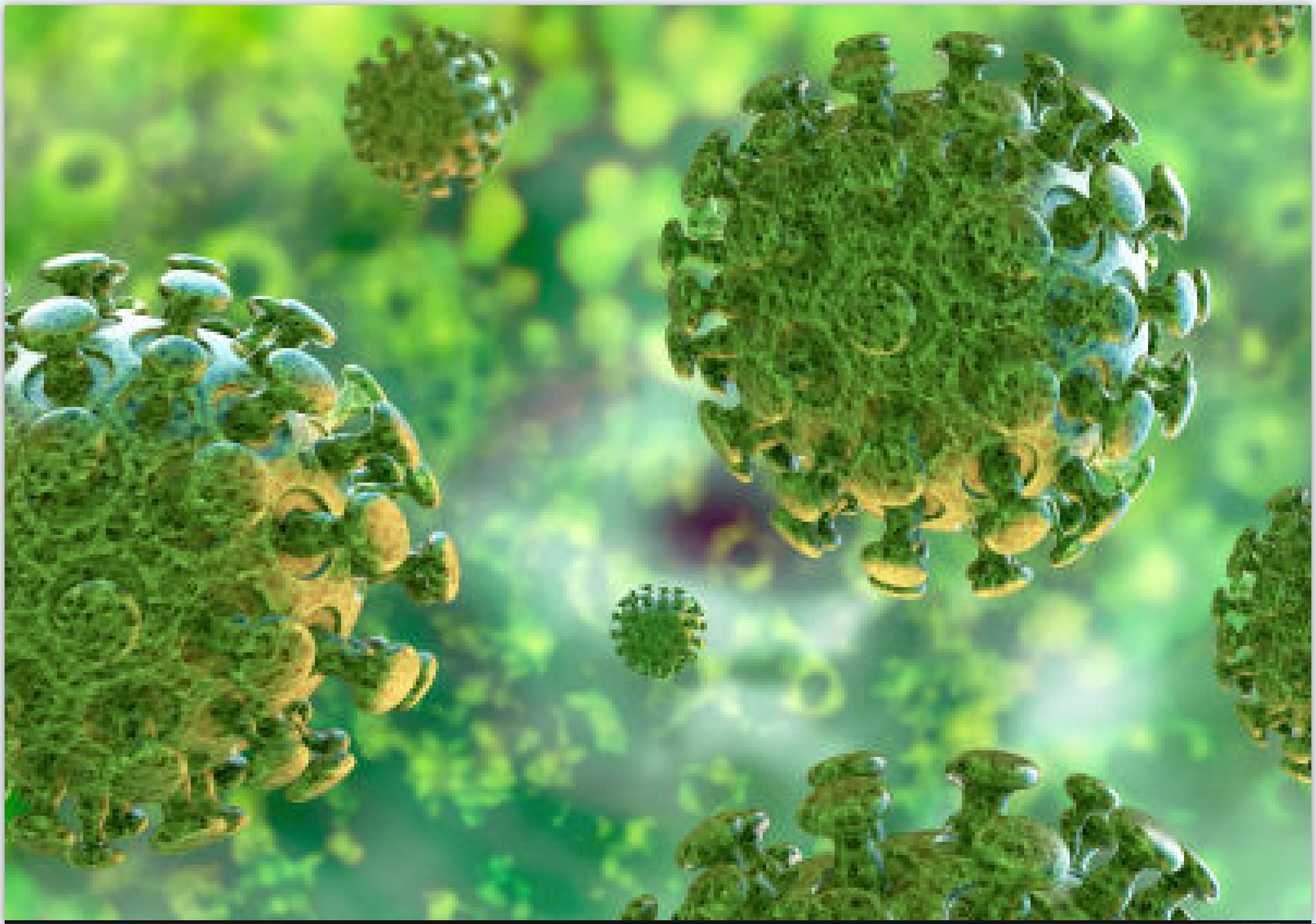

New Coronavirus Identified in Central China Pneumonia Outbreak

The virus, which has sickened at least 59 people, does not appear to transmit easily between humans.

Shawna Williams
Jan 9, 2020

A mysterious new type of pneumonia linked to a seafood market in Wuhan, China, is caused by a novel coronavirus, Chinese state media reported today (January 9). The reports come a day after the World Health Organization (WHO) stated that multiple known viruses had been ruled out as a cause of the outbreak, and that a coronavirus was the likely cause. The virus had sickened at least 59 people in China as of Sunday, and according to the Associated Press, one suspected case—a woman who fell ill after returning from China—has been identified in South Korea.

ABOVE: © ISTOCK.COM, XRENDER

Xinhua reports that the virus was identified by the Chinese Academy of Engineering's Xu Jianguo based on tests of samples from 15 patients with the illness. Known coronaviruses include some that cause a cold, as well as the pathogens behind severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS).

"Preliminary identification of a novel virus in a short period of time is a notable achievement and demonstrates China's increased capacity to manage new outbreaks," the WHO's Gauden Galea says in a statement quoted by multiple news outlets.

See "Cause of Viral Pneumonia Outbreak in China Unknown"

"If the Chinese truly have sequenced the virus and they've demonstrated that it's present in other patients, [that] means there's a PCR diagnostic test available. And the Chinese need to make that available to the rest of the world immediately," Ralph Baric, a coronavirus expert at the University of North Carolina, tells *STAT*. He explains that coronaviruses could be transmitted to people from bats, or through a different animal species that had been infected by a bat.

"I am stunned by the timeline and speed of this isolation and characterization, if it's all true," says Matthew Frieman, a coronavirus expert at the University of Maryland School of Medicine, in remarks to *STAT*. He expressed skepticism about Chinese authorities' claim that the virus can't be transmitted between humans, saying, "I don't know how you know that at all." Given the number of reported cases, he says, it's not likely that animal-to-human transmission is the only way the virus can spread.

David Hui, an emerging infections expert at the Chinese University of Hong Kong, shares a similar take with *The New York Times*. "So, there are still a lot of question marks," he says. "It's premature to say that there's no human-to-human transmission."

Shawna Williams is a senior editor at The Scientist. *Email her at swilliams@the-scientist.com or follow her on Twitter @coloradan.*

Keywords:

2019-nCoV, China, coronavirus, COVID-19, disease & medicine, infectious disease, MERS, nutshell, outbreak, SARS, SARS-CoV-2, virus, WHO, World Health Organization

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One Dead in Pneumonia Outbreak from New Coronavirus in China

Pers

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The next once-a-century pandemic is coming sooner than you think – but COVID-19 can help us get ready

June 14, 2020 9.56pm SAST

David Murdoch, *University of Otago*

COVID-19 is being referred to as a "once in a century event" – but the next pandemic is likely to hit sooner than you think.

In the next few decades, we will likely see other pandemics. We can predict that with reasonable confidence because of the recent increased frequency of major epidemics (such as SARS and Ebola), and because of social and environmental changes driven by humans that may have contributed to COVID-19's emergence.

A COVID-19-type pandemic had long been predicted, but scientists' warnings weren't heeded. Right now, while we have the full attention of politicians and other key decision-makers, we need to start rethinking our approaches to future preparedness internationally and within our own nations. That includes countries like New Zealand, where – despite getting its active COVID-19 cases down to zero in June 2020 – big challenges remain.

Read more: New Zealand hits zero active coronavirus cases. Here are 5 measures to keep it that way

We can't say we weren't warned

Less than five years ago, I was one of about 100 global experts invited to a World Health Organization (WHO) meeting in Geneva, prompted by the then ongoing Ebola outbreak in West Africa.

Then, as now, WHO was criticised for its response to the outbreak. The December 2015 meeting was meant to improve international collaboration and preparation for future epidemics and other infectious disease risks.

The very last presentation was from Dr David Nabarro, then the United Nations Special Envoy on Ebola (and now a Special Envoy on COVID-19).

In the wake of the Ebola outbreak, politicians were more focused on public health than ever before. Nabarro urged us to show greater leadership and capture that interest, before political and public attention moved on. He stressed the importance of trust, respect, transparent communication, and working with nature.

Yet five years later, we're still talking about inadequate funding for pandemic preparedness; delays in adopting preventive measures; failure to develop surge capacity in health systems, laboratories and supply chain logistics; and reduced infectious disease expertise.

Read more:* *The World Health Organization must answer these hard questions in its coronavirus inquiry

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But there are signs that some lessons may have been learned. For example, countries most affected by SARS (such as Taiwan and Singapore) have tended to respond more quickly and decisively to COVID-19 than other countries.

Health workers stand ready to apply sanitising gel on people's hands at a market in Taipei in May 2020, as Taiwan began loosening its COVID-19 restrictions. EPA/David Chang

Primed and ready, vaccine developers have progressed at enormous pace, with several COVID-19 vaccine candidates already undergoing clinical trials. The volume and pace of sharing scientific information about COVID-19 has been unprecedented.

We've also seen a number of rapid reports urging us to learn from this pandemic and past epidemics to protect us from future events – especially by taking an holistic "One Health" approach. This brings together expertise across human health, animal health and the environment.

For instance, last month the Lancet One Health Commission called for more transdisciplinary collaboration to solve complex health challenges. Similarly, the World Wide Fund for Nature's March 2020 report on The Loss of Nature and Rise of Pandemics highlighted the likely animal origin of COVID-19, and how intimately connected the health of humans is to animal and environmental health.

Read more: Caring for community to beat coronavirus echoes Indigenous ideas of a good life

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What New Zealand can learn from COVID-19

As well as working more effectively together internationally, each country will need its own strategy. So what should we be doing to protect New Zealand from future infectious diseases threats?

Our health system has, for the most part, responded well to COVID-19. Our research institutions and universities have engaged quickly and effectively to provide scientific support for the public health response.

Yet we can and must still do better. Our expertise and systems are not always well joined up – vital for coordinated and timely responses to challenges like COVID-19.

We allow scientists to work in silos, despite obvious overlapping interests and skill sets. Of particular importance for tackling infectious diseases is the need to break down artificial barriers between human, animal and environmental health.

This approach makes particular sense in New Zealand. We are an island nation vulnerable to introduced infectious diseases, and economically dependent on agriculture and the physical environment. But we're also home to an existing indigenous Māori worldview and knowledge system that emphasises interconnectivity between humans, animals and the environment.

University-led efforts, such as One Health Aotearoa, have brought together professionals and researchers from different disciplines. But more investment is needed to get even better value from such collaborations.

We need to strengthen capability in such areas as epidemiology, modelling and outbreak management, and build pandemic plans that are flexible enough to respond to all eventualities. New Zealand has a Centre of Research Excellence in plant biosecurity – but not in animal biosecurity or infectious diseases.

We also need to better integrate science and research into the health system, a key feature of the New Zealand Health Research Strategy 2017-2027. This requires a culture change so research is regarded as business as usual for district health boards, providing the science needed to inform policy, preparedness and best practice.

Read more: As collective memory fades, so will our ability to prepare for the next pandemic

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Crucially, we need a new generation of scientists and professionals who are systems thinkers and comfortable working with multiple disciplines and across the human-animal-environment interface.

And we need the kind of leadership Nabarro called for: science-informed and forward-looking, rather than reactive.

We have seen good leadership based on science in the highest levels of New Zealand's government in response to COVID-19.

We now need to see this at all levels of health, research and politics to get us out of this pandemic in the best shape possible – and be better prepared for our next pandemic.

New Zealand | Infectious diseases | Pandemic | Preventative health | Ebola | World Health Organization (WHO) | One Health | New Zealand stories | COVID-19 | COVID-19 pandemic | COVID pandemic

Trump Suspends WHO Funds, Alleges a Poor COVID-19 Response

President Donald Trump claims the World Health Organization failed to investigate early reports of the coronavirus, while public health experts argue that stripping the agency of its funding endangers us all.

Amy Schleunes
Apr 15, 2020

President Donald Trump announced yesterday (April 14) that he is halting funding for the World Health Organization, pending a formal review of the global body's response to the coronavirus pandemic, reports *STAT*.

ABOVE: © ISTOCK.COM, MSEIDELCH

"America and the world have chosen to rely on the WHO for accurate, timely, and independent information to make important public health recommendations and decisions," Trump said in prepared remarks, according to *STAT*. "If we cannot trust that this is what we will receive from the WHO, our country will be forced to find other ways to work with other nations to achieve public health goals."

Devi Sridhar, a global health expert at the University of Edinburgh in the UK, tells *Science*, "This is a short-sighted decision which will be disastrous for the agency. We need the WHO more than ever to support all countries, especially low and middle income ones."

Trump said in his speech that the global health agency is responsible for "severely mismanaging and covering up the spread of the coronavirus," reports *Science*. The President criticized the WHO for failing to investigate early credible reports of the coronavirus out of Wuhan, China, according to *The Guardian*, and told reporters on Tuesday, "Through the middle of January, it parroted and publicly endorsed the idea that there was not human to human transmission happening, despite reports and clear evidence to the contrary."

His criticism conflicts with the fact that the WHO warned the US and other countries as early as January 10 that there was a risk of human-to-human transmission.

Trump also called the WHO's decision to oppose travel bans "disastrous," and claimed that his February 2 prohibition on foreign nationals from China entering the US has saved "thousands and thousands of lives," reports *Science*.

Jeremy Konyndyk, a senior policy fellow at the Center for Global Development, tells *Science* that Trump's decision "leaves the U.S. and the world less safe" and is "a transparent attempt to shift blame for the U.S. administration's own failings."

The WHO's director-general, Tedros Adhanom Ghebreyesus, tweeted this morning, "The WHO's singular focus is on working to serve all people to save lives and stop the COVID19 pandemic."

The US was the WHO's largest single donor in the agency's 2018–2019 budget cycle, contributing nearly $900 million of the $5.6 billion budget, reports *Science*.

Bill Gates, whose foundation also funds the WHO, said in a tweet today that Trump's move was "as dangerous as it sounds."

O'Neill Institute for National and Global Health Law director Lawrence Gostin warns in remarks to *Science*, "If WHO is ensnared in a political and funding crisis, it simply won't be able to provide the leadership that is so urgently needed in this unique time in human history."

According to the Johns Hopkins Coronavirus Resource Center, the United States is now the country with the most confirmed COVID-19 cases—610,774 as of today.

Keywords:

coronavirus, COVID-19, disease & medicine, Donald Trump, funding, government, nutshell, SARS-CoV-2, Trump administration, WHO, World Health Organization

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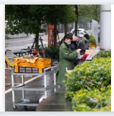
Follow the Coronavirus Outbreak



Estin

Two Genetic Regions Linked with Severe COVID-19

In a genome-wide association study, variants in both the*ABO* blood group locus and a cluster of genes on human chromosome 3 are more common among COVID-19 patients with respiratory failure than in the general population.

Abby Olena
Jun 8, 2020

It's not yet clear why some people infected with SARS-CoV-2, the virus that causes COVID-19, get really sick, while others have only mild symptoms. There's some evidence that chronic health conditions—such as hypertension and diabetes can play a role, and scientists know that people's genes can influence how their bodies react to other viruses. In a preprint posted to *medRxiv* on June 2, researchers describe a genome-wide association study (GWAS) of samples from 1,610 hospitalized patients with COVID-19 and 2,205 healthy controls. The authors identified variants in two regions—the locus that encodes blood type and a multi-gene cluster on chromosome 3—that were linked to respiratory failure during SARS-CoV-2 infection.

ABOVE: © ISTOCK.COM, KRULUA

"We know that people vary in their susceptibility to infectious diseases, and variation in the human genome plays a . . . role in that susceptibility," Charlotte Houldcroft, who studies interactions between viruses and hosts at the University of Cambridge and was not involved in the work, writes in an email to *The Scientist.* "A genome-wide association study is a very good way to look at lots of variants across the human genome all at once, without a preconceived idea about which genes might be involved."

> **Each variant found here only increases a person's risk a little bit, and we have no idea how.**
>
> —Charlotte Houldcroft, University of Cambridge

Finding anything meaningful in a GWAS depends upon having enough genomes to analyze. In a pandemic, that's especially tricky. According to Andre Franke, a geneticist at Christian-Albrechts-University of Kiel in Germany, it was the connections that his colleague Tom Hemming Karlsen, a physician-scientist at the University of Oslo in Norway, has to clinicians and researchers in COVID-19 hot spots in Spain and Italy that made the study possible.

See "DNA Could Hold Clues to Varying Severity of COVID-19"

The research team collected, genotyped, and analyzed samples from 775 patients and 950 controls from Spain and 835 patients and 1,255 controls from Italy. The patients were all hospitalized and were either in need of mechanical ventilation or on supplemental oxygen, both of which the researchers categorized as respiratory failure. They pulled out two genomic regions in which certain variants showed up more in patients hospitalized for COVID-19 than in unhospitalized people from the same geographic region.

Ideally, a GWAS analysis would analyze the genomes of people with COVID-19 and compare those who didn't get very sick to those who experienced severe symptoms, instead of using population-based controls whose exposure to the virus is unknown, says Priya Duggal, a genetic epidemiologist at the Johns Hopkins Bloomberg School of Public Health who did not participate in the study. Nevertheless, "it's really incredible to see how much work was done in such a short period of time. In about two months, these investigators moved from cases being identified in the hospitals to being genotyped to the identification of two putative regions."

One region the authors identified is the locus that encodes blood type. They found that people with blood type A were at a higher risk for respiratory failure, while blood group O seemed to be protective. The odds for those with blood type A to be hospitalized with severe respiratory symptoms were nearly 1.5 times the odds for people with other blood types. And those with type O had about two-thirds the odds of being hospitalized as those with other blood types. This analysis echoes preprint findings from patient datasets collected in China and New York, which Franke says makes the research team more confident that it's a real association.

The other genomic region the researchers identified shows up on the human chromosome 3 and contains several genes of interest. One is *SLC6A20*, which encodes an amino acid transporter that interacts with ACE2, the main receptor that SARS-CoV-2 uses to get into human cells. Two other genes in this cluster encode immune system–related chemokine receptors: the C-X-C motif chemokine receptor 6 and the CC-motif chemokine receptor 9. Both proteins play a role in T-cell differentiation and recruitment during influenza viral infections. This region also shows up in publicly available results from the COVID-19 Host Genetics Initiative, which gives it weight, the authors write.

"Chemokine receptors are important in many manifestations of multiple diseases, so that's interesting," says Benjamin Fairfax, a geneticist at the University of Oxford who did not participate in the study. He adds that the *SLC6A20* association is also intriguing because of the interaction with ACE2, but that the findings for both the chromosome 3 and blood group loci need to be replicated to give more insight into the underlying biological mechanisms of the disease.

"From the individual perspective of a patient or those people wandering around with blood group A who may think they're at higher risk, these effect sizes are going to be very, very small compared to major risk factors such as age and sex," Fairfax says.

The gene cluster on chromosome 3 has an even higher effect size than that of the *ABO* locus, says Franke, "but we cannot say at the moment which of the many candidate genes is most important. All of them are very attractive in this region." The odds of being hospitalized with respiratory failure from COVID-19 were 1.77 times higher for those with the variants on chromosome 3 than for people without this genotype.

See "Alzheimer's Gene Linked to Higher Risk of Severe COVID-19"

"Each variant found here only increases a person's risk a little bit, and we have no idea how," Houldcroft says. "It doesn't allow us to predict who will be a severe case, and it doesn't open up any treatment options. However, it does give us a plausible place to start looking."

The work is "a really good first step," says Duggal. "I hope that what follows is some additional studies from other groups and researchers that are able to evaluate what else may be driving this or what these genetic associations might actually mean."

D. Ellinghaus et al., "The ABO blood group locus and a chromosome 3 gene cluster associate with SARS-CoV-2 respiratory failure in an Italian-Spanish genome-wide association analysis," *medRxiv*, doi:10.1101/2020.05.31.20114991, 2020.

Keywords:

coronavirus, COVID-19, disease & medicine, genetic variation, genetics & genomics, genotype, gwas, human genetics, News, pandemic, SARS-CoV-2

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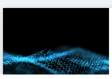
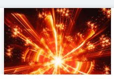


Alzheimer's Gene Linked to Higher Risk of Severe COVID-19



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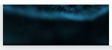

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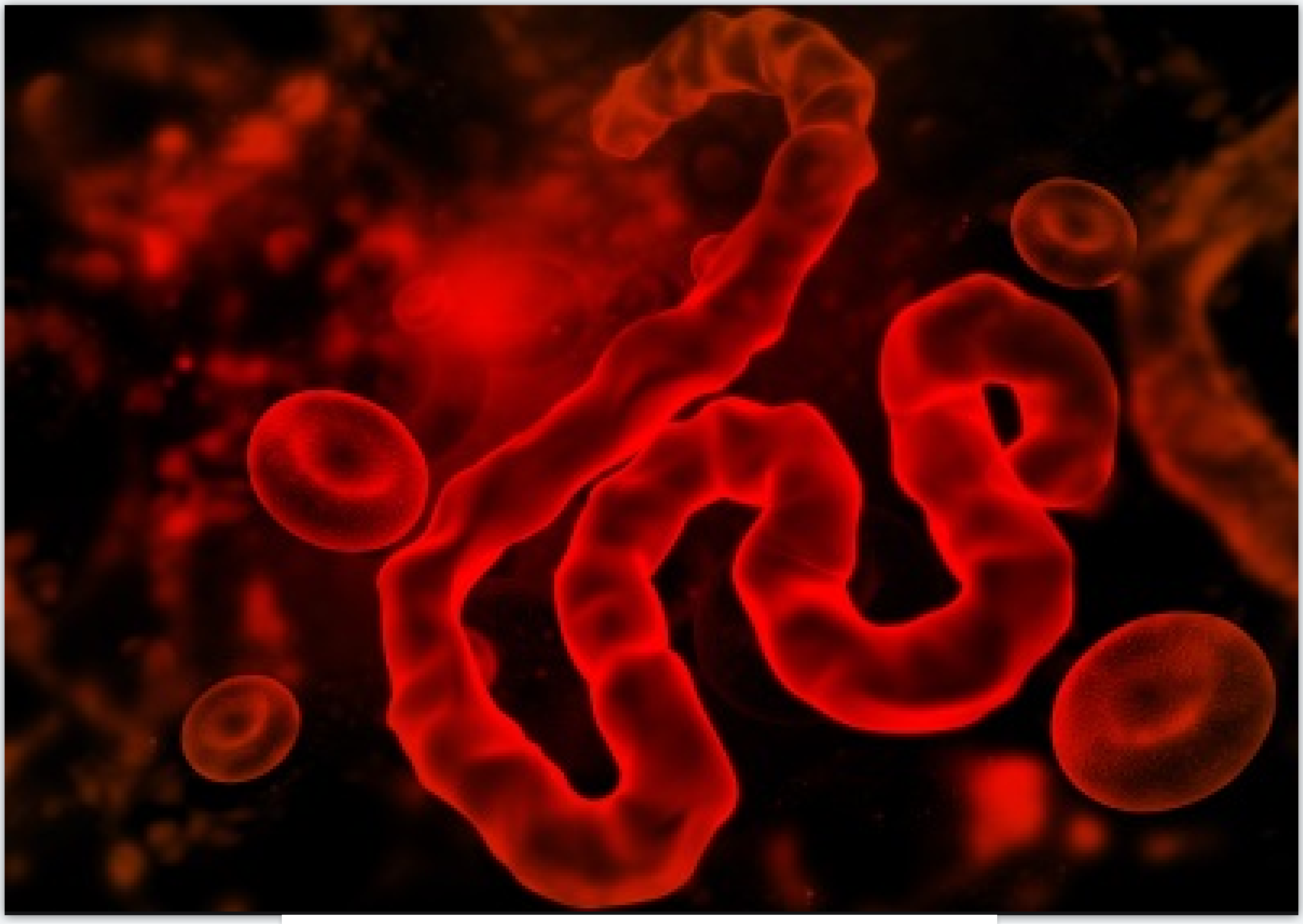

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Two New Ebola Deaths Recorded in DRC Outbreak

The recent cases come just as Democratic Republic of Congo was set to declare the outbreak's end.

Amy Schleunes
Apr 13, 2020

A new case of Ebola has been confirmed in Beni, a city in the North Kivu province of Democratic Republic of Congo, the World Health Organization announced on Friday (April 10). The 26-year-old man died from the infection in the first Ebola case to have emerged after 52 days without a diagnosis, reports *STAT*. DRC was expected to declare the end of the outbreak today, but the new diagnosis puts that declaration on hold.

ABOVE: © ISTOCK.COM, MOHAMMED HANEEFA NIZAMUDEEN

"I am so sad," WHO epidemiologist Marie-Roseline Darnycka Bélizaire tells *Nature*. "I expected a sporadic case earlier, but not two days before the end."

Tedros Adhanom Ghebreyesus, the director-general of the WHO, stated during a briefing that the DRC government would not be able to "declare an end to the outbreak on Monday as was hoped," but that "WHO and all partners remain on the ground and committed as ever to working with the government . . . to end the outbreak," according to *STAT*.

Over the weekend, another case emerged: an 11-month-old girl who was treated at the same health center as the first patient also died of Ebola, *Al Jazeera* reports.

There have been 3,456 confirmed and probable cases of Ebola and 2,276 resulting deaths as of April 10, 2020, according to the WHO. The outbreak in DRC began in August 2018 and has been particularly complex due to political instability and ongoing wars in the region, where armed groups have injured both responders and people suffering from the disease. The virus's spread appeared to have slowed this January, and before these last two cases, the most recent diagnosis had occurred on February 17. No new cases had emerged among more than 2,000 people who had been tested during the following 40 days, reports *Nature*.

See "Violence in Congo Threatens Fight Against Ebola"

Today (April 13) would have marked 42 days since the last survivor had been cleared of the infection, the point at which two incubation periods of the disease would have passed and the outbreak could have been reasonably declared over, reports *STAT*.

The WHO has identified 215 people who came into contact with Friday's victim, a number that includes 53 health care workers, all but one of whom had been vaccinated, according to *Al Jazeera*.

"We take thousands of samples every single week," says Mike Ryan, head of the WHO's health emergencies committee, in remarks to *STAT*. "And we will continue that active surveillance right the way through. It's a testament to the strength and resilience of workers in North Kivu, to the local workers who continue to trace and track, continue to investigate, continue to report and continue to leave in place the infrastructure needed."

Keywords:

democratic republic of congo, disease & medicine, Ebola, infectious disease, nutshell, outbreak, public health, violence, World Health Organization

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Measles Kills Thousands in Democratic Republic of Congo

End N

Was the coronavirus outbreak an intelligence failure?

June 15, 2020 2.20pm SAST

Erik J. Dahl, *Naval Postgraduate School*

Dan Coats, left, then director of national intelligence, told Congress in 2019 about the potential danger of a pandemic. Office of the Director of National Intelligence

As the coronavirus pandemic continues to unfold, it's clear that having better information sooner, and acting more quickly on what was known, could have slowed the spread of the outbreak and saved more people's lives.

There may be finger-pointing about who should have done better – and President Donald Trump has already begun laying blame. But as a former naval intelligence officer who teaches and studies the U.S. intelligence community, I believe it's useful to look at the whole process of how information about diseases gets collected and processed, by the U.S. government but also by many other organizations around the world.

The role of traditional US intelligence agencies

The U.S. intelligence community has for many years considered the possible threat of disease among the potential risks to national stability and security.

For instance, then-Director of National Intelligence Dan Coats told Congress in January 2019 that a large-scale outbreak "could lead to massive rates of death and disability, severely affect the world economy, strain international resources, and increase calls on the United States for support."

The traditional national-security intelligence agencies, like the CIA and the National Security Agency, can be useful in tracking pandemics once they are identified, using human informants and other sensitive intelligence sources to determine where an outbreak developed and what other nations have done in response.

But the main burden for pandemic detection within the intelligence community falls on little-known agencies, like the National Center for Medical Intelligence. It is a part of the Department of Defense that tracks emerging diseases, bioterrorist threats and the medical capabilities of other countries.

A building on the Centers for Disease Control and Prevention's campus in Atlanta.Jim Gathany/CDC/Wikimedia Commons

US domestic medical intelligence gathering

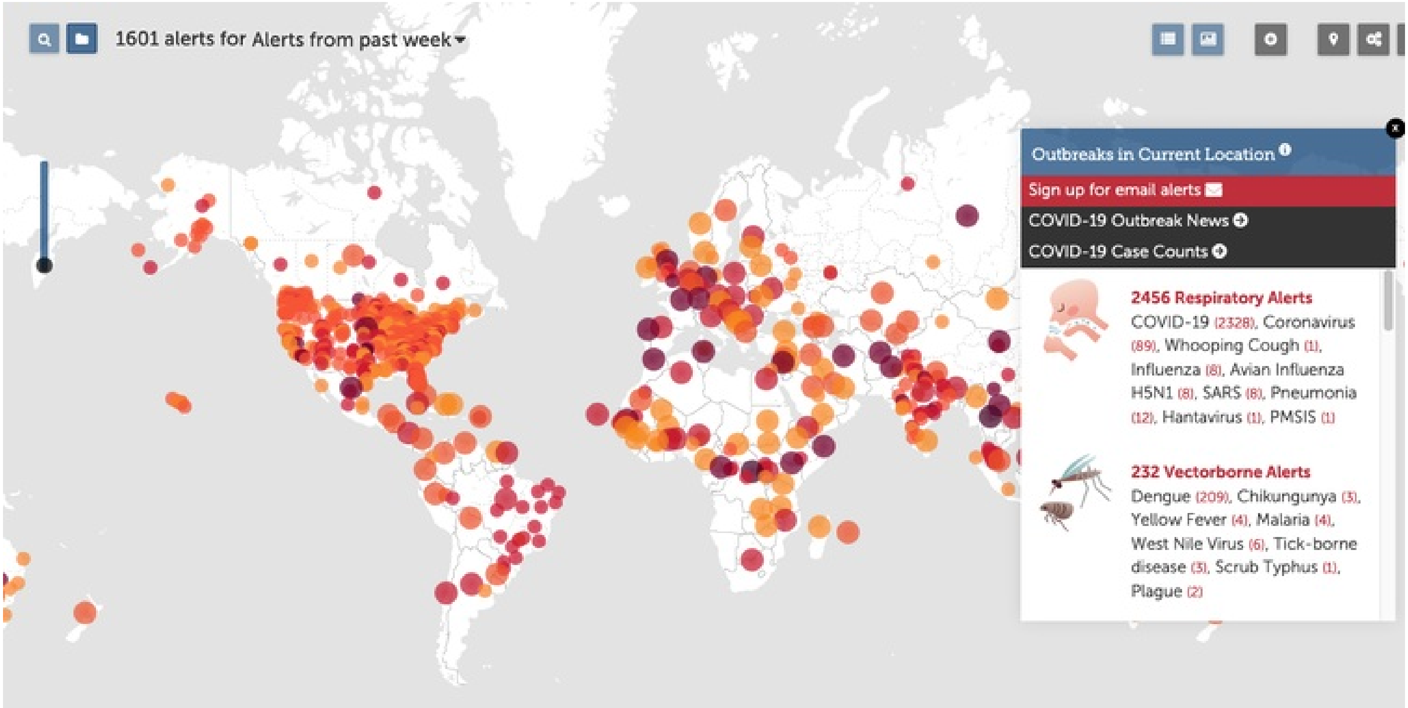
Beyond the intelligence community, the U.S. has a complex system of civilian medical and public-health information collection, coordinated by the Centers for Disease Control and Prevention.

The CDC manages some 100 different health surveillance systems, including collecting data from local and state health officials on particularly important diseases such as anthrax, cholera and Ebola, through the National Notifiable Diseases Surveillance System. The CDC also gathers information from medical facilities and public health departments on potentially dangerous health symptoms before they have been diagnosed by medical experts, in the National Syndromic Surveillance Program.

International medical surveillance systems

The World Health Organization sits atop an even more complex network of international health and disease surveillance systems. For example, its Global Outbreak Alert and Response Network attempts to identify outbreaks in developing countries. But the WHO does not have its own medical intelligence system; its role is to encourage and support its member nations to develop their own capabilities for detecting and reporting disease outbreaks.

Other international medical surveillance programs gather information from news media, internet sites, and other sources in an effort to identify and warn about disease outbreaks. These efforts include the Global Public Health Intelligence Network, the Program for Monitoring Emerging Diseases and HealthMap. Many of these programs make their information available for free to public health departments, medical professionals, and others including the media.



The HealthMap website tracks reports of all sorts of diseases all around the world.

How well did they do?

Initial indications are that the U.S. intelligence community did well in reporting on the virus once news of the outbreak in China became widely known by early January. Whether it could have done more before that time, and why the Trump administration did not act more decisively early on, will have to wait for a future national coronavirus commission to help us sort out.

Some news accounts indicate U.S. intelligence agencies may have detected a new disease in China as early as November – even before Chinese authorities recognized the problem. These reports have been denied by U.S. officials, but it is clear that by mid-January, the U.S. intelligence community had begun briefing the president on the outbreak.

The CDC was handicapped by having eliminated the position of a U.S. epidemiologist embedded in China's public-health system just months before the coronavirus outbreak began.

As a result, the CDC could only get information from Chinese authorities, who covered up the severity of the crisis until it was too late to prevent its spread internationally. Chinese police even reprimanded a doctor who warned of the outbreak. He later died of the virus.

Critics have pointed fingers at the World Health Organization for not having raised the alarm soon enough. The WHO has agreed to an independent international investigation into whether the organization responded properly to the outbreak.

But the WHO has been warning for years about the possibility of a new pandemic. In 2018, for instance, the group published a list of disease threats, including one called Disease X, which "represents the knowledge that a serious international epidemic could be caused by a pathogen currently unknown to cause human disease."

The fundamental problem appears to lie in the fact that the WHO depends on countries to detect and report serious disease outbreaks – rather than having its own set of global health monitors keeping their eye on potential outbreaks.

A 2018 meeting of the World Health Organization at its headquarters in Geneva, Switzerland. Harold Cunningham/Getty Images

What should be done?

Early indications are that the U.S. national intelligence community should consider steps such as boosting the visibility and importance of the National Center for Medical Intelligence. Just as the National Counterterrorism Center was created after the 9/11 attacks to provide a single place where all terrorism-related intelligence would be handled, the U.S. may need to create a true national intelligence center focused on infectious disease, biological terrorism and other health issues.

The most important actions, however, are likely to be at the international level. Experts have suggested providing the World Health Organization with significantly greater authority to enforce individual nation reporting requirements, such as by revising the International Health Regulations – the international treaty that describes what WHO member states must do – to give the WHO inspection powers similar to that of the International Atomic Energy Agency.

Others have suggested developing a global early warning system for infectious diseases and other health threats that would integrate the global hodge-podge of disease surveillance systems that currently exists, and provide a worldwide system similar to those already in place to warn about earthquakes and tsunamis.

So far, though, the pandemic has failed to inspire the sort of coordinated international effort that is needed to effectively meet a truly global problem. The ability of any one nation – even the U.S. – to identify and respond to a global crisis remains limited, and ultimately it will require political action on the part of nation states and the international community to enable the world to learn from this global failure of intelligence and warning, and come together effectively to combat the next pandemic.

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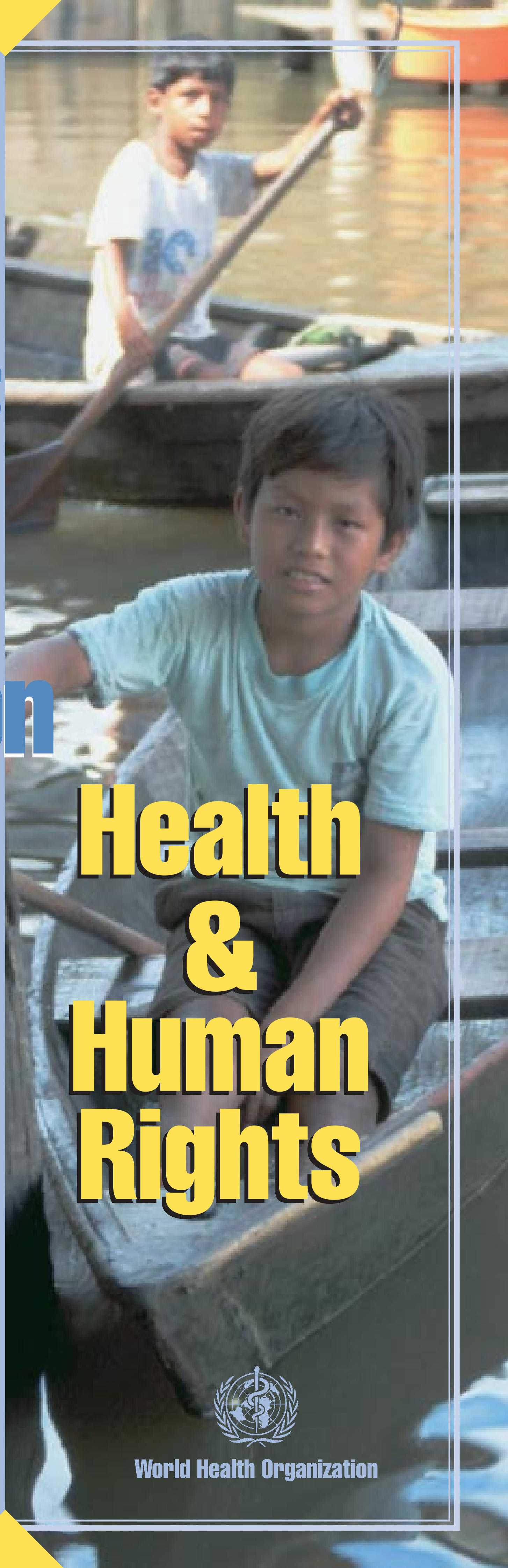
National security | Pandemic | CIA | World Health Organization (WHO) | National Security Agency | Centers for Disease Control and Prevention | US Centers for Disease Control and Prevention | Coronavirus 2020 | Centers for Disease Control

25 Questions & Answers on Health & Human Rights



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25 Questions & Answers on Health & Human Rights

World Health Organization

"It is my aspiration that health will finally be seen not as a blessing to be wished for, but as a human right to be fought for."

United Nations Secretary General, Kofi Annan

Foreword

The enjoyment of the highest attainable standard of health as a fundamental right of every human being was enshrined in WHO's Constitution over fifty years ago. In our daily work, WHO is striving to make this right a reality for everyone, paying particular attention to the poorest and most vulnerable.

The human rights discourse provides us with an inspirational framework as well as a useful guide for analysis and action. The United Nations human rights mechanisms provide important avenues towards increasing accountability for health.

Attention to human rights is growing worldwide. WHO is actively engaged in increasing its understanding of human rights in relation to health. We are learning from other United Nations agencies, the international community, and other stakeholders.

It is in this context that WHO has launched the *Health and Human Rights Publication Series*. We have chosen *25 Questions and Answers* as the first in this series, suggesting answers to key questions which explore the linkages between different aspects of health and human rights.

I hope this *Q & A* will provide guidance to a broad audience interested in the relationship between health and human rights.

Gro Harlem Brundtland
Geneva
July 2002

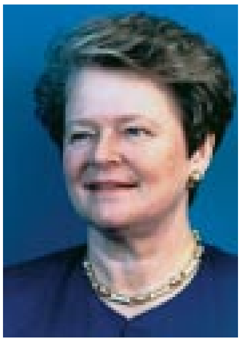

Table of Contents

Abbreviations and Acronyms

ACC	Administrative Committee on Coordination
CAT	Convention against Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment (1984)
CCA	Common Country Assessment
CCPOQ	Consultative Committee on Programme and Operational Questions
CDF	Comprehensive Development Framework
CEDAW	Convention on the Elimination of All Forms of Discrimination Against Women (1979)
CERD	International Convention on the Elimination of All Forms of Racial Discrimination (1963)
CRC	Convention on the Rights of the Child (1989)
ECOSOC	Economic and Social Council
IACHR	Inter-American Commission on Human Rights
ICCPR	International Covenant on Civil and Political Rights (1966) and its two Protocols (1966 and 1989)
ICESCR	International Covenant on Economic, Social and Cultural Rights (1966)
ILO	International Labour Organisation
IMF	International Monetary Fund
NGO	Non-Governmental Organization
OHCHR	United Nations Office of the High Commissioner for Human Rights
PAHO	Pan-American Health Organization
PRSP	Poverty Reduction Strategy Paper
UN	United Nations
TRIPS	Trade Related Aspects of Intellectual Property Rights
UDHR	Universal Declaration of Human Rights (1948)
UNDP	United Nations Development Programme
UNDAF	United Nations Development Assistance Framework
UNGASS	United Nations General Assembly Special Session
UNICEF	United Nations Children's Fund
WANAHR	World Alliance for Nutrition and Human Rights
WHO	World Health Organization
WTO	World Trade Organization

Section 1: Health & Human Rights Norms and Standards

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Q.1 What are human rights?

Human Rights:[1]
- Are guaranteed by international standards;
- Are legally protected;
- Focus on the dignity of the human being;
- Protect individuals and groups;
- Oblige states and state actors;
- Cannot be waived or taken away;
- Are interdependent and interrelated;
- Are universal.[2]

Human rights are legally guaranteed by human rights law, protecting individuals and groups against actions that interfere with fundamental freedoms and human dignity.[3] They encompass what are known as civil, cultural, economic, political and social rights. Human rights are principally concerned with the relationship between the individual and the state. Governmental obligations with regard to human rights broadly fall under the principles of *respect, protect and fulfil*.[4]

> *"All human rights are universal, indivisible and interdependent and interrelated. The international community must treat human rights globally in a fair and equal manner, on the same footing, and with the same emphasis. While the significance of national and regional particularities and various historical, cultural and religious backgrounds must be borne in mind, it is the duty of States, regardless of their political, economic and cultural systems, to promote and protect all human rights and fundamental freedoms."*
>
> Vienna Declaration and Programme of Action adopted at the World Conference on Human Rights.[5]

Q.2 How are human rights enshrined in international law?

In the aftermath of World War II, the international community adopted the Universal Declaration of Human Rights (UDHR, 1948). However, by the time that States were prepared to turn the provisions of the Declaration into binding law, the Cold War had overshadowed and polarised human rights into two separate categories. The West argued that civil and political rights had priority and that economic and social rights were mere aspirations. The Eastern bloc argued to the contrary that rights to food, health and education were paramount and civil and political rights secondary. Hence two separate treaties were created in 1966 – the International Covenant on Economic, Social and Cultural Rights (ICESCR) and the International Covenant on Civil and Political Rights (ICCPR). Since then, numerous treaties, declarations and other legal instruments have been adopted, and it is these instruments that encapsulate human rights.

- International human rights treaties are binding on governments that ratify them;
- Declarations are non-binding, although many norms and standards enshrined therein reflect principles which are binding in customary international law;
- United Nations conferences generate non-binding consensual policy documents, such as declarations and programmes of action.

(1) Administrative Committee on Coordination (ACC); The United Nations System and Human Rights: Guidelines and Information for the Resident Coordinator System; approved on behalf of the ACC by the Consultative Committee on Programme and Operational Questions (CCPOQ) at its 16th Session, Geneva, March 2000.

(2) This means that they apply to everyone everywhere.

(3) Human Rights: A Basic Handbook for UN Staff issued by the Office of the High Commissioner for Human Rights (OHCHR) and the United Nations Staff College Project, 1999, p.3.

(4) In turn, the obligation to fulfil contains obligations to facilitate, provide and promote (Section II.33, footnote 23 of General Comment 14 on the right to the highest attainable standard of health adopted by the Committee on Economic, Social and Cultural Rights in May 2000), (E/C.12/2000/4, CESCR dated 4 July 2000).

(5) Vienna Declaration and Programme of Action adopted at the World Conference on Human Rights, Vienna, 14-25 June 1993, paragraph 5, (United Nations General Assembly document A / CONF. 137/23).

> *"It was never the people who complained of the universality of human rights, nor did the people consider human rights as a Western or Northern imposition. It was often their leaders who did so."*
>
> United Nations Secretary-General, Kofi Annan

Q.3 What is the link between health and human rights?

There are complex linkages between health and human rights:

- Violations or lack of attention to human rights can have serious health consequences;[6]
- Health policies and programmes can promote or violate human rights in the ways they are designed or implemented;
- Vulnerability and the impact of ill health can be reduced by taking steps to respect, protect and fulfil human rights.

The normative content of each right is fully articulated in human rights instruments. In relation to the right to health and freedom from discrimination, the normative content is outlined in Questions 4 and 5, respectively. Examples of the language used in human rights instruments to articulate the normative content of some of the other key human rights relevant to health follows:

- **Torture:** "No one shall be subjected to torture or to cruel, inhuman or degrading treatment or punishment. In particular, no one shall be subjected without his free consent to medical or scientific experimentation."[7]
- **Violence against children:** "All appropriate legislative, administrative, social and educational measures to protect the child from all forms of physical or mental violence, injury or abuse, neglect or negligent treatment, maltreatment or exploitation, including sexual abuse..." shall be taken.[8]
- **Harmful traditional practices:** "Effective and appropriate measures with a view to abolishing traditional practices prejudicial to the health of children" shall be taken.[9]
- **Participation:** The right to "…active, free and meaningful participation."[10]

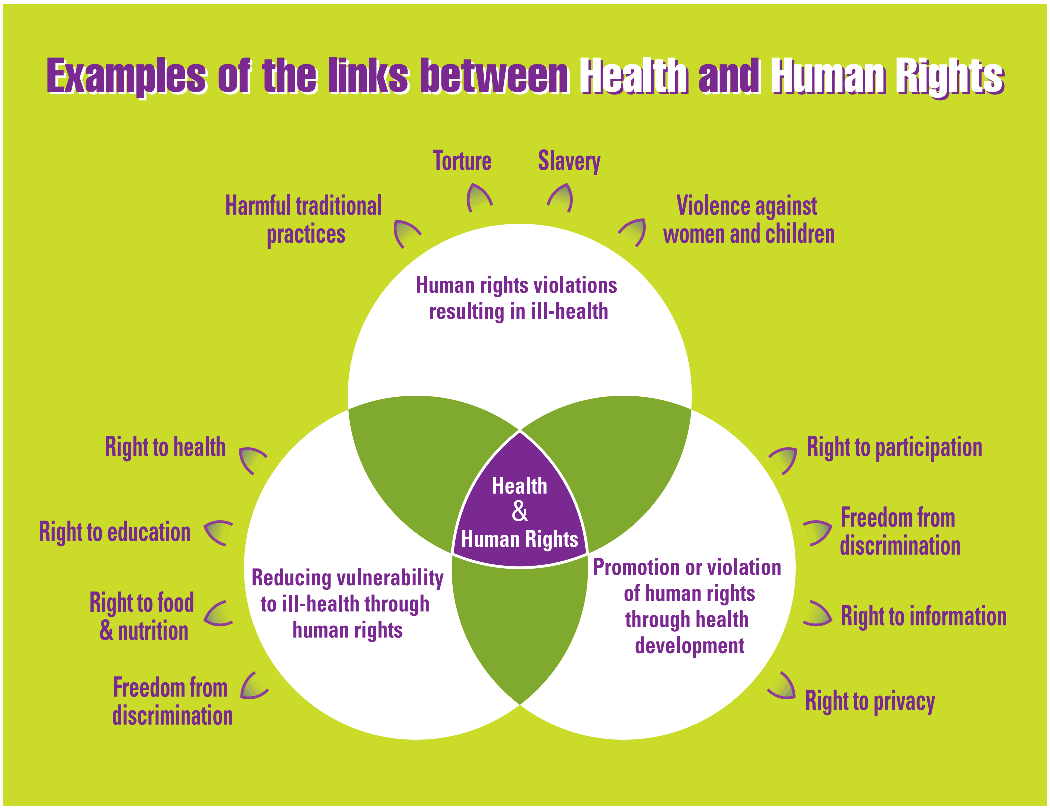
(6) Mann J, Gostin L, Gruskin S, Brennan T, Lazzarini Z, and Fineberg HV, "Health and Human Rights," *Health and Human Rights: An International Journal*, Vol. 1, No. 1, 1994.

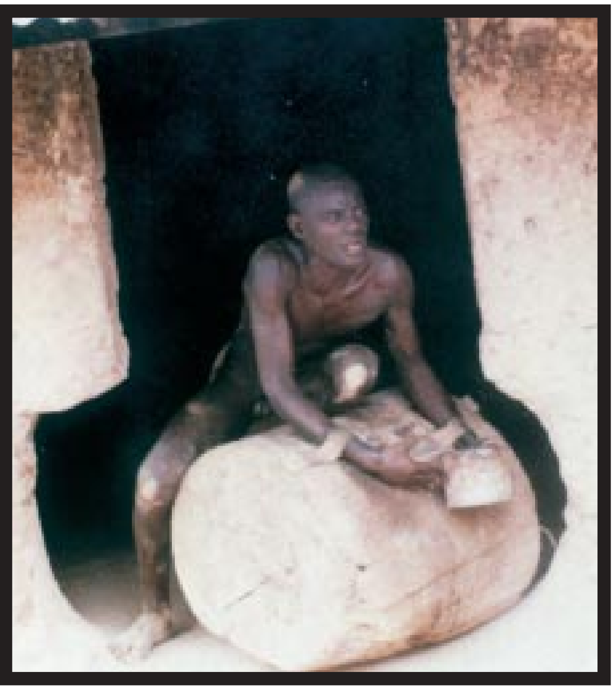
(7) Article 7, ICCPR. The prohibition of torture is also articulated in other human rights instruments, including the CAT and article 37 of the CRC.

(8) Article 19, CRC. The prohibition of violence against women is also articulated in the Declaration on the Elimination of Violence Against Women, 1993.

(9) Article 24, CRC. The prohibition of harmful traditional practices against women is also articulated in the Declaration on the Elimination of Violence Against Women, and General Recommendation 24 on Women and Health of the Committee on the Elimination of all forms of Discrimination Against Women, 1999.

(10) Article 2, Declaration on the Right to Development, 1986. The right to participation is also articulated in other human rights instruments, including article 25 of the ICCPR, article 15 of the ICESCR, article 5 of CERD, articles 7, 8, 13 and 14 of CEDAW, and articles 3, 9 and 12 of the CRC.





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- **Information:** "Freedom to seek, receive and impart information and ideas of all kinds." [11]
- **Privacy:** "No one shall be subjected to arbitrary or unlawful interference with his privacy..." [12]
- **Scientific progress:** The right of everyone to enjoy the benefits of scientific progress and its applications. [13]
- **Education:** The right to education, [14] including access to education in support of basic knowledge of child health and nutrition, the advantages of breast-feeding, hygiene and environmental sanitation and the prevention of accidents. [15]
- **Food and nutrition:** "The right of everyone to adequate food and the fundamental right of everyone to be free from hunger…" [16]
- **Standard of living:** Everyone has the right to an adequate standard of living, including adequate food, clothing, housing, and medical care and necessary social services. [17]
- **Right to social security:** The right of everyone to social security, including social insurance. [18]

Persons suffering from mental disabilities are particularly vulnerable to discrimination. Not only does this impact negatively on their ability to access appropriate treatment and care but the stigma associated with mental illness means that they experience discrimination in many other aspects of their lives, affecting their rights to employment, adequate housing, education, etc.

The United Nations Resolution on the Protection of Persons with Mental Illness, prohibits discrimination on the grounds of mental illness. [19]

(11) Article 19, ICCPR. The right to information is also articulated in other human rights instruments, including articles 10, 14 and 16 of the CEDAW, and articles 13, 17 and 24 of the CRC.

(12) Article 17, ICCPR. The right to privacy is also articulated in other human rights instruments, including article 16 of CEDAW, and article 40 of the CRC.

(13) Article 15, ICESCR.

(14) Article 13, ICESCR. The right to education is also articulated in other human rights instruments, including article 5 of CERD, articles 10 and 16 of CEDAW, and articles 19, 24, 28 and 33 of the CRC.

(15) Article 24, CRC.

(16) Article 11, ICESCR. The right to food is also articulated in other human rights instruments, including article 12 of CEDAW, and article 27 of the CRC.

(17) Article 25 UDHR and article 11 ICESCR.

(18) Article 9, ICESCR. The right to social security is also articulated in other human rights instruments, including article 5 of CERD, articles 11, 13 and 14 of CEDAW, and article 26 of the CRC.

(19) 18 February 1992, UN General Assembly Resolution on the Protection of Persons with Mental Illness and the Improvement of Mental Health Care, Principle 1 (A/RES/46).

(20) *Basic Documents*, Forty-third Edition, Geneva, World Health Organization, 2001. The Constitution was adopted by the International Health Conference in 1946.

(21) WHA51.7, annex.

Q.4 What is meant by "the right to health"?

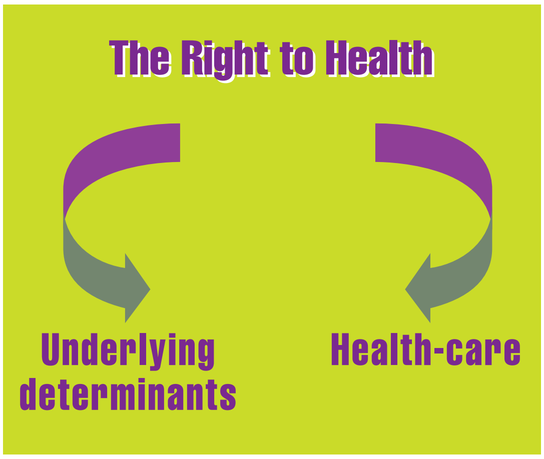
"The right to health does not mean the right to be healthy, nor does it mean that poor governments must put in place expensive health services for which they have no resources. But it does require governments and public authorities to put in place policies and action plans which will lead to available and accessible health care for all in the shortest possible time. To ensure that this happens is the challenge facing both the human rights community and public health professionals."

United Nations High Commissioner for Human Rights, Mary Robinson

The right to the highest attainable standard of health (referred to as "the right to health") was first reflected in the WHO Constitution (1946) [20] and then reiterated in the 1978 Declaration of Alma Ata and in the World Health Declaration adopted by the World Health Assembly in 1998. [21] It has been firmly endorsed in a wide range of international and regional human rights instruments. [22]

The right to the highest attainable standard of health in international human rights law is a claim to a set of social arrangements – norms, institutions, laws, an enabling environment – that can best secure the enjoyment of this right. The most authoritative interpretation of the right to health is outlined in Article 12 of the ICESCR, which has been ratified by 145 countries (as of May 2002). In May 2000, the Committee on Economic, Social and Cultural Rights, which monitors the Covenant, adopted a General Comment on the right to health. [23] General Comments serve to clarify the nature and content of individual rights and States Parties' (those states that have ratified) obligations. The General Comment recognized that the right to health is closely related to and dependent upon the realization of other human rights, including the right to food, housing, work, education, participation, the enjoyment of the benefits of scientific progress and its applications, life, non-discrimination, equality, the prohibition against torture, privacy, access to information, and the freedoms of association, assembly and movement.

Further, the Committee interpreted the right to health as an inclusive right extending not only to timely and appropriate health care but also to the underlying determinants of health, such as access to safe and potable water and adequate sanitation, an adequate supply of safe food, nutrition and housing, healthy occupational and environmental conditions, and access to health-related education and information, including on sexual and reproductive health.



The General Comment sets out four criteria by which to evaluate the right to health: [24]

(a) *Availability*. Functioning public health and health-care facilities, goods and services, as well as programmes, have to be available in sufficient quantity. [25]

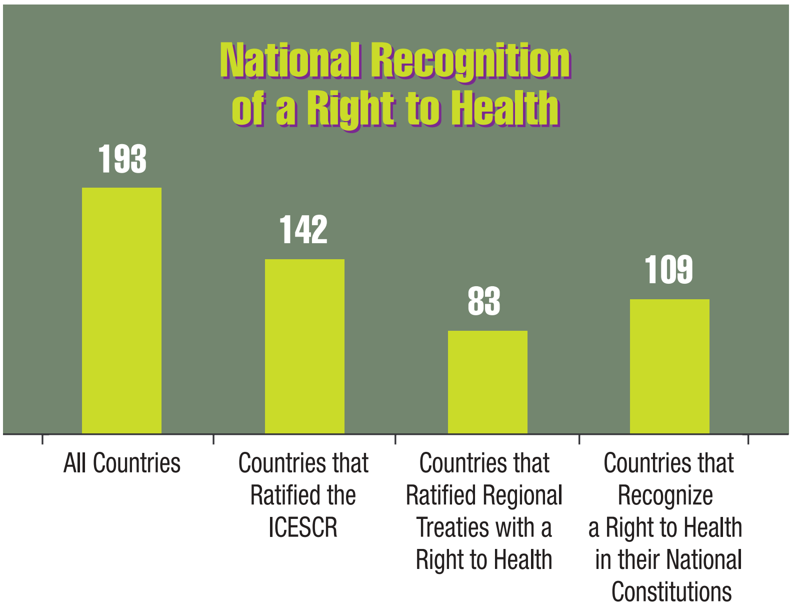
(b) *Accessibility*. Health facilities, goods and services have to be accessible to everyone without discrimination, within the jurisdiction of the State party. Accessibility has four overlapping dimensions:

- Non-discrimination; [26]
- Physical accessibility; [27]
- Economic accessibility (affordability); [28]
- Information accessibility. [29]

(c) *Acceptability*. All health facilities, goods and services must be respectful of medical ethics and culturally appropriate, sensitive to gender and life-cycle requirements, as well as being designed to respect confidentiality and improve the health status of those concerned.

(d) *Quality*. Health facilities, goods and services must be scientifically and medically appropriate and of good quality [30].

The following graph illustrates the number of countries that recognize the right to health at different levels:



Source: Eleanor D. Kinney, *The International Human Right to Health: What Does This Mean For Our Nation And World?* Indiana Law Review, Vol. 34, page 1465, 2001.

(22) The human right to health is recognized in numerous international instruments. Article 25(1) of the UDHR affirms that "everyone has a right to a standard of living adequate for the health of himself and his family, including food, clothing, housing, and medical care and necessary social services." The ICESCR provides the most comprehensive article on the right to health in international human rights law. According to article 12(1) of the Covenant, States Parties recognize "the right of everyone to the enjoyment of the highest attainable standard of physical and mental health", while article 12(2) enumerates, by way of illustration, a number of "steps to be taken by the States Parties "... to achieve the full realization of this right". Additionally, the right to health is recognized, *inter alia*, in the CERD of 1963, the CEDAW of 1979 and in the CRC of 1989. Several regional human rights instruments also recognize the right to health, such as the European Social Charter of 1961 as revised, the African Charter on Human and Peoples' Rights of 1981 and the Additional Protocol to the American Convention on Human Rights in the Area of Economic, Social and Cultural Rights of 1988 (the Protocol entered into force in 1999). Similarly, the right to health has been proclaimed by the Commission on Human Rights and further elaborated in the Vienna Declaration and Programme of Action of 1993 and other international instruments.

(23) General Comment 14.

(24) General Comment 14.

(25) This should include the underlying determinants of health, such as safe and potable drinking-water and adequate sanitation facilities, hospitals, clinics and other health-related buildings, trained medical and professional personnel receiving domestically competitive salaries, and essential drugs, as defined by the WHO Action Programme on Essential Drugs.

(26) Health facilities, goods and services must be accessible to all, in law and in fact, without discrimination on any of the prohibited grounds.

(27) Health facilities, goods and services must be within safe physical reach for all sections of the population, especially vulnerable or marginalized groups, such as ethnic minorities and indigenous populations, women, children, adolescents, older persons, persons with disabilities and persons with HIV/AIDS, including in rural areas.

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Q.5 How does the principle of freedom from discrimination relate to health?

Vulnerable and marginalized groups in societies tend to bear an undue proportion of health problems. Overt or implicit discrimination violates a fundamental human rights principle and often lies at the root of poor health status. In practice, discrimination can manifest itself in inadequately targeted health programmes and restricted access to health services.

Discrimination manifests itself in a complex variety of ways, which may directly or indirectly, impact upon health. For example, the Declaration on the Elimination of Violence against Women recognizes the link between violence against women and the historically unequal power relations between men and women.[31]

The prohibition of discrimination does not mean that differences should not be acknowledged, only that different treatment – and the failure to treat equal cases equally – must be based on objective and reasonable criteria intended to rectify imbalances within a society.

In relation to health and health-care the grounds for non-discrimination have evolved and can now be summarized as proscribing "any discrimination in access to health care and the underlying determinants of health, as well as to means and entitlements for their procurement, on the grounds of race, colour, sex, language, religion, political or other opinion, national or social origin, property, birth, physical or mental disability, health status (including HIV/AIDS), sexual orientation, civil, political, social or other status, which has the intention or effect of nullifying or impairing the equal enjoyment or exercise of the right to health."[32]

"Public health practice is heavily burdened by the problem of inadvertent discrimination. For example, outreach activities may 'assume' that all populations are reached equally by a single, dominant-language message on television; or analysis 'forgets' to include health problems uniquely relevant to certain groups, like breast cancer or sickle cell disease; or a problem 'ignores' the actual response capability of different population groups, as when lead poisoning warnings are given without concern for financial ability to ensure lead abatement. Indeed, inadvertent discrimination is so prevalent that all public health policies and programmes should be considered discriminatory until proven otherwise, placing the burden on public health to affirm and ensure its respect for human rights."

Jonathan Mann[33]

(28) Health facilities, goods and services must be affordable for all. Payment for health-care services, as well as services related to the underlying determinants of health, has to be based on the principle of equity, ensuring that these services, whether privately or publicly provided, are affordable for all.

(29) Accessibility includes the right to seek, receive and impart information and ideas concerning health issues. However, accessibility of information should not impair the right to have personal health data treated with confidentiality.

(30) This requires, inter *alia*, skilled medical personnel, scientifically approved and unexpired drugs and hospital equipment, safe and potable water, and adequate sanitation.

(31) Declaration on the Elimination of Violence against Women, 85th plenary meeting, 20 December 1993, (A/RES/48/104), preamble.

(32) General Comment 14.

(33) The Hastings Center Report, Volume 27, No.3, May-June 1997, p. 9.

Q.6 What international human rights instruments set out governmental commitments?

Governments decide freely whether or not to become parties to a human rights treaty. Once this decision is made, however, there is a commitment to act in accordance with the provisions of the treaty concerned. The key international human rights treaties, the International Covenant on Economic, Social and Cultural Rights (ICESCR, 1966) and the International Covenant on Civil and Political Rights (ICCPR, 1966) further elaborate the content of the rights set out in the Universal Declaration of Human Rights (UDHR, 1948), and contain legally binding obligations for the governments that become parties to them. Together these documents are often called the "International Bill of Human Rights."

Building upon these core documents, other international human rights treaties have focused on either specific groups or categories of populations, such as racial minorities,[34] women[35] and children,[36] or on specific issues, such as torture.[37] In considering a normative framework of human rights applicable to health, human rights provisions must be considered in their totality.

The Declarations and Programmes of Action from United Nations world conferences such as the World Conference on Human Rights (Vienna, 1993), the International Conference on Population and Development (Cairo, 1994), the World Summit for Social Development (Copenhagen, 1995), the Fourth World Conference on Women (Beijing, 1995) and the World Conference Against Racism, Racial Discrimination, Xenophobia and Related Intolerance (Durban, 2001), provide guidance on some of the policy implications of meeting government's human rights obligations.

> Every country in the world is now party to at least one human rights treaty that addresses health-related rights, including the right to health, and a number of rights related to conditions necessary for health.

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Q.7 What international monitoring mechanisms exist for human rights?

The implementation of the core human rights treaties is monitored by committees of independent experts known as treaty monitoring bodies, created under the auspices of and serviced by the United Nations. Each of the six major human rights treaties has its own monitoring body which meets regularly to review State Party reports and to engage in a "constructive dialogue" with governments on how to live up to their human rights obligations. Based on the principle of transparency, States are required to submit their progress reports to the treaty bodies, and to make them widely available to their own populations. Thus reports can play an important catalytic role, contributing to the promotion of national debate on human rights issues, encouraging the engagement and participation of civil society, and generally fostering a process of public scrutiny of governmental policies. At the end of the session, the treaty body makes concluding observations which include recommendations on how the government can improve its human rights record. Specialized agencies such as WHO can play an important role in providing relevant health information to facilitate the dialogue between the State Party and the treaty monitoring body.

(34) International Convention on the Elimination of All Forms of Racial Discrimination, 1963.
(35) Convention on the Elimination of All Forms of Discrimination Against Women, 1979.
(36) Convention on the Rights of the Child, 1989.
(37) Convention Against Torture and other Cruel, Inhuman or Degrading Treatment or Punishment, 1984.

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Other mechanisms for monitoring human rights in the United Nations system include the Commission on Human Rights and the Sub-Commission on the Promotion and Protection of Human Rights. These bodies appoint special rapporteurs and other independent experts and working groups to monitor and report on thematic human rights issues (such as violence against women, sale of children, harmful traditional practices, and torture) or on specific countries. In addition, the post of High Commissioner for Human Rights was created in 1994 to head the United Nations human rights system. The High Commissioner's mandate extends to every aspect of the United Nations human rights activities: monitoring, promotion, protection and coordination.

Regional arrangements have been established within existing regional intergovernmental organizations. The African regional human rights instrument is the African Charter on Human and Peoples' Rights, which is located within the Organization of African Unity. The regional human rights mechanism for the Americas is located within the Organization of American States and is based upon the American Convention of Human Rights. In Europe, a human rights system forms a part of the Council of Europe. Key human rights instruments are the European Convention on the Protection of Human Rights and Fundamental Freedoms and the European Social Charter.[38] The 15 member state organization — the European Union — has detailed rules concerning human rights issues and has integrated human rights into its common foreign policy. In addition, the Organization for Security and Cooperation in Europe (OSCE), a 55 member state organization, has separate mechanisms and agreements. In the Asia-Pacific region, extensive consultations among Governments are underway concerning the possible establishment of regional human rights arrangements.

The collaboration between PAHO/WHO and the Inter-American Commission on Human Rights (IACHR, the body responsible for overseeing the American Convention on Human Rights) concerning the rights of persons with mental disabilities, is an example of the key role specialized agencies can play within international monitoring mechanisms. PAHO/WHO offers technical opinions and assistance on the interpretation of the American Convention on Human Rights and the American Declaration on the Rights and Duties of Man, in light of international standards on mental disability rights. In turn, the IACHR incorporates these standards into final reports of relevant individual cases and in country reports. As a result of this technical assistance, the IACHR has issued the Recommendation for the Promotion and Protection of the Rights of the Mentally Ill (28 February 2001).[39]

(38) http://conventions.coe.int/Treaty/EN/CadreListeTraites.htm.

(39) This recommendation was included in the IACHR annual report (2001), constituting the first time the latter has devoted a section to mental disability rights.

Q.8 How can poor countries with resource limitations be held to the same human rights standards as rich countries?

Steps towards the full realization of rights must be deliberate, concrete and targeted as clearly as possible towards meeting a government's human rights obligations. [40] All appropriate means, including the adoption of legislative measures and the provision of judicial remedies as well as administrative, financial, educational and social measures, must be used in this regard. This neither requires nor precludes any particular form of government or economic system being used as the vehicle for the steps in question.

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The principle of *progressive realization* of human rights [41] imposes an obligation to move as expeditiously and effectively as possible towards that goal. It is therefore relevant to both poorer and wealthier countries, as it acknowledges the constraints due to the limits of available resources, but requires all countries to show constant progress in moving towards full realization of rights. Any deliberately retrogressive measures require the most careful consideration and need to be fully justified by reference to the totality of the rights provided for in the human rights treaty concerned and in the context of the full use of the maximum available resources. In this context, it is important to distinguish the *inability* from the *unwillingness* of a State Party to comply with its obligations. During the reporting process the State Party and the Committee identify indicators and national benchmarks to provide realistic targets to be achieved during the next reporting period.

Q.9 Is there, under human rights law, an obligation of international cooperation?

Malaria, HIV/AIDS and tuberculosis are examples of diseases which disproportionately affect the world's poorest populations, placing a tremendous burden on the economies of developing countries. In this regard, it should be noted that although the human rights paradigm concerns obligations of States with respect to individuals and groups within their own jurisdictions, where the human rights instruments refer to the State's resources, they include international assistance and cooperation.

In accordance with Articles 55 and 56 of the Charter of the United Nations, international cooperation for development and the realization of human rights is an obligation of all States. Similarly, the Declaration on the Right to Development [42] emphasizes an active programme of international assistance and cooperation based on sovereign equality, interdependence, and mutual interest. [43]

In addition, the ICESCR requires each State who is party to the Covenant to "take steps, individually and through international assistance and cooperation, especially

(40) ICESCR General Comment 3 on the nature of States Parties obligations adopted by the Committee on Economic, Social and Cultural Rights, Fifth Session 1990 (E/1991/23).
(41) ICESCR, Article 2 (1).
(42) Adopted by the General Assembly in its resolution 41/128 of 4 December 1986.
(43) Declaration on the Right to Development, Article 3, adopted by General Assembly resolution 41/128 of 4 December 1986.

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economic and technical, to the maximum of its available resources, with a view to achieving progressively the full realization of the rights recognized [herein]." [44]

In this spirit, "the framework of international cooperation" is referred to, which acknowledges, for instance, that the needs of developing countries should be taken into consideration in the area of health. The role of specialized agencies is recognized in human rights treaties in this context. For example, the ICESCR stresses that "international action for the achievement of the rights ... includes such methods as ... furnishing of technical assistance and the holding of regional meetings and technical meetings for the purpose of consultation and study organized in conjunction with the Governments concerned." [45]

Q.10 What are governmental human rights obligations in relation to other actors in society?

As government roles and responsibilities include increased reliance on non-state actors (health insurance companies, etc.), governmental health systems must ensure the existence of social safety nets and other mechanisms to ensure that vulnerable population groups have access to the services and structures they need.

The obligation of the State to *protect* human rights means that governments are responsible for ensuring that non-state actors act in conformity with human rights law within their jurisdiction. Governments are obliged to ensure that third parties conform with human rights standards by adopting legislation, policies and other measures to assure adequate access to health care, quality information, etc., and an accessible means of redress if individuals are denied access to these goods and services. An example of this is the obligation of governments to ensure the regulation of the tobacco industry in order to protect its population against infringements of the right to health, the right to information, and other relevant human rights provisions.

In the corporate and NGO contexts, [46] there is a proliferation of voluntary codes which reflect international human rights norms and standards. Increasing attention to the human rights implications of work in the private sector has resulted in human rights being placed higher on the business agenda, with several businesses beginning to incorporate concern for human rights into their daily operations. [47]

(44) ICESCR, Article 2.
(45) ICESCR, Article 23.
(46) In the area of humanitarian assistance, for example, the Sphere Project's (draft) Charter on Minimum Humanitarian Standards in Disaster Relief provides a comprehensive catalogue of technical standards for NGO and other international relief workers on matters such as food, nutrition, water and sanitation, based upon international human rights law.
(47) http: // www.unglobalcompact.org.

Section 2: Integrating Human Rights in Health

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Q.11 What is meant by a rights-based approach to health?

A rights-based approach to health refers to the **processes** of:

- *Using human rights as a framework for health development.* [48]
- *Assessing and addressing the human rights implications of any health policy, programme or legislation.*
- *Making human rights an integral dimension of the design, implementation, monitoring and evaluation of health-related policies and programmes in all spheres, including political, economic and social.*

Substantive elements to apply, within these processes, could be as follows:

✓ Safeguarding ***human dignity***.

✓ Paying attention to those population groups considered most vulnerable in society. [49] In other words, recognizing and acting upon the characteristics of those affected by health policies, programmes and strategies — children (girls and boys), adolescents, women, and men; indigenous and tribal populations; national, ethnic, religious and linguistic minorities; internally displaced persons; refugees; immigrants and migrants; the elderly; persons with disabilities; prisoners; economically disadvantaged or otherwise marginalized and/or ***vulnerable groups***.

✓ Ensuring health systems are made ***accessible*** to all, especially the most vulnerable or marginalized sections of the population, in law and in fact, without discrimination on any of the prohibited grounds.

✓ Using a ***gender*** perspective, recognizing that both biological and sociocultural factors play a significant role in influencing the health of men and women, and that policies and programmes must consciously set out to address these differences.

> A rights-based approach to health entails recognizing the individual characteristics of the population groups concerned. In all actions relating to children, for example, the guiding principles of the Convention on the Rights of the Child should be applied. These include:
> - The best interests of the child shall be a primary consideration;
> - The views of the child shall be given due weight.

✓ Ensuring ***equality and freedom from discrimination***, advertent or inadvertent, in the way health programmes are designed or implemented.

(48) See Question 3 for an explanation of the links between health and human rights.

(49) Many are spelt out in specific human rights instruments, such as the International Labour Organisation Convention concerning Indigenous and Tribal Peoples in Independent Countries (No. 169, 1989) and the International Convention on the Protection of the Rights of All Migrant Workers and Members of their Families (1990).

✓ *Disaggregating* health data to detect underlying discrimination.

✓ Ensuring free, meaningful, and effective *participation* of beneficiaries of health development policies or programmes in decision-making processes which affect them.

✓ Promoting and protecting the *right to education* and the right to seek, receive and impart *information* and ideas concerning health issues. However, the right to information should not impair the right to *privacy*, which means that personal health data should be treated with confidentiality.

> It has been demonstrated that "respect for human rights in the context of HIV/AIDS, mental illness, and physical disability leads to markedly better prevention and treatment. Respect for the dignity and privacy of individuals can facilitate more sensitive and humane care. Stigmatization and discrimination thwart medical and public health efforts to heal people with disease or disability". [50]

✓ Only limiting the exercise or enjoyment of a right by a health policy or programme as a last resort, and only considering this legitimate if each of the provisions reflected in *the Siracusa principles* is met.[51] (See Question 13).

✓ Juxtaposing the human rights implications of any health legislation, policy or programme with the desired public health objectives and ensuring the *optimal balance* between good public health outcomes and the promotion and protection of human rights.

✓ Making *explicit linkages to international human rights norms and standards* to highlight how human rights apply and relate to a health policy, programme or legislation.

✓ Making the attainment of the *right to the highest attainable standard of health* the explicit ultimate aim of activities, which have as their objective the enhancement of health.

✓ Articulating the concrete government *obligations* to respect, protect and fulfil human rights.

✓ Identifying *benchmarks and indicators* to ensure monitoring of the progressive realization of rights in the field of health.

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✓ Increasing *transparency* in, and *accountability* for, health as a key consideration at all stages of programme development.

✓ Incorporating *safeguards* to protect against majoritarian threats upon minorities, migrants and other domestically "unpopular" groups, in order to address power imbalances. For example, by incorporating redress mechanisms in case of impingements on health-related rights.

Possible "ingredients" in a rights-based approach to health:

Right to health
Information
Gender
Human dignity
Transparency
Siracusa principles

Benchmarks and indicators
Accountability
Safeguards
Equality and freedom from discrimination
Dissaggregation

Attention to vulnerable groups
Participation
Privacy
Right to education
Optimal balance between public health goals and protection of human rights
Accessibility
Concrete government obligations
Human rights expressly linked

(50) Eds. Mann J, Gruskin S, Grodin M, Annas G, Health and Human Rights: A Reader, (Routledge, 1999), Introduction, para. 4.

(51) The Siracusa principles on the limitation and derogation provisions in the international covenant on civil and political rights. UN Doc. E/CN.4/1985/4, Annex.

Q.12 What is the value-added of human rights in public health?

Overall, human rights may benefit work in the area of public health by providing:

- Explicit recognition of the highest attainable standard of health as a "human right" (as opposed to a good or commodity with a charitable construct);
- A tool to enhance health outcomes by using a human rights approach to designing, implementing and evaluating health policies and programmes;

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- An "empowering" strategy for health which includes vulnerable and marginalized groups engaged as meaningful and active participants;
- A useful framework, vocabulary and form of guidance to identify, analyze and respond to the underlying determinants of health;
- A standard against which to assess the performance of governments in health;
- Enhanced governmental accountability for health;
- A powerful authoritative basis for advocacy and cooperation with governments; international organizations; international financial institutions; and in the building of partnerships with relevant actors of civil society;
- Existing international mechanisms to monitor the realization of health as a human right;[52]
- Accepted international norms and standards (e.g. definitions of concepts and population groups);
- Consistent guidance to states as human rights cross-cut all United Nations activities;
- Increased scope of analysis and range of partners in countries.

[52] See Question 7.

Q.13 What happens if the protection of public health necessitates the restriction of certain human rights?

There are a number of human rights that cannot be restricted in any circumstance such as freedom from torture and slavery, and freedom of thought, conscience and religion. Limitation and derogation clauses in the international human rights instruments recognize the need to limit human rights at certain times.

Public health is sometimes used by states as a ground for limiting the exercise of human rights.

A key factor in determining if the necessary protections exist when rights are restricted is that each one of the five criterion of the Siracusa Principles must be met. Even in circumstances where limitations on grounds of protecting public health are basically permitted, they should be of limited duration and subject to review.

The Siracusa Principles

Only as a last resort can human rights be interfered with to achieve a public health goal. Such interference can only be justified when all of the narrowly defined circumstances set out in human rights law, known as the Siracusa Principles, are met:

- The restriction is provided for and carried out in accordance with the law;
- The restriction is in the interest of a legitimate objective of general interest;
- The restriction is strictly necessary in a democratic society to achieve the objective;
- There are no less intrusive and restrictive means available to reach the same objective; and
- The restriction is not drafted or imposed arbitrarily, i.e. in an unreasonable or otherwise discriminatory manner.

Interference with freedom of movement when instituting quarantine or isolation for a serious communicable disease — for example, Ebola fever, syphilis, typhoid or untreated tuberculosis — are examples of restrictions on rights that may, under certain circumstances, be necessary for the public good, and therefore could be considered legitimate under international human rights law.[53] By contrast, a state which restricts the movements of, or incarcerates, persons with HIV/AIDS, refuses to allow doctors to treat persons believed to be opposed to a government or fails to provide immunization against the community's major infectious diseases, on grounds such as national security or the preservation of public order, has the burden of justifying such serious measures.[54]

(53) Gruskin S and Tarantola D in Ed. Retels R, Mc Ewen J, Beaglehole R, Tanaka H, Oxford Textbook of Public Health, Fourth Edition, Oxford, Oxford University Press, (in press).

(54) General Comment 14, paragraphs 28-29.

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Q.14 What implications could human rights have for evidence-based health information?

The process that gives birth to an internationally recognized human right is generated from the pressing reality on the ground. For example, the development of a declaration on the rights of indigenous populations[55] stems from the recognition that this is a vulnerable and marginalized population group lacking full enjoyment of a wide range of human rights, including rights to political participation, health and education. In other words, the establishment of human rights norms and standards is itself evidence of a serious problem and governmental recognition of the importance of addressing it. The existence of human rights norms and standards should therefore stimulate the collection of evidence, indicating the data needed to tackle complex health challenges. For example, disaggregating data beyond traditional markers could detect discrimination on the basis of ethnicity against indigenous and tribal peoples which is considered an underlying determinant of their overall poor health status. However, the political sensitivities which underpin human rights in exposing how different population groups are treated and why, hampers the extent to which human rights are welcomed as a driving force for data collection.

More widely accepted is the notion that human rights are relevant to the way in which health data should be collected. This includes the choice of the methods of data collection which must include considerations on how to ensure respect for human rights, such as privacy, participation and non-discrimination. Secondly, international instruments can be helpful in defining various population groups. For example, the ILO Convention Concerning Indigenous and Tribal Peoples[56] provides an authoritative basis for identifying and differentiating indigenous and tribal peoples from other population groups.

> Collecting personal information from individuals about their health status (e.g. HIV infection, cancer or genetic disorders), or behaviour (e.g. sexual orientation or the use of alcohol or other potentially harmful substances) has the potential for misuse by the state, whether directly or because this information is intentionally or inadvertently made available to others.[57]

(55 The open-ended inter-sessional Working Group on the draft declaration was established in 1995 in accordance with Commission on Human Rights resolution 1995/32 and Economic and Social Council resolution 1995/32. The Working Group has the sole purpose of elaborating a draft declaration on the rights of indigenous peoples, considering the draft contained in the annex to resolution 1994/45 of 26 August 1994 entitled draft "United Nations declaration on the rights of indigenous peoples". The draft is being prepared for consideration and adoption by the General Assembly during the International Decade of the World's Indigenous People.

(56) The International Labour Organisation Convention Concerning Indigenous and Tribal Peoples in Independent Countries (Convention 169) adopted by the International Labour Organisation on 27 June 1989.

(57) Gruskin S and Tarantola D (refer to footnote 49).

Indicators

United Nations agencies' work on health indicators, human rights indicators, and human development indicators can assist in forging common agendas. Greater coordination to ensure a common framework for the design, development, use and assessment of indicators is needed. The UNDG working group on Common Country Assessment (CCA) Indicators adopted the definition of an indicator as a variable or measurement, conveying information that may be qualitative or quantitative, but which is consistently measurable. Human rights were integrated in the CCA indicator framework which lead to the goal of developing a list of simple development indicators, designed to measure "what is", on a right-by-right basis. This would not include benchmarks, targets or goals, or answer definitely "what should be" or "by when," as these are appropriately developed in country-specific, participatory national processes.[58]

"Information and statistics are a powerful tool for creating a culture of accountability and for realizing human rights."

Human Development Report 2000[59]

(58) See Mokhiber, C. G. "Toward a Measure of Dignity: Indicators for Rights-Based Development". Session I-PL 4, Montreux, 4-8 September 2000.

(59) United Nations Development Programme, Human Development Report 2000, (New York and Oxford: Oxford University Press, 2000), p. 10.

(60) The World Health Report 2000 *Health Systems: Improving Performance.*

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Q.15 How can human rights support work to strengthen health systems?

Human rights provide a standard against which to evaluate existing health policies and programmes, including highlighting the differential treatment of individual groups of people in, for example, manifestations, frequency and severity of disease, and governmental responses to it. Human rights norms and standards also form a strong basis for health systems to prioritize the health needs of vulnerable and marginalized population groups. Human rights moves beyond averages and focuses attention on those population groups in society which are considered most vulnerable (e.g. indigenous and tribal populations; refugees and migrants, ethnic, religious, national and racial monitories), as well as putting forward specific human rights which may help guide health policy, programming, and health system processes (e.g. the right of those potentially affected by health policies, strategies and standards to participate in the process in which decisions affecting their health are made).

World Health Report 2000: WHO Framework on Health Systems Performance Assessment

In working towards an evidence-based model of health, WHO developed health system performance indicators in its World Health Report 2000. The fundamental principles underlying these indicators are: to clarify the boundaries of health systems; to assess how health and other systems interact to achieve key social goals; to define and measure health, responsiveness, and fairness in financial contribution; and to show how different policies contribute towards improving health systems performance.[60] In particular with regard to the responsiveness of the health system, human rights norms and standards have been incorporated shaping the definitions of the various domains being measured.

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Q.16 What is the relationship between health legislation and human rights law?

Health legislation can be an important vehicle towards ensuring the promotion and protection of the right to health. In the design and review of health legislation, human rights provide a useful tool to determine its effectiveness and appropriateness in line with both human rights and public health goals. In this context, HIV/AIDS has caused many countries to revisit their public health laws, including in relation to quarantine and isolation.[61]

Restrictive laws and policies that deliberately focus on certain population groups without sufficient data, epidemiological and otherwise, to support their approach may raise a host of human rights concerns. Two examples in this regard are health policies concerning the involuntary sterilization of women from certain population groups that are justified as necessary for their health and well-being, and sodomy statutes criminalizing same-sex sexual behaviour that are justified as necessary to prevent the spread of HIV/AIDS.[62]

Government capacity to develop national health policy and legislation that conforms to human rights obligations needs to be strengthened. This includes developing the tools to review health-related laws and policies to determine whether, on their face or application, they violate human rights, and providing the means to rectify any violation which exists.

Q.17 How do human rights apply to situational analyses of health in countries?

Increased attention to human rights may, firstly, broaden the scope of situational health analysis in countries, and secondly, as a result, allow new partners to be identified. New areas of attention include consideration of the health components of national human rights action plans and, conversely, the inclusion of human rights in national health strategies and action plans. Given that human rights obligations relevant to health rest with the government as a whole, health and human rights goals need to figure in policies and plans which may be generated outside the health sector per se but which have a strong bearing on health, such as national food and nutrition policies and plans. The focus on vulnerable population groups draws attention to how national legislation and development policies impact upon the status of such groups, which institutions work to protect their best interests, and how civil society movements represent them. Finally, the reports to and comments from the United Nations human rights treaty monitoring bodies and the views of civil society organizations are another issue for consideration.

Practical implications may be to engage at the national level with a greater range of Ministries other than Health Ministries, e.g. Justice Ministries and those with responsibility for human rights (including independent human rights institutions), women's affairs, children's affairs, education, social affairs, finance, etc. United Nations agencies and other intergovernmental organizations working on human rights, international and national human rights NGOs, national human rights institutions, ombudspersons, national human rights commissions, human rights think-tanks and research institutes, also constitute fruitful partners for advancing the global health agenda.

(61) Gostin L, Burris S, and Lazzarini Z, "The Law and the Public's Health: A study of Infectious Disease Law in the United States", *Columbia Law Review*, Vol. 99, No.1, (1999).

(62) Gruskin S and Tarantola D, refer to footnote 48.

Section 3: Health & Human Rights in a broader context

Q.18 How do ethics relate to human rights?

Ethics are norms of conduct for individuals and for societies. These norms derive from many sources, including religion, cultural tradition, and reflection, which accounts in part for the complexity within each ethical outlook. Ethics as a system of norms employs many component concepts, including obligations and duties, virtues of character, standards of value and goodness in outcomes and consequences of action, standards of fairness, and justice in allocation of resources and in reward and punishment.

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Human rights refer to an internationally agreed upon set of principles and norms embodied in international legal instruments. These international human rights principles and norms are the result of deep and long-standing negotiations among Member States on a range of fundamental issues. In other words, human rights are generated by governments through a consensus-building process.

Work in ethics needs to take into account human rights norms and standards, not only in substance but also in relation to the processes of ethical discourse and reasoning. For example, where issues concern a specific population group, individuals representing this group should be participants in any determination of the ethical implications of the issues affecting them. Ethics is particularly useful in areas of practice where human rights do not provide a definite answer, for example, in new and emerging areas where human rights law has not been applied or codified, such as human cloning.

Q.19 How do human rights principles relate to equity?

Equity means that people's needs, rather than their social privileges, guide the distribution of opportunities for well-being.[63] This means eliminating disparities in health and in health's major determinants that are systematically associated with underlying social disadvantage within a society. Within the human rights discourse, the principle of equity is increasingly serving as an important non-legal generic policy term aimed at ensuring fairness. It has been used to embrace policy-related issues, such as the accessibility, affordability and acceptability of available health care services. The focused attention on vulnerable and disadvantaged groups in society in international human rights instruments reinforces the principle of equity. Also, at the international level, human rights instruments address equity by encouraging international cooperation to realize rights as well as addressing intrastate relations, most notably in the United Nations Declaration on the Right to Development.[64]

(63) *Equity in Health and Health Care: A WHO/SIDA Initiative*, WHO, Geneva, 1996.
(64) Declaration on the Right to Development, 4 December 1986, (A/RES/41/128).

Q.20 How do health and human rights principles apply to poverty reduction?

The right to a standard of living adequate for health and well-being, including necessary social services, and the right to security in the event of sickness, disability, old age or other lack of livelihood is enshrined in the Universal Declaration of Human Rights.[65] The Committee on Economic, Social and Cultural Rights has defined poverty as "a human condition characterized by sustained or chronic deprivation of the resources, capabilities, choices, security and power necessary for the enjoyment of an adequate standard of living and other civil, cultural, economic, political and social rights."[66]

"The challenge for development professionals, and for policy and practice, is to find ways to weaken the web of powerlessness and to enhance the capabilities of poor women and men so that they can take more control of their lives."[67]

Human rights empower individuals and communities by granting them entitlements that give rise to legal obligations on others. Human rights can help to equalize the distribution and exercise of power both within and between societies, mitigating the powerlessness of the poor. As economic and social rights, such as the right to health, are increasingly gaining weight through increased normative clarity and application, they will provide an important tool for poverty reduction. A human rights approach also requires the active and informed participation of the poor in the formulation, implementation and monitoring of strategies which may affect them.

Accountability, transparency, democracy and good governance, are essential ingredients to addressing poverty and ill-health. Legal rights and obligations, at the domestic and international level, demand accountability: effective legal remedies, administrative and political accountability mechanisms at the domestic level, as well as human rights monitoring at the international level.[68] Overall, human rights provide a holistic framework to poverty reduction, demanding consideration of a spectrum of approaches, including legislation, polices and programmes.

Disability can become a cause of poverty and poverty can also be a risk factor for disability. Human rights provide a legal framework to ensure non-discrimination and equal opportunity for persons with disabilities, and thus provides a potential avenue to go "upstream" to prevent persons with disabilities from becoming poor.

A report from Action on Disability and Development looks at the vicious circle linking poverty and disability. It argues that the basic cause of disabled people's poverty is social, economic, and political exclusion.

The scale of exclusion is dramatic:

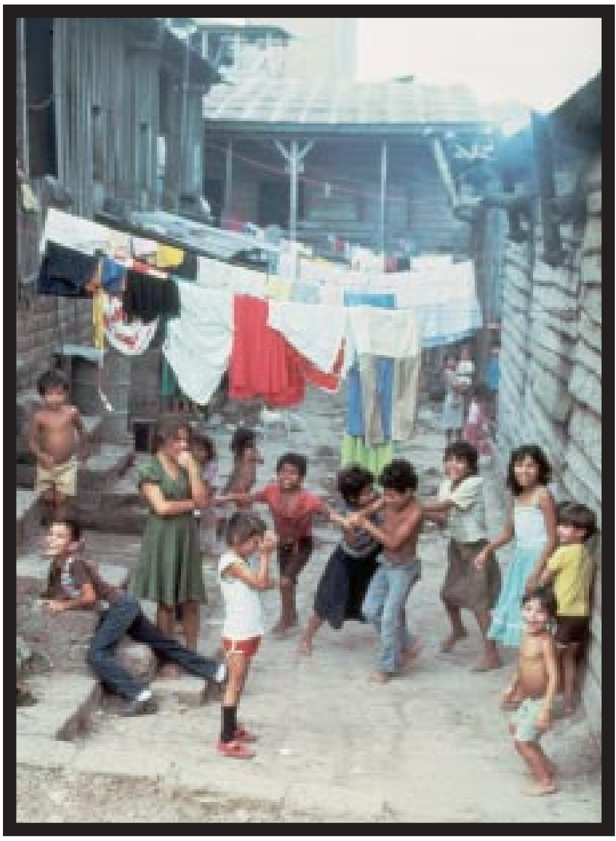
- 98 per cent of disabled children in developing countries are denied any formal education and excluded from many of the day-to-day interactions that non-disabled children take for granted.
- One hundred million people world wide have preventable impairments caused by malnutrition and poor sanitation
- 70 per cent of childhood blindness and 50 per cent of hearing impairment in Africa and Asia are preventable or treatable.

These impairments then lead to discrimination, exclusion and further poverty. The Standard Rules on the Equalisation of Opportunities for People with Disabilities have been endorsed by all United Nations Member States. Although not legally enforceable, they have encouraged many governments to introduce disability legislation.[69]

(65) Article 25 UDHR (1948).
(66) "Poverty and the International Covenant on Economic, Social and Cultural Rights", statement adopted by the Committee on Economic, Social and Cultural Rights on 4 May, 2001 (E/C.12/2001/10), paragraph 8.
(67) *Voices of the Poor: Crying Out for Change*, Chapter 7, 'Social Ill-being: Left Out and Pushed Down', World Bank 2000, page 235.
(68) Human rights and poverty reduction strategies: A discussion paper, *prepared by Professor Paul Hunt, Professor Manfred Nowak, Professor Siddiq Osmani for the UN Office of the High Commissioner for Human Rights (February 2002).*
(69) *Disability, Poverty and Development*, Department for International Development (DFID), ID21 Highlights, January 2002.

Q.21 HOW DOES GLOBALIZATION AFFECT THE PROMOTION AND PROTECTION OF HUMAN RIGHTS?

The Secretary-General of the United Nations, Kofi Annan, has underscored that *"the pursuit of development, the engagement with globalization, and the management of change must all yield to human rights imperatives rather than the reverse. Respect for human rights, as proclaimed in the international instruments, is central to our mandate. If we lose sight of this fundamental truth, all else will fail."*[72]



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Globalization is a term used to cover many different phenomena, most of which concern increasing flows of money, goods, services, people, and ideas across national borders. This process has brought benefits to many peoples and countries, lifting many people from poverty and bringing greater awareness of people's entitlement to basic human rights. In many cases, however, the globalization process has contributed to greater marginalization of people and countries that have been denied access to markets, information, and essential goods such as new life-saving drugs.

Within the human rights community, certain trends associated with globalization have raised concern with respect to their effect on states' capacity to ensure the protection of human rights, especially for the most vulnerable members of society. Located primarily in the economic-political realm of globalization, these trends include: an increasing reliance upon the free market; a significant growth in the influence of international financial markets and institutions in determining national policies; cutbacks in public sector spending; the privatization of functions previously considered to be the exclusive domain of the state; and the deregulation of a range of activities with a view to facilitating investment and rewarding entrepreneurial initiative.[70] These trends serve to reduce the role of the state in economic affairs, and at the same time increase the role and responsibilities of private (non-state) actors, especially those in corporate business, but also those in civil society. Human rights analysts are concerned that such trends limit the ability of the state to protect the vulnerable from adverse effects of globalization, and enforce human rights.

In this context, the United Nations Committee on Economic, Social and Cultural Rights has emphasized the strong and continuous responsibility of international organizations, as well as the governments that have created and manage them, to take whatever measures they can in the context of globalization to assist governments to act in ways which are compatible with their human rights obligations, and to seek to devise policies and programmes which promote respect for those rights.[71]

"Although we refer to our world as a global village it is a world sadly lacking in the sense of closeness towards neighbour and community which the word village implies. In each region, and within all countries, there are problems stemming from either a lack of respect for, or lack of acceptance of, the inherent dignity and equality of all human beings."

United Nations High Commissioner for Human Rights, Mary Robinson

(70) Statement by the Committee on Economic, Social and Cultural Rights, to the Third Ministerial Conference of the World Trade Organization, 1999.
(71) Statement by the Committee on Economic, Social and Cultural Rights, May 1998, paragraph 5.
(72) Report of the Secretary-General on the work of the Organization, 1999, General Assembly, Official Records, 54th session. Supplement No.1 (A/54/1).

Q.22 How does international human rights law influence international trade law?

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Recently, the United Nations human rights system has begun addressing trade laws and practices in relation to human rights law and, in turn, the World Trade Organization (WTO) and other organizations dealing with trade have begun to consider the human rights implications of their work.

For example, the question of access to drugs has been increasingly addressed in the context of human rights. In an unprecedented move, the Commission on Human Rights last year adopted a resolution on access to medication in the context of pandemics such as HIV/AIDS[73] which reaffirms that access to medication in this context is a fundamental element for the progressive realization of the right to health. States are called upon to pursue policies which would promote the availability, accessibility and affordability for all without discrimination of scientifically appropriate and good quality pharmaceuticals and medical technologies used to treat pandemics such as HIV/AIDS. They are also asked to adopt legislation or other measures to safeguard access to such pharmaceuticals and medical technologies from any limitations by third parties.

Also in relation to the question of access to drugs, the relationship between the Agreement on the Trade Related Aspects of Intellectual Property Rights (TRIPS) and human rights was considered in a report to the Subcommission on Human Rights, last year, by the High Commissioner for Human Rights.[74] This report notes that of the 141 Members of the WTO, 111 have ratified the ICESCR. Members should therefore implement the minimum standards of the TRIPS Agreement bearing in mind both their human rights obligations as well as the flexibility inherent in the TRIPS Agreement, and recognizing that "human rights are the first responsibility of Governments."[75]

Article 15 of the International Covenant on Economic, Social and Cultural Rights recognizes "the right of everyone to enjoy the benefits of scientific progress and its applications." This right places obligations on governments to take the steps necessary to conserve, develop and diffuse science and scientific research, as well as ensure freedom of scientific enquiry. The implications of this right for health issues have only recently begun to be explored, for example, with respect to access to drugs for developing countries.

(73) Commission on Human Rights resolution 2001/33: Access to medication in the context of pandemics such as HIV/AIDS, adopted 20 April 2001, (E/CN.4.RES.2001.33).

(74) Report of the High Commissioner for Human Rights both Sub-Commission on the Promotion and Protection of Human Rights on intellectual property rights and human rights; the impact of the agreement on trade related aspects of Intellectual Property Rights on human rights ; Fifty-second session of June 2001 (E/CN.4/Sub.2/2001/13 paras. 61-69.)

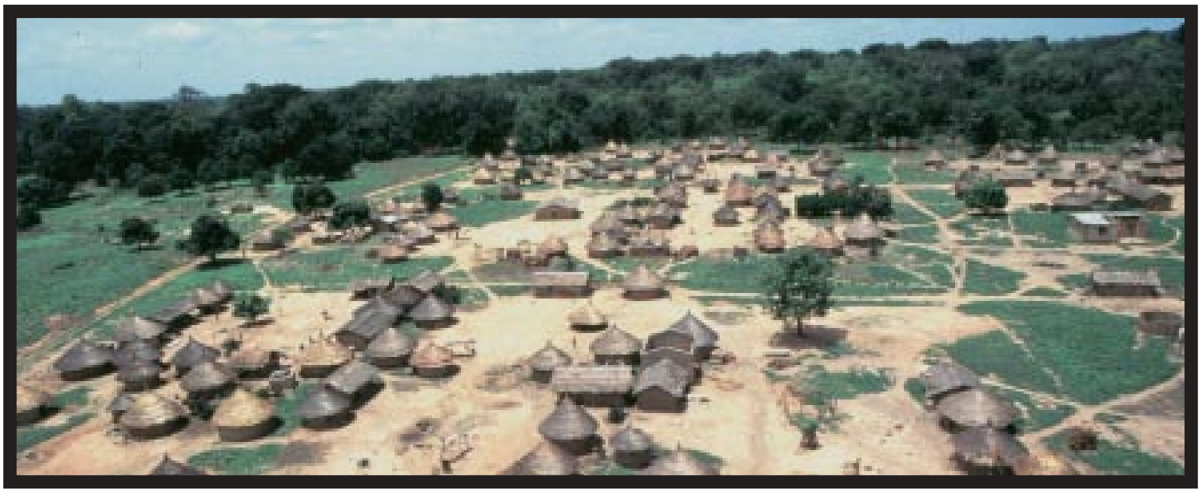
(75) Vienna Declaration and Programme of Action, Article 1.

Q.23 What is meant by a rights-based approach to development?

There is increasing recognition, within the United Nations system and beyond, that development itself is not only a human right as recognized in the United Nations Declaration on the Right to Development (1986), but that the development process must, in itself, be consistent with human rights. In this regard, OHCHR has advocated a rights-based approach to development as a conceptual framework for the process of human development that is normatively based on international human rights. This approach integrates the norms, standards and principles of the international human rights system into the plans, policies and processes of development. The norms and standards are those contained in the wealth of international treaties and declarations. The principles include those of participation, accountability, non-discrimination and attention to vulnerability, empowerment and express linkage to international human rights instruments.

"A rights-based approach to development describes situations not simply in terms of human needs, or of developmental requirements, but in terms of society's obligations to respond to the inalienable rights of individuals, empowers people to demand justice as a right, not as charity, and gives communities a moral basis from which to claim international assistance when needed."

United Nations Secretary-General, Kofi Annan



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"A rights-based approach to development sets the achievement of human rights as an objective of development. It uses thinking about human rights as a scaffolding of development policy. It invokes the international apparatus of human rights accountability in support of development action. In all of these, it is concerned with not just civil and political rights but also with economic, social and cultural rights. Further, the implementation of a rights-based approach implies that performance standards be set."[76]

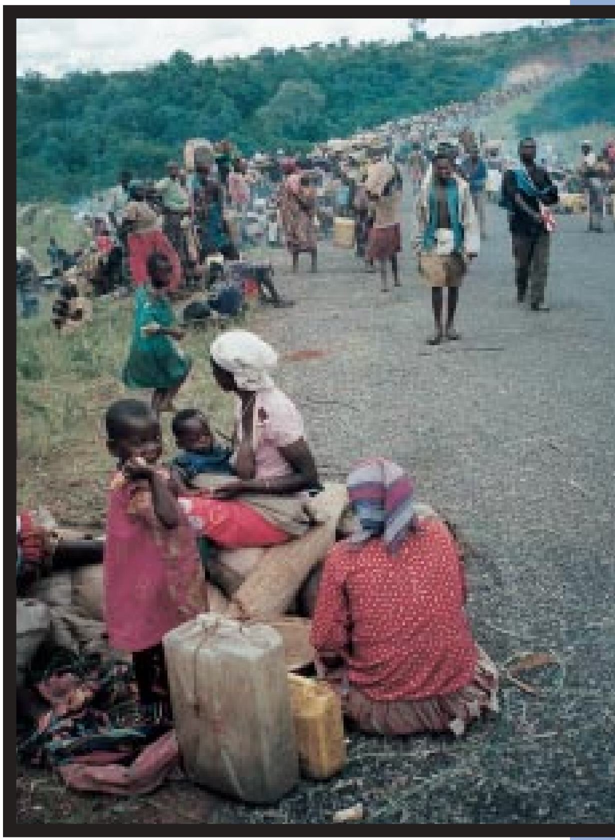
(76) Overseas Development Institute, "What can we do with a rights-based approach to development?". Briefing Paper, 1999 (3) September.

Q.24 How do human rights law, refugee law and humanitarian law interact with the provision of health assistance?

The large number and changing nature of emergencies and conflicts, including the explosion of religious and ethnic turmoil around the world, has prompted the need for new thinking and approaches within the United Nations system and beyond. Fresh attention is being drawn to the international legal framework for dealing with these emergencies, in particular the relationship between humanitarian law, human rights law and refugee law and their applicability in a changing crisis environment.(77)

> Refugee law acts to protect refugees by spelling out specific legal provisions protecting the human rights of refugees most notably through the United Nations Convention Relating to the Status of Refugees (1950) and its protocol (1966).

Human rights, humanitarian law and refugee law are distinct yet closely related branches of the international legal system. Human rights and refugee law were developed within the United Nations framework and thus have similar underpinnings. Humanitarian law, however, has profoundly different origins and uses different mechanisms for its implementation. All branches of law have, however, a fundamental common objective: the respect for human dignity without any discrimination whatsoever as to race, colour, religion, sex, birth or wealth, or any similar criteria. In addition, they share a great number of detailed objectives and conceptual similarities.



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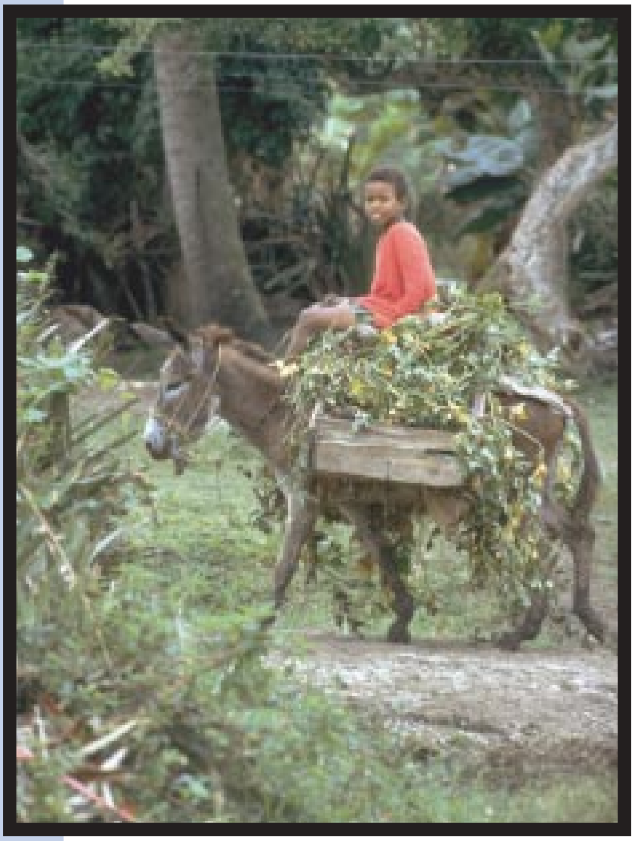
> Humanitarian law is the law of armed conflict or the law of wars: a body of rules which in wartime protect persons who are not or no longer participating in the hostilities and which limit methods and means of warfare. The central instruments of humanitarian law are the four 1949 Geneva Conventions and their two Additional Protocols of 1977.

Efforts are under way to ensure that international human rights and humanitarian law principles provide the standard and reference for humanitarian action by the United Nations and its agencies as well as other actors. Health practices in preparing for, assessing, implementing, and evaluating the impact of health assistance in the context of an armed conflict need to be grounded within a framework of international law. The sick and wounded, health workers, medical equipment, hospitals and various medical units (including medical transportation) are all protected under humanitarian law principles. Moreover, denying access to medical care in some circumstances could constitute a war crime.

(77) See paper by Uwe Kracht, Development Consultant and Co-Coordinator of the World Alliance for Nutrition and Human Rights (WANAHR) Human Rights and Humanitarian Law and Principles in Emergencies - An overview of concepts and issues, prepared for UNICEF.



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Overall, humanitarian action in the field of health represents action towards the fulfilment of *the right to health* in situations where the threats to health are greatest. Moreover, in the provision of health care in emergency situations, consideration of the human rights dimension can help ensure that strategies pay particular attention to vulnerable groups. The particular vulnerability of refugees, internally displaced, and migrants requires a special emphasis on human rights. Within these groups, women as single heads of households, unaccompanied minors, persons with disabilities, and the elderly are in need of special attention. Specific human rights principles exist that provide guidance in ensuring protection in emergencies against exposure of vulnerable groups to risk-factors of disease and ill-health.[78]

According to United Nations Guidelines, United Nations staff in the field, "should generally not reject complaints of human rights violations. Once received, these should be promptly and confidentially transmitted to OHCHR for processing..."[79]

Q.25 HOW DOES HUMAN RIGHTS RELATE TO HEALTH DEVELOPMENT WORK IN COUNTRIES?

Human rights are upheld as a cross-cutting issue in the United Nations' development work at country level.[80] The Common Country Assessment (CCA) and the United Nations Development Assistance Framework (UNDAF) provide the major principles upon which a human rights-based approach to development is founded. The CCA and UNDAF Guidelines refer to the implementation of United Nations Conventions and Declarations and underscore the importance of taking full account of human rights in both these processes. The CCA thus helps to facilitate efforts for coherent, integrated and coordinated United Nations support to government follow-up to the Conferences and the implementation of Conventions at the field level.

This parallels the principles enunciated in the World Bank's Comprehensive Development Framework (CDF), the joint World Bank/IMF Poverty Reduction Strategy Paper (PRSP) initiative, the formal design of which reflects human rights concepts and standards. A project of the OHCHR to produce guidelines for the integration of human rights in poverty reduction strategies, including Poverty Reduction Strategy Papers (HRPRS Guidelines), has highlighted the close correspondence between "the realities of poor people," as identified by Voices of the Poor[81] and other poverty studies, and the international human rights normative framework. Thus, attention to human rights will help to ensure that the key concerns of poor people become, and remain, the key concerns of poverty reduction strategies. For example, the integration of human rights into anti-poverty strategies will help to ensure that vulnerable individuals and groups are not neglected; that the active and informed participation of the poor is provided for; that key sectoral issues (e.g. education, housing, health and food) receive due attention; that immediate and intermediate (as well as long-term) targets are identified; that effective monitoring methods (e.g. indicators and benchmarks) are established; and that accessible mechanisms of accountability, in relation to all parties, are instituted. Furthermore, human rights provide poverty reduction strategies with norms, standards and values that have a high-level of global legitimacy.[82]

(78) Guiding Principles on Internal Displacement (1998).
(79) In March 2000, the ACC issued the Human Rights Guidelines and Information for the Resident Coordinator System which is an important reference for the collective effort to integrate human rights within the United Nations system, approved on behalf of ACC by the CCPOQ at its 16th Session, Geneva, March 2000, http://accsubs.unsystem.org/ccpoq/documents/manual/human-rights-gui.pdf, para. 59.
(80) *Idem.*
(81) Refer to footnote 68.
(82) Human rights and poverty reduction strategies: A discussion paper, footnote 57.

Annex I: Legal Instruments

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International treaties and conventions (in chronological order) relevant to health & human rights

Convention (No. 29) concerning Forced Labour (1930);

United Nations Charter (1945);

Convention on the Prevention and Punishment of the Crime of Genocide (1948);

Convention for the Suppression of the Traffic in Persons and of the Exploitation of the Prostitution of Others (1949);

Geneva Convention for the Amelioration of the Condition of the Wounded and Sick in Armed Forces in the Field (1949);

Geneva Convention for the Amelioration of the Condition of Wounded, Sick and Shipwrecked Members of Armed Forces at Sea (1949);

Geneva Convention relative to the Treatment of Prisoners of War (1949);

Geneva Convention relative to the Protection of Civilian Persons in Time of War (1949), and the Protocol Additional to the Geneva Conventions relating to the Protection of Victims of International Armed Conflicts (Protocol 1) (1977) and the Protocol relating to the Protection of Victims of Non-International Armed Conflicts (Protocol II) (1977) ;

Convention relating to the Status of Refugees (1950) and its Protocol (1967);

Convention (No. 105) on Abolition of Forced Labour (1957);

International Convention on the Elimination of All Forms of Racial Discrimination (1963);

International Covenant on Economic, Social and Cultural Rights (1966);

International Covenant on Civil and Political Rights (1966) and its two Protocols (1966 and 1989);

Convention on the Elimination of All Forms of Discrimination Against Women (1979) and its Protocol (1999);

Convention against Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment (1984);

Convention on the Rights of the Child (1989);

Convention (No. 169) concerning Indigenous and Tribal Peoples in Independent Countries (1989);

International Convention on the Protection of the Rights of All Migrant Workers and Members of their Families (1990);

Convention (No. 182) on the Prohibition and Immediate Action for the Elimination of the Worst Forms of Child Labour (1999);

Maternity Protection Convention (No. 183, 2000).

International declarations, norms and standards (in chronological order) relevant to health &human rights

Universal Declaration of Human Rights (1948);

Declaration on the Use of Scientific and Technological Progress in the Interests of Peace and for the Benefit of Mankind (1975);

Declaration on the Rights of Disabled Persons (1975);

Principles of Medical Ethics relevant to the Role of Health Personnel, particularly Physicians, in the Protection of Prisoners and Detainees against Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment (1982);

Declaration on the Right to Development (1986);

Principles for the Protection of Persons with Mental Illness and the Improvement of Mental Health Care (1991);

United Nations Principles for Older Persons (1991);

Declaration on the Rights of Persons Belonging to National or Ethnic, Religious and Linguistic Minorities (1992);

United Nations Standard Rules on the Equalization of Opportunities for Persons with Disabilities (1993);

Declaration on the Elimination of Violence Against Women (1993);

Universal Declaration on the Human Genome and Human Rights (1997);

Declaration on the Right and Responsibility of Individuals, Groups and Organs of Society to Promote and Protect Universally Recognized Human Rights and Fundamental Freedoms (1998);

Guiding Principles on Internal Displacement (1998).

Regional instruments (in chronological order) in relation to health & human rights

American Declaration of the Rights and Duties of Man (1948);

European Convention for the Protection of Human Rights and Fundamental Freedoms (1950) and its Eleven Protocols (1952 - 1994);

European Social Charter (1961), (revised 1996);

American Convention on Human Rights (1969);

African Charter on Human and Peoples' Rights (1981);

Inter-American Convention to Prevent and Punish Torture (1985);

Additional Protocol to the American Convention on Human Rights in the Area of Economic, Social and Cultural Rights - "Protocol of San Salvador" (1988);

Protocol to the American Convention on Human Rights to Abolish the Death Penalty (1990);

African Charter on the Rights and Welfare of the Child (1990);

Convention on the Prevention, Punishment and Eradication of Violence against Women "Convention of Belem do Para." (1994);

Arab Charter on Human Rights (1994);

European Convention on Human Rights and Dignity of the Human Being with regard to the Application of Biology and Medicine: Convention on Human Rights and Biomedicine (1997);

Inter-American Convention on the Elimination of All Forms of Discrimination Against Persons With Disabilities. (1999).

International conference documents and their follow-up (in chronological order) relevant to health & human rights

World Summit for Children, New York (1990): World Declaration on the Survival, Protection and Development of Children and Plan of Action for Implementing the World Declaration, and its follow-up, the United Nations General Assembly Special Session (UNGASS) on Children (2002): A World Fit for Children;

United Nations Conference on Environment and Development, Rio de Janeiro (1992): Rio Declaration on Environment and Development and Agenda 21;

World Conference on Human Rights, Vienna (1993): Vienna Declaration and Programme of Action;

International Conference on Population and Development, Cairo, 1994: Programme of Action;

World Summit for Social Development, Copenhagen (1995): Copenhagen Declaration on Social Development and Programme of Action of the World Summit for Social Development, and its follow-up, Copenhagen Plus 5 (2000);

Fourth World Conference on Women, Beijing (1995): Beijing Declaration and Platform for Action, and its follow-up, Beijing Plus 5 (2000);

Second United Nations Conference on Human Settlements (Habitat II), Istanbul (1996): Istanbul Declaration on Human Settlements;

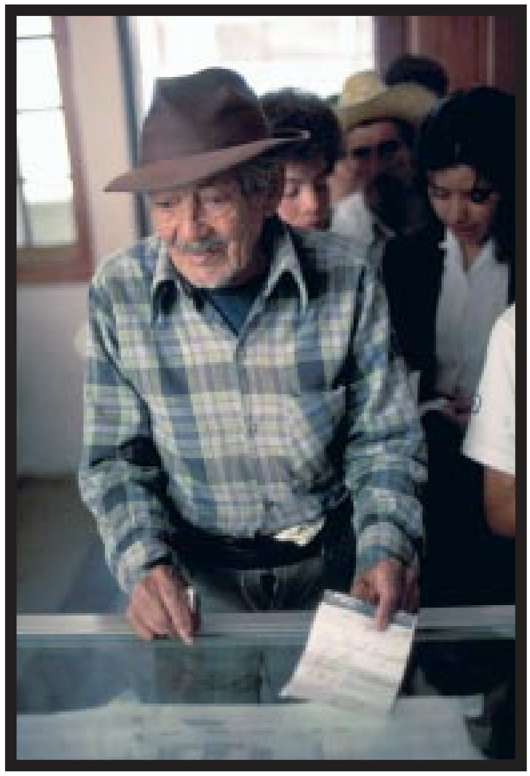
World Food Summit, Rome (1996): Rome Declaration on World Food Security and World Food Summit Plan of Action, and its follow-up, Declaration of the World Food Summit: Five Years Later, International Alliance Against Hunger (2002);

United Nations General Assembly Special Session (UNGASS) on AIDS (2001): Declaration of Commitment on HIV/AIDS "Global Crisis – Global Action;"

World Conference Against Racism, Racial Discrimination Xenophobia and Related Intolerance, Durban (2001): Durban Declaration and Programme of Action;

Second World Assembly on Ageing (2002): Political Declaration and Madrid International Programme of Action on Ageing.

Annex II: United Nations Human Rights Organizational Structure



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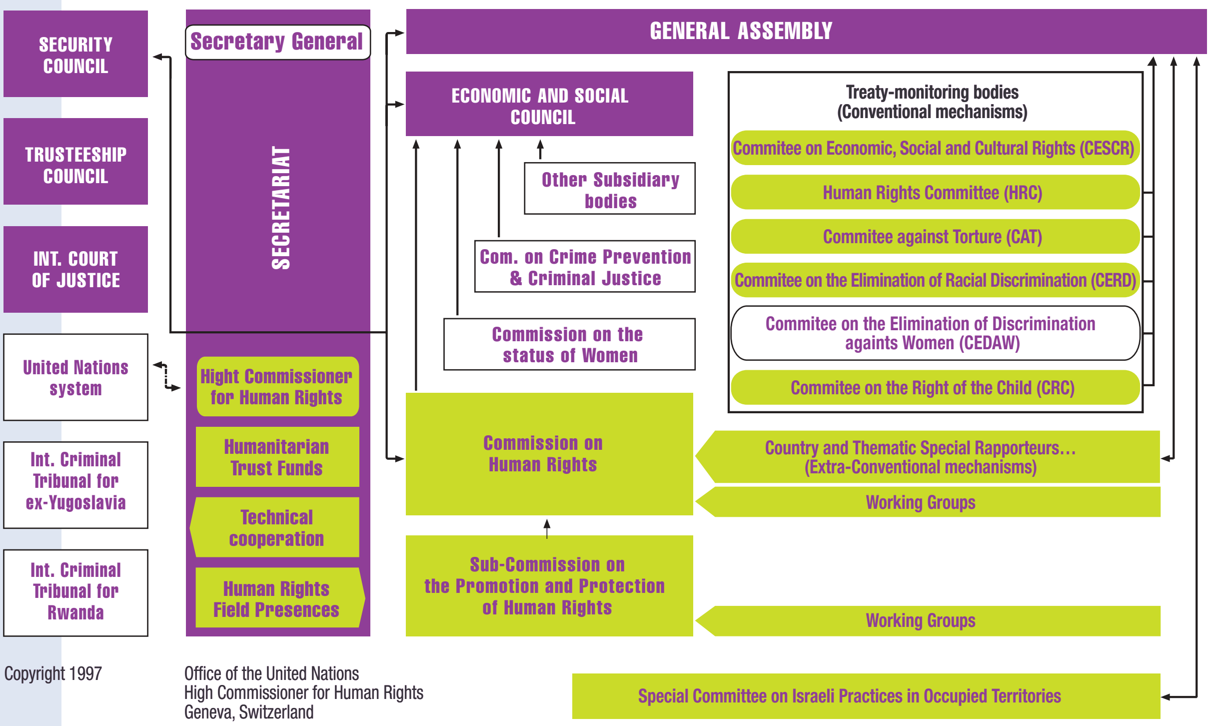
This chart, which is not exhaustive, describes the functioning of the United Nations system in the field of human rights. Emphasis is given to those bodies and programmes with major human rights responsibilities. The purple areas indicate six principle organs of the United Nations, whereas the green ones indicate bodies or programmes serviced by the Office of the United Nations High Commissioner for Human Rights.[83]



(83) This organizational chart is used courtesy of the Office of the High Commissioner for Human Rights. http://www.unhchr.ch/hrostr.htm

The enjoyment of the highest attainable standard of health as a fundamental right of every human being was enshrined in WHO's Constitution over fifty years ago. WHO strives to make this right a reality for everyone, paying particular attention to the poorest and most vulnerable.

In this context, WHO has launched the Health and Human Rights Publication Series to explore the complex relationship between health and human rights regarding various health challenges. The first in this series, *25 Questions and Answers on Health and Human Rights,* attempts to answer key questions that come to mind in exploring the linkages between health and human rights. It is intended as a practical guide to generate increased clarity and understanding among WHO staff and other health, development and human rights practitioners about the important synergy between health and human rights.

Health & Human Rights Publication Series Issue No.1

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WHO Comments Breed Confusion Over Asymptomatic Spread of COVID-19

After stating that asymptomatic individuals are unlikely to transmit the novel coronavirus, World Health Organization officials clarify that this is very much an open question.

Jef Akst
Jun 10, 2020

The World Health Organization's technical lead for coronavirus response, Maria Van Kerkhove, said at a press briefing on Monday (June 8) that asymptomatic transmission of the SARS-CoV-2 virus was "very rare." On Tuesday, Van Kerkhove clarified at a follow-up Q&A session on COVID-19 transmission that she was referring only to patients who never show any symptoms at all, not those who have not yet begun to show symptoms—individuals who are classified as being presymptomatic—nor those cases that involve only mild symptoms. The WHO estimates that among truly asymptomatic patients, 16 percent can infect others. "We do know that some people who are asymptomatic can transmit the virus on," Van Kerkhov said on Tuesday.

ABOVE: FLICKR, UNITED STATES MISSION GENEVA

Still, many researchers, including National Institute of Allergy and Infectious Diseases Director Anthony Fauci, have challenged the WHO's assertion that the virus is only rarely spread by truly asymptomatic individuals. "[This] is not backed up by any data," Fauci tells *Science News*. "We know that there is asymptomatic transmission. . . . What we do not know is the extent to which that occurs. So when we hear statements that this is very rare, we do not know that as a fact."

Research on asymptomatic spread has yielded mixed results, and it's still not even clear what proportion of people infected with SARS-CoV-2 will remain symptom-free. While some studies estimate that fewer than 20 percent of cases are asymptomatic, one review published last week (June 3) in the *Annals of Internal Medicine* stated it may be as high as 45 percent, and noted that these individuals "can transmit the virus to others for an extended period."

"What we need to better understand is how many people in the population don't have symptoms," Van Kerkhove said on Tuesday. "And, separately, how many of those individuals go on to transmit [the virus] to others."

She emphasized that the information she'd shared on the previous day was based on a handful of studies that had tracked spread among known asymptomatic cases, and stated that she had not intended to imply that "asymptomatic transmission globally" was uncommon. The WHO said it regrets the statement that transmission by asymptomatic individuals is "very rare," *Axios* reports.

The scientific community questioned whether the clarifications from the WHO were enough to overcome the initial misinformation. Given the uncertainty surrounding the issue, the way the WHO's comments were initially interpreted by the public and covered by the media was "a disaster public relations–wise," Marm Kilpatrick, an infectious diseases researcher at the University of California, Santa Cruz, tells *Science News*. "We've been trying to get 7 billion people on the planet to wear masks even though they [feel] fine, so to misinterpret [data] like that is super counterproductive."

Lawrence Gostin, director of the O'Neill Institute for National and Global Health Law at Georgetown University, tells *BuzzFeed News*, "WHO is tarnishing its reputation as a science agency by putting out conflicting and confusing statements."

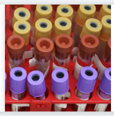
"On the one hand, I do want to cut the W.H.O. some slack, because it is hard to do this in an evolving pandemic," Ashish Jha, director of Harvard University's Global Health Institute, tells *The New York Times*. "At the same time, we do rely on the W.H.O. to give us the best scientific data and evidence." In a statement on Tuesday, Jha's institute wrote, "All of the best evidence suggests that people without symptoms can and do readily spread SARS-CoV-2," *STAT* reports.

Keywords:

coronavirus, COVID-19, disease & medicine, epidemiology, infectious disease, nutshell, outbreak, pandemic, public health, SARS-CoV-2, transmission, WHO, World Health Organization

Related Articles

Follow the Coronavirus Outbreak



How

Ensuring multisectoral action on the determinants of reproductive, maternal, newborn, child, and adolescent health in the post-2015 era

Kumanan Rasanathan and colleagues explain how integrating action on determinants of women's, children's, and adolescents' health beyond the health sector into core health strategies is crucial to achieving sustainable development goal targets to end preventable deaths and ensure healthy lives

Despite impressive improvements since the launch of the millennium development goals (MDGs), many countries will not reach the targets on maternal and child mortality, partly because of the lack of attention to determinants of health (box 1) beyond the health sector. For example, the 2010-15 Global Strategy for Women's and Children's Health, launched by the United Nations secretary general to accelerate progress on MDGs 4-6,[1] failed to consider determinants of health or interventions beyond the health sector. The maturation of the goals this year provides an opportunity to reflect on how coordinated multisectoral action could achieve more ambitious targets for women and children's health, such as ending preventable maternal, newborn, and child deaths in all countries.

The finalisation of the 2016-30 sustainable development goals (SDGs; which urge a more integrated and transformative view of development) and the upcoming launch of the 2016-30 Global Strategy for Women's, Children's and Adolescents' Health (Every Woman Every Child 2.0; EWEC 2.0) also make it timely to consider how multisectoral action can be facilitated in countries, including in updating and developing new national strategies for reproductive, maternal, newborn, child and adolescent health (RMNCAH). Here we review evidence on the contribution of action on determinants, discuss major obstacles, and propose key steps for global and national strategies to provide guidance.

KEY MESSAGES

Social, economic, political, environmental, and cultural determinants of health have crucial effects on reproductive, maternal, newborn, child, and adolescent health

The goal of ending preventable maternal, newborn, and child deaths requires multisectoral action to improve determinants of health, including within the health sector itself

Key steps to improving determinants of health include appropriately framing determinants and multisectoral action in health strategies; identifying key targets and indicators; prioritising key policies and interventions; and mobilising resources, improving governance, and generating evidence of multisectoral efforts

We propose the convening of a new United Nations commission on implementation and accountability of multisectoral action for women's, children's, and adolescents' health to assist these efforts

Methods

The conclusions and recommendations in this article are drawn from a review of the literature, estimates of the effects of interventions, country lessons, and the authors' experiences. The range of products from the Commission on Social Determinants of Health[2] and the Success Factors[5] project provided key inputs, along with multiple rounds of consultation undertaken as part of the process of updating the global strategy, which included online and face to face consultations.

The determinants of health paradox: increasing recognition but limited action

Progress on RMNCAH can be accelerated by interventions beyond the health sector. The contribution of non-health sectors, including the contributions of different sectors and interventions, is best understood for mortality in children under 5.[6] About half the decrease in child mortality in low and middle income countries since 1990 is due to non-health sector investments.[5]

Estimates for the contribution of educational improvement vary—as high as 51.2% for 1970-2009.[7] Malnutrition remains the underlying cause of 45% of child deaths.[8] Environmental factors are important contributors to diarrhoea, malaria, and respiratory infections (among the greatest causes of death in children under 5), as well as injury and malnutrition. About a third of all disease in children can be attributed to modifiable environmental factors such as water quality and access, air pollution, unsafe sanitation, exposure to chemicals, and climate change.[9]

Better female education, reduced fertility rates, urbanisation, women's access to resources, and infrastructure improvements (roads, electricity, housing, information and communications technology) can also reduce maternal mortality.[10] Interactions between different determinants, such as the impact of women's and girls' education on fertility rates and their joint impact on health outcomes, are also important.[11]

Structural societal factors, such as poverty, gender inequality, and other forms of discrimination (such as racism) and inequality directly and indirectly affect RMNCAH and generate health inequities. Interventions to mitigate these adverse factors (such as reducing poverty, ending child marriage, or tackling violence against women and children) help improve women's, children's, and adolescents' health, but there is a lack of comprehensive evidence of the effects of specific interventions on mortality. The correlation between economic growth and improvements in maternal and child mortality is complex, with wide variations in performance between countries of similar wealth levels,[12] mediated by differences in health systems and determinants. This underscores the importance of policy choices and attention to inequities in health and wealth, and of prioritising new resources for marginalised communities, which often lack political influence. Globally there has been a call for attention to transnational and commercial determinants of health given their increasing impact on health and widening disparities.[13-15]

Multisectoral efforts to improve determinants of health are therefore extremely important for RMNCAH—to reduce inequities, create healthier environments, and increase coverage of health interventions. The related millennium and sustainable development goals will not be achieved without them. For example, no country has reduced newborn and child mortality to the SDG target levels through healthcare alone, without transformations in social and economic development. Evidence on which policies and interventions are necessary is also accumulating.[16]

Despite the eight MDGs being presented as a joint agenda, including key determinants, in practice the different goals were not

BOX 1: DETERMINANTS OF HEALTH

The determinants of health are the conditions in which people are born, grow, live, work, and age, and the distribution of power, money, and resources that affect these conditions.[2] They encompass social, economic, political, environmental, and cultural dimensions. Here, we use "determinants" to cover all of these factors ("social determinants of health"[2] or "underlying determinants"[3] are sometimes used in a similar way).

Determinants crucially influence the health of women, children, and adolescents, who often experience discrimination and unequal access to resources and realisation of their rights, resulting in exposure to adverse socioeconomic, political, and environmental conditions. These factors directly cause inequities of health in this population within and between countries. Determinants affect access and coverage of essential health interventions and directly affect health, including through the shaping of social norms and behaviours.

Gender (in)equality is a key determinant of health that transcends sectors and illustrates this concept well.[4] Manifestations of gender inequality (such as differential access to education and health services, forced and early child marriage, unequal labour market participation and remuneration, and violence against women and children) are major contributors to maternal and child mortality. Measures to mitigate these factors can improve health outcomes and reduce disparities.

Determinants are not static but interact with each other and change with the evolving context. Action within various sectors (such as health, education, water and sanitation, environment related sectors, and nutrition) and joint action across and between sectors (cross sectoral and intersectoral action) is needed to improve determinants.

managed together.[17] Improvements in health service coverage have been crucial to progress in MDGs 4-6, but the contribution of multisectoral interventions to the health specific goals has been insufficiently tracked and documented. This failure to recognise the importance of key policies across a range of sectors undermines efforts to reach RMNCAH outcome targets, as well as efforts to increase coverage of healthcare interventions. Identifying why some groups have lower health service coverage, even in countries with overall strong performance, requires a focus on, and measurement of, determinants such as discrimination, poverty, and gender inequality. All providers of healthcare (including faith based organisations) must be considered and interventions in other sectors such as roads, utilities, and finance proritised. The effects of deficiencies in other sectors on health systems have been neglected—a recent review of healthcare facilities found that 38% lacked water, 19% had no sanitation, and 35% lacked water and soap for handwashing.[18]

Investment in institutions to advocate for, pioneer new approaches, or regulate multisectoral work has also been inadequate. Working across sectors for health has proved challenging, especially in settings with a high RMNCAH burden. The challenge is not just how to identify the key interventions in non-health sectors but how to catalyse work with other sectors and contribute to policies and interventions that are of core concern to other sectors but that can be shaped to maximise positive health outcomes. This requires building the capacity of the health sector to work with other sectors and identify areas of mutual concern. Issues of governance, financing (and co-financing across sectors), implementation, and monitoring will need to be addressed to change the status quo.

One obstacle to engaging other sectors has been the lack of clear mechanisms for public and social accountability for RMNCAH. Despite progress in accountability within the health sector at global and national levels (including through the Commission on Information and Accountability for Women's and Children's Health), little attention has been paid to increasing the accountability of other sectors. This gap reflects how responsibility for maternal, child, and adolescent health is still perceived as the interest of the health sector only.

What is now needed for action on determinants of RMNCAH

Ensuring multisectoral action on determinants of RMNCAH will require prioritisation and resources to overcome the obstacles discussed above. Global and national strategies, including EWEC 2.0, can contribute by integrating a focus on determinants as "core business." We propose four key steps for inclusion in such strategies.

1. Framing determinants and multisectoral action

The health sector often lacks conceptual and practical understanding of determinants of RMNCAH and multisectoral action. New global and national strategies need to clarify the different types of action required:

- Addressing structural forces and social and gender norms that affect all of society, including those that drive disparities, which require wide ranging cross sectoral policies driven by heads of government and championed by key societal agents of change
- Supporting actions within single sectors that form their core business (such as ensuring children attend school and learn well for the education sector, access to safe water for the water and sanitation sector, or access to clean power for the energy sector)
- Ensuring the health sector recognises its own role in generating health disparities (such as discrimination and abuse, provision of differential quality of care to different groups, and inadequate water and energy supplies to health facilities) and maximises its key role in primary prevention
- Identifying, promoting, and co-financing actions that require collaboration between two or more sectors (intersectoral work) to produce joint or "co-benefits" and to maximise health benefits (such as the use of cleaner stoves to reduce indoor air pollution, or sexuality education in schools).

Although work on determinants often focuses on intersectoral efforts, the greatest benefits often lie in the first two activities above—addressing structural forces and social and gender norms (for example, reducing poverty or increasing gender equality) and single sectors doing their own core business well. For example, for the education sector, keeping adolescent girls in school and providing a good education that enables their economic empowerment has greater health impact than collaborative activities to increase health literacy or undertake school based health clinics.[7 11 19] When considering multisectoral action, the health sector has too often focused on marginal collaborations at the expense of recognising the impact of the core work of other sectors.

Determinants also influence global and national leadership, accountability, and the actions of the health and other sectors. Structural inequities in power at global, national, district, and community levels obstruct the policy and implementation choices needed for equitable delivery of essential services and for harnessing the resources needed for multisectoral implementation. The MDGs were not explicitly aimed at reducing these imbalances in power, and although the SDGs focus on inequality more explicitly, it is unclear how effectively global targets can deal with such structural challenges. Global and national strategies can draw from existing conceptual frameworks for determinants, such as that of the Commission on Social Determinants of Health,[20] and recent adaptations, such as for child wellbeing,[21] to consider how implementation can account for these obstacles.

2. Identifying key SDG targets for joint tracking and action

MDGs 4-6 strongly underpinned global and national efforts on maternal and child health and the SDGs aim to provide a similar platform. RMNCAH is well represented by SDG 3 (the "health goal"), with updated MDG 4-6 targets, new targets on non-communicable diseases and injuries, and on universal health coverage, all of which require multisectoral efforts.

However, the SDGs will be more comprehensive, with 17 goals and 169 targets proposed, encompassing a greater number of sectors related to RMNCAH. This comprehensive scope implies a need to learn from the fragmentation of sectors during the implementation of the MDGs, with goals identified with single sectors.[17] Unintended risks of this comprehensiveness are dilution of efforts and a lack of focus on specific interventions. This can be mitigated by prioritising targets across different sectors to help focus global and national efforts to improve RMNCAH.

Almost all of the proposed goals have some relevance to the determinants of RMNCAH. Difficult choices need to be made about which targets are crucial. We drew up an initial priority list of targets for global and national strategies, drawn from a longer list of potential targets and informed by other efforts at prioritisation (figure).[22] It excludes the priority SDG 3 health targets in which the health sector will take the lead. Exceptions are targets 3.6 on road traffic injury and 3.9 on pollution where non-health sectors need to lead.

There is a need to mobilise efforts across these targets and facilitate their joint monitoring, along with the health outcome targets, for accountability at country and global level (for example, extending and expanding the current Countdown to 2015 platform[23]). This is a clear avenue for EWEC 2.0 to make a contribution.

3. Prioritising key multisectoral interventions, policies, and indicators for action

Most global and national strategies on RMNCAH have highlighted key healthcare interventions needed but not interventions and policies led by other sectors. As global and national strategies are updated to incorporate the SDGs (including EWEC 2.0), they should include a guide to multisectoral action on determinants, prioritising key policies and interventions, with indicators for joint monitoring against the SDG targets.

Table 1 lists initial proposals for key determinants, interventions, policies, indicators, and SDG targets to be prioritised as part of EWEC 2.0.

4. Implementing multisectoral efforts

Efforts to drive multisectoral action on determinants of health have often stalled at the implementation phase, even when policy makers accept the rationale and conceptual framework. Governance, financing, and joint monitoring of multisectoral action to achieve targets on RMNCAH have proved difficult in practice. While the details of these problems are often beyond the scope of global and national strategies, they are fundamental to implementation. Different countries' successes in driving multisectoral efforts to improve RMNCAH (table 2) provide useful guidance that merits greater dissemination, including through South-South collaboration (direct collaboration and technical assistance between low and middle income countries).

Specific guidance is needed on the work and governance of different types of multisectoral action (single sector, intersectoral, and cross sectoral), including on how key policies for RMNCAH can be implemented and linked across sectors, even in low income, high burden settings. Lessons are available from the HIV movement's response, tobacco control, and the environmental sector. Building governance for a multisectoral approach can benefit from obligations under the human right to health, which calls for healthcare and interventions

1.1 By 2030 eradicate extreme poverty for all people everywhere, currently measured as living on less than $1.25 a day

1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of poor and vulnerable people

2.2 By 2030 end all forms of malnutrition, including achieving the internationally agreed targets on stunting and wasting in children under 5 years of age by 2025. Address the nutritional needs of adolescent girls, pregnant and lactating women, and older women

3.6 By 2020 halve the number of global deaths and injuries from road traffic accidents

3.9 By 2030 substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

4.1 By 2030 ensure that all girls and boys complete free, equitable, and quality primary and secondary education that leads to relevant and effective learning outcomes

4.2 By 2030 ensure that all girls and boys have access to good quality early childhood development, care, and pre-primary education so that they are ready for primary education

5.1 End all forms of discrimination against all women and girls everywhere

5.2 Eliminate all forms of violence against all women and girls in public and private spheres, including trafficking and sexual and other types of exploitation

5.3 Eliminate all harmful practices, such as child, early and forced marriage, and female genital mutilation

5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision making in political, economic, and public life

5.6 Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with the Programme of Action of the International Conference on Population and Development and the Beijing Platform for Action and the outcome documents of their review conferences

6.1 By 2030 achieve universal and equitable access to safe and affordable drinking water for all

6.2 By 2030 achieve access to adequate and equitable sanitation and hygiene for all, and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations

7.1 By 2030 ensure universal access to affordable, reliable, and modern energy services

13.2 Integrate climate change measures into national policies, strategies, and planning

16.2 End abuse, exploitation, trafficking, and all forms of violence against and torture of children

16.9 By 2030 provide legal identity for all including birth registration

17.18 By 2020 enhance capacity building support to developing countries, including for least developed countries and small island developing states, to increase significantly the availability of high quality, timely, and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographical location, and other characteristics relevant in national contexts

Priority sustainable development goal targets for reproductive, maternal, newborn, child, and adolescent health

Table 1 | Key reproductive, maternal, newborn, child, and adolescent health determinants; interventions; indicators; and corresponding sustainable development goal (SDG) targets

Determinant	Policies and interventions	Indicator	SDG targets*
Income and social protection	Reduce poverty through the use of child and gender sensitive cash transfer programmes designed with health sector input, especially on use of conditionality	Proportion of population below $1.25†/day disaggregated by sex and age group	1.1, 5.4
Food security	Prioritise measures to enhance food security in communities with high mortality burden	Prevalence of undernourishment	2.1
Nutrition in infants and young children	Implement Infant and Young Child Feeding (IYCF) guidelines	Prevalence of stunting in children under 5 years of age; rate of exclusive breast feeding among infants under 6 months of age	2.2
Education of adolescent girls	Prioritise support for adolescent girls to receive a good quality education, including through mechanisms such as cash transfers	Completion rate (%) of upper secondary education by girls	4.1
Early child development	Implement a multisectoral approach to early child development for all children, using a progressive universalism approach to maximise gains for the worst off	Early Childhood Development Index	4.2
Ending child marriage	Enact legislation and provide social support services to end child marriage	Proportion of women aged 20-24 who were married or in a union before age 18 years	5.3
Ending violence against women and children	Enact legal frameworks criminalising all forms of violence and abuse against women and children	Proportion of ever partnered women and girls (aged 15-49) subjected to physical or sexual violence (or both) by a current or former intimate partner in the past 12 months	5.2
		Proportion of young adults aged 18-24 years who have experienced violence by age 18, by type (physical, psychological, or sexual)	16.2
Political participation of women	Implement minimum quotas for participation of women in political institutions, such as parliaments	Proportion of seats held by women in local governments	5.5
Safe drinking water	Provide universal access to safely managed, affordable, and sustainable drinking water through investments in education on the importance of safely managed water use and infrastructure in households, communities, schools, and health facilities	Proportion of population using safely managed drinking water services	6.1
Access to improved sanitation and hygiene	End open defecation and provide universal access to improved sanitation facilities and hygiene measures, and encourage implementation of sanitation safety plans	Proportion of population using safely managed sanitation services	6.2
Access to electricity	Prioritise new infrastructural development for energy access in communities with high mortality burden, including in health facilities	Proportion of population with electricity access	7.1
Exposure to household air pollution	Increase use of clean home energy fuels and technologies (for cooking, heating, lighting)	Proportion of people using primarily clean fuels or technologies (for cooking, heating, lighting), where "clean" is defined by WHO guidelines	7.1
		Child mortality and morbidity attributable to household air pollution	3.9
Hazardous child labour	Systematic detection and elimination of hazardous child labour	Proportion and number of children aged 5-17 years engaged in child labour, by sex and age group (disaggregated by the worst forms of child labour)	8.7
Lead in the environment	Eliminate non-essential uses of lead (such as in paint) and ensure the safe recycling of waste that contains lead	Number of countries that have regulated lead in paint	12.4
Climate change	Enhance climate resilience of environmental determinants of health (such as climate resilient water, sanitation, and hygiene infrastructure and management practice)	Population coverage with climate resilient infrastructure and management practices (such as climate resilient water safety plans)	13.2
Birth registration	Build civil registration and vital statistics systems to achieve universal birth and death registration	Proportion of children under 5 whose births have been registered with civil authority	16.9

*See figure.
†Purchasing power parity.

on the "underlying" determinants, providing a legal and normative framework for tackling determinants.[3]

Tools and methods are available for analysing health risks and benefits associated with policies implemented across and within different sectors (such as "health in all policies" and health impact assessment) and to review specific determinants (such as gender assessments and audits and gender responsive planning and budgeting).[24 25] The engagement of women, children, and adolescents in decisions about their own health should be prioritised when designing new governance structures, measurement tools, standards, and policies.

EWEC 2.0 should aim to mobilise financial resources for action on determinants of RMNCAH. All countries already invest resources on determinants as part of core work in other sectors. The question is whether EWEC 2.0, and its follow-up, can accelerate investment in a set of key policies and interventions on determinants. Discussions on single national investment plans have already identified key areas where non-health sector interventions are crucial for RMNCAH outcomes.[26]

Global and national RMNCAH strategies (particularly EWEC 2.0 at the global level) should monitor key determinants and interventions beyond the health sector as part of their accountability follow-up, harnessing existing monitoring initiatives in other sectors. Global reports on RMNCAH need to be linked with efforts in other sectors—such as nutrition, water, and sanitation—to deliver joint information and accountability and allow cross sectoral analysis and prioritisation for investment and implementation at country level. Disaggregating data for indicators for interventions in health and non-health sectors would facilitate a greater focus on equity and reinforce attention on determinants, given that drivers of disparity lie mostly beyond the health sector.

Evidence gaps on determinants remain to be filled, mostly by implementation research. For example, evidence on the health impacts of specific interventions within sectors and on interventions and policies to address societal or structural forces is sparse, whereas evidence on interventions for social protection and environmental

Table 2 | Examples of successful multisectoral interventions on determinants of reproductive, maternal, newborn, child, and adolescent health

Country	Determinant	Action	Impact
Peru	Malnutrition in children under 3 and in pregnant and lactating women	"Buen Inicio"—a package of community based interventions including health promotion by rural trained health promoters, hygiene, and antenatal care	Reduction in child stunting and anaemia in pilot communities; foundation for national strategy to combat child malnutrition
Rwanda	Governance and sex equality	Biannual joint health sector reviews and establishment of health sector working groups; creation of the Rwanda Women Parliamentarian Forum and the Women's Council	Passage of bill to reduce gender based violence; highest global rates of female parliament participation; planned programme of health sector decentralisation
Zimbabwe	Sex equality and girls' education	Efforts to increase girls' participation in school	75% of women aged 15-24 completed lower secondary school in 2010; HIV prevalence decreased from 29% in 1997 to 14% by 2007
Malawi	Girls' education	Randomised controlled trial provided conditional cash transfers ($1-$15*/month) to 1200 women aged 13-22 and their parents while also paying school fees	Reduction in teenage pregnancies (29%) and early marriage (32%); prevalence of HIV infection fell by 64%
Uganda	Sex based violence	Collaborative SASA! study aimed at reducing sex based violence by implementing a violence prevention intervention in eight communities in Kampala; qualitative data on social change also collected	52% lower rates of sex based violence and fewer concurrent sexual partners among men in SASA! communities versus controls; sex based violence believed to be less acceptable and the idea that women can refuse sex more acceptable in SASA! communities
Niger	Early marriage and fertility	Creating safe spaces for adolescent women to interact with trained female mentors; community dialogue; home visits by mentors; health check-ups, literacy and numeracy training for girls; sexual and reproductive health promotion	Increased sexual and reproductive health knowledge among adolescent women; increased ability to read the alphabet, nearly 100% of females set up a savings plan; girls believe they have the right to choose their spouse and programme is overall acceptable
Mozambique	Information and communication technologies	Community based, multisectoral project in which community health volunteers improve community use of maternal, newborn, and child health services through community engagement and mobile phones to follow pregnant women through pregnancy; reminders and advice provided through text or audio messages; made antenatal and postpartum visits	Increased credibility among community health volunteers, stronger linkages to health system, and expedited management of minor and major health complications
New Zealand	Poor housing	Insulation and thermal envelope improvements in 1350 low income households	Reduced self reported respiratory illness, doctor visits, hospital admissions, and days off work or school; marginal increase in indoor temperatures but 13% reduction in energy use; health gains cost effective compared with carbon dioxide mitigation

*$1=£0.64; €0.91.

determinants is more robust. Evidence of multisectoral impact is scattered and often drawn from modelling exercises, which assess correlation but do not provide specific evidence on the mechanisms that directly improve health. Tools used in RMNCAH planning and budgeting (such as the lives saved tool[27 28]) should encompass interventions beyond the health sector, but this will require improving the evidence base. The generation of costing and effectiveness data for key interventions and policies for RMNCAH outside of the health sector would increase understanding of their health gains and of the value of "co-benefits" shared between health and other sectors.

BOX 2: KEY GLOBAL ACTIVITIES TO SUPPORT MULTISECTORAL ACTION ON DETERMINANTS OF REPRODUCTIVE, MATERNAL, NEWBORN, CHILD AND ADOLESCENT HEALTH (RMNCAH)

1. Joint global and national monitoring of interventions and targets (table 1) driven by the United Nations secretary general's office, building on existing sectoral monitoring efforts and incorporating a gender sensitive lens
2. Efforts to synthesise and generate data on the cost and effectiveness of key RMNCAH outcomes of multisectoral interventions and policies
3. Efforts to synthesise and build knowledge on incentives for intersectoral action, including how joint efforts can drive mutual benefits for RMNCAH and the core business of other sectors
4. Mobilise the Every Woman Every Child movement, in particular governments and civil society (including faith based organisations), to invest in champions (such as parliamentarians) and institutions to steer multisectoral action on determinants
5. Mobilise financing and incentivise multisectoral collaboration and action through existing partnerships and new financing mechanisms
6. Consider how the Every Woman Every Child innovation pipeline can contribute further to multisectoral action[33]
7. Request the United Nations to coordinate, as appropriate, the work needed between sectors, including setting an example by better coordination within itself

Limitations

The above four areas are first steps in a full determinants approach to RMNCAH. This approach may seem "selective," missing the complexity and comprehensiveness required. The ambitious visions of initiatives such as the UN Commission on Sustainable Development and the WHO Commission on Social Determinants of Health are not limited to increased uptake of specific interventions within sectors but mark a paradigm shift in the organisation of societies. A multidisciplinary and multi-institutional approach with new participatory processes is needed to realise the full vision of the SDGs.

We did not cover the two way association and contribution of health to other sectors because of the abundance of literature in this area. For example, it has been estimated that increases in health expenditure in high burden countries would have enormous economic and social benefits,[29] and that about 24% of recent full income growth in low and middle income countries came from health gains.[30] The association between determinants and individual agency, capability, and opportunities is also complex,[31 32] and further work on the drivers of behaviour is warranted, including social and cultural norms—for example, their role in perpetuating gender inequality, racism, and other forms of discrimination.

We acknowledge these limitations and do not imply that these broader questions can be ignored. Instead, the areas highlighted represent practical starting points in moving efforts on RMNCAH beyond the health sector to tackle determinants, with the hope that follow-up work can engage with these greater complexities, which are particularly important for reducing disparities.

Conclusion

The launch of the SDGs and the 2016-2030 Global Strategy for Women's, Children's and Adolescents' Health provides an opportunity to "mainstream" multisectoral efforts on improving determinants of RMNCAH at global, national, and district levels. Important first steps are to clarify how multisectoral efforts on determinants fit into post-2015 efforts on improving RMNCAH; prioritise key determinants, interventions, policies, indicators, and SDG targets; and build the governance, financing, monitoring, and research needed for implementation. Box 2 summarises key activities at the global level, but the extent to which national strategies and implementation policies reorient their efforts to integrate a multisectoral focus on determinants of RMNCAH, informed by EWEC 2.0, will be more important. To support these efforts, we propose a UN commission on implementation and accountability of multisectoral action for women's, children's, and adolescents' health. Similar to the Commission on Information and Accountability for Women's and Children's Health, this should collect available knowledge and put in place a multisectoral focus on improving determinants of RMNCAH at global and national levels.

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AIR POLLUTION AND CHILD HEALTH

Prescribing clean air

World Health Organization

Air pollution and child health: prescribing clean air

World Health Organization

Contents

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Abbreviations and acronyms

AAP ambient air pollution
ALRI acute lower respiratory infection
ASD autism spectrum disorders
BMI body mass index
CO carbon monoxide
DALY disability-adjusted life–year
FEV1 forced expiratory volume in 1 s
FVC forced vital capacity
HAP household air pollution
HIC high-income country
LMIC low- or middle-income country
LPG liquefied petroleum gas
NO_x nitrogen oxides
O_3 ozone
PM particulate matter
PM_1 particles < 1 µm in diameter
$PM_{2.5}$ particles < 2.5 µm in diameter
PM_{10} particles < 10 µm in diameter
SDG Sustainable Development Goal
SGA small for gestational age
SO_2 sulfur dioxide
TB tuberculosis

Preface

This report summarizes the latest scientific knowledge on the links between exposure to air pollution and adverse health effects in children. It is intended to inform and motivate individual and collective action by health care professionals to prevent damage to children's health from exposure to air pollution. Air pollution is a major environmental health threat. Exposure to fine particles in both the ambient environment and in the household causes about seven million premature deaths each year *(1,2)*. Ambient air pollution (AAP) alone imposes enormous costs on the global economy, amounting to more than US$ 5 trillion in total welfare losses in 2013 *(3)*.

> *The evidence is clear: air pollution has a devastating impact on children's health.*

This public health crisis is receiving more attention, but one critical aspect is often overlooked: how air pollution affects children in uniquely damaging ways. Recent data released by the World Health Organization (WHO) show that air pollution has a vast and terrible impact on child health and survival. Globally, 93% of all children live in environments with air pollution levels above the WHO guidelines (see Annex 2). More than one in every four deaths of children under 5 years is directly or indirectly related to environmental risks *(4)*. Both AAP and household air pollution (HAP) contribute to respiratory tract infections that resulted in 543 000 deaths in children under 5 years in 2016 *(1)*.

Although air pollution is a global problem, the burden of disease attributable to particulate matter in air is heaviest in low- and middle-income countries (LMICs), particularly in the WHO African, South-East Asia, Eastern Mediterranean and Western Pacific regions *(1,5)*. LMICs in these regions – especially the African Region – have the highest levels of exposure to HAP due to the widespread use of polluting fuels and technologies for basic daily needs, such as cooking, heating and lighting *(6)*. Poverty is correlated with high exposure to environmental health risks. Poverty can also compound the damaging health effects of air pollution, by limiting access to information, treatment and other health care resources.

The enormous toll of disease and death revealed by these new data should result in an urgent call to action for the global community – and especially for those in the health sector. Strong action to reduce exposure to air pollution offers an unparalleled opportunity to protect the health of children everywhere. Health professionals have a central role to play in this effort. Health effects experienced early in life can increase a child's future risk of disease and lead to lifelong consequences. A child who is exposed to unsafe levels of pollution early in life can thus suffer a "life sentence" of illness. Health professionals are well positioned to communicate with families, communities and decision-makers about these and other serious risks of exposure to air pollution.

The Sustainable Development Goals (SDGs) recognize the importance of social and environmental factors as determinants of health. All the SDGs are clearly linked to health-related targets, reflecting the growing awareness that health, environmental and poverty alleviation are interconnected –that ensuring healthy lives for all (SDG 3) and making cities inclusive, safe, resilient and sustainable (SDG 11) require universal access to energy (SDG 7) and hinge upon combating climate change (SDG 13). The launch of the 2030 Agenda for Sustainable Development offers an unparalleled opportunity to increase action to address the environmental hazards that undermine children's health. Implementing evidence-based policies and health practices to protect children from air pollution will, in turn, be essential to realizing the Sustainable Development Agenda: reducing children's exposure can have enormous benefits due to avoided disease, reduced mortality and improved well-being. Reducing air pollution can also improve health and well-being by slowing climate change. It is estimated that, by 2030, climate change will be responsible for 250 000 deaths each year *(7)*. As many of the same pollutants that threaten health, such as black carbon and ozone (O_3), are also important agents of atmospheric warming, interventions that reduce their emissions are likely to result in benefits for both children's health and the climate.

We must seize this opportunity to create healthy, sustainable environments for our children. Everyone has a role to play, at every level: individuals, families, paediatricians, family doctors, nurses, obstetricians and gynaecologists, primary health care providers and other community workers, communities, medical students, national governments and international agencies. Their efforts should be guided by the best available evidence on the health effects of air pollution on children and on effective interventions to counter them. This document is designed to support this effort. It reports the latest scientific knowledge on the health effects of air pollution in children. The breadth and depth of the evidence make clear that air pollution is a formidable disruptor of children's health – one that deserves far greater attention from both policy-makers and health professionals. As children experience the consequences of air pollution in special, specific ways, they deserve to be assessed in a special way. This publication provides practical, reliable information for health professionals, paediatricians and other clinicians in all countries. It will be a useful reference for action: a compendium of the accumulating evidence on the links between air pollution and children's health and a source of guidance for health care providers in their clinical practice and in their collective communication of risks and solutions to the public and to policy-makers.

Children are uniquely vulnerable to the damaging health effects of air pollution.

Children are society's future. But they are also its most vulnerable members. The immense threat posed to their health by air pollution demands that health professionals respond with focused, urgent action. Although more rigorous research into how air pollution affects children's health will continue to be valuable, there is already ample evidence to justify strong, swift action to prevent the damage it clearly produces. Health professionals must come together to address this threat as a priority, through collective, coordinated efforts. For the millions of children exposed to polluted air every day, there is little time to waste and so much to be gained.

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Executive summary

Children's exposure to air pollution

Exposure to air pollution is an overlooked health emergency for children[1] around the world. While such exposure is a persistent problem in some high-income countries (HICs) – especially in low-income communities within those countries – the vast majority of child deaths from exposure to particulate matter air pollution occur in LMICs.

Exposure to air pollution from particulate matter occurs both outdoors and indoors. AAP is primarily derived from fossil fuel combustion, industrial processes, waste incineration, agricultural practices and natural processes such as wildfires, dust storms and volcanic eruptions. The main sources of air pollution may vary from urban to rural areas, but no area is, strictly speaking, safer. AAP was responsible for 4.2 million premature deaths in 2016; of these, almost 300 000 were children under 5 years *(1,2)*.

The risks associated with breathing HAP can be just as great. Breathing clean air at home is essential for children's healthy development, but widespread dependence on solid fuels and kerosene for cooking, heating and lighting results in far too many children living in terribly polluted home environments. About three billion people worldwide still depend on polluting fuels and devices for cooking and heating *(3)*. Women and children spend most of their time around the hearth, exposed to smoke from cooking fires, resulting in indoor concentrations of some pollutants that are five or six times the levels in ambient air. The widespread lack of access to clean household energy has tragic consequences on a vast scale: HAP was responsible for 3.8 million premature deaths in 2016, including over 400 000 deaths of children under 5 years *(4)*.

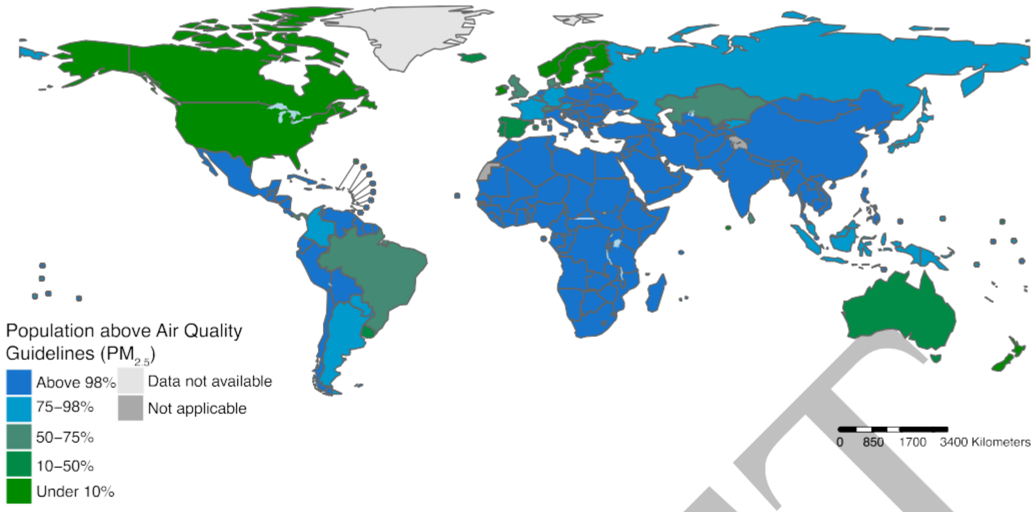
Exposure to ambient air pollution

The proportions of children exposed to levels of fine particulate matter ($PM_{2.5}$) higher than the WHO air quality guideline levels (Fig. 1) are as follows:

- 93% of all children and about 630 million children under 5 years in the world;
- in LMICs, 98% of all children under 5 years;
- in HICs, 52% of children under 5 years;
- in the WHO African and Eastern Mediterranean regions, 100% of all children under 5 years;
- in LMICs in the South-East Asia Region, 99% of all children under 5 years;
- in LMICs in the Western Pacific Region, 98% of all children under 5 years; and
- in LMICs in the Region of the Americas, 87% of all children under 5 years.

Fig. 1. Proportions of children under 5 years living in areas in which the WHO Air Quality Guidelines ($PM_{2.5}$) are exceeded, by country, 2016

[1] WHO defines a "child" as a person under 19 years of age, an "adolescent" as a person aged 10–19 years, an "infant" as a person aged 0–11 months and a "newborn" as a person aged 0–28 days. References to "child mortality" usually pertain to children aged 0–59 months.



Source: (*5*)

Exposure to household air pollution

In 2016, 41% of the world's population was exposed to HAP from cooking with polluting fuels and technologies. The use of polluting fuels and technologies for cooking is almost exclusively a problem in LMICs, as 83% of the population in the African Region, 59% in the South-East Asia Region and 42% in the Western Pacific Region rely primarily on polluting cooking fuels. The Eastern Mediterranean Region follows, with 31% of its population relying primarily on polluting fuels and devices, while the proportions in the Region of the Americas and the European Region are 13% and 6%, respectively.

Children's vulnerability and susceptibility to air pollution

Air pollution is a global public health crisis. Exposure to pollutants in the air threatens the health of people of all ages, in every part of the world, in both urban and rural areas, but it affects the most vulnerable among us – children – in unique ways. Children are at greater risk than adults from the many adverse health effects of air pollution, owing to a combination of behavioural, environmental and physiological factors. Children are uniquely vulnerable and susceptible to air pollution, especially during fetal development and in their earliest years. Their lungs, organs and brains are still maturing. They breathe faster than adults, taking in more air and, with it, more pollutants. Children live closer to the ground, where some pollutants reach peak concentrations. They may spend much time outside, playing and engaging in physical activity in potentially polluted air. New-borns and infants, meanwhile, spend most of their time indoors, where they are more susceptible to HAP. Children spend much time near their mothers while the latter cook with polluting fuels and devices.

Children have a longer life expectancy than adults, so latent disease mechanisms have more time to emerge and affect their health. Their bodies, and especially their lungs, are rapidly developing and therefore more vulnerable to inflammation and other damage caused by pollutants. In the womb, they are vulnerable to their mothers' exposure to pollutants. Health effects from preconception exposure can also impose latent risks on the fetus. Even after birth, they often remain powerless to change their environment: the very youngest cannot simply get up and walk out of a smoke-filled room. The consequences of their exposure – through inhalation, ingestion or in utero – can lead to illness and other health burdens that last a lifetime. But children depend entirely on us – adults – to protect them from the threat of unsafe air.

Children's burden of disease related to air pollution

Tables 1 and 2 show the joint burden of disease from AAP and HAP.

- Globally in 2016, one in every eight deaths was attributable to the joint effects of AAP and HAP – a total of 7 million deaths.
- Some 543 000 deaths in children under 5 years and 52 000 deaths in children aged 5–15 years were attributed to the joint effects of AAP and HAP in 2016.
- Together, HAP from cooking and AAP cause more than 50% of acute lower respiratory infections (ALRI) in children under 5 years of age in LMICs.
- Of the total deaths attributable to the joint effects of HAP and AAP worldwide in 2016, 9% were in children.

Table 1. Death rate per 100 000 children attributable to the joint effects of HAP and AAP in 2016, by WHO region and income level

WHO region	Income level	Children < 5 years	Children 5–14 years
African	LMIC	184.1	12.9
	HIC	4.3	1.4
Americas	LMIC	14.2	0.7
	HIC	0.3	0
South-East Asia	LMIC	75	2.5
European	LMIC	8.8	0.6
	HIC	0.3	0
Eastern Mediterranean	LMIC	98.6	3.6
	HIC	5.3	0.4
Western Pacific	LMIC	20.5	1
	HIC	0.3	0
All	LMIC	88.7	4.5
	HIC	0.6	0.1
World		80.5	4.1

LMIC, low- and middle-income country; HIC, high-income country

Table 2. Population attributable fractions of child mortality due to ALRI as a joint effect of HAP and AAP, 2016, by WHO region, the world and income level

WHO region	Income level	Children < 5 years (%)	Children 5–14 years (%)
African	LMIC	66	66
	HIC	25	24
Americas	LMIC	34	34
	HIC	8	7
South-East Asia	LMIC	63	62
European	LMIC	27	27
	HIC	13	14
Eastern Mediterranean	LMI	58	55
	HIC	40	40
Western Pacific	LMIC	53	52
	HIC	12	11

All	LMIC	62	62
	HIC	18	15
World		62	62

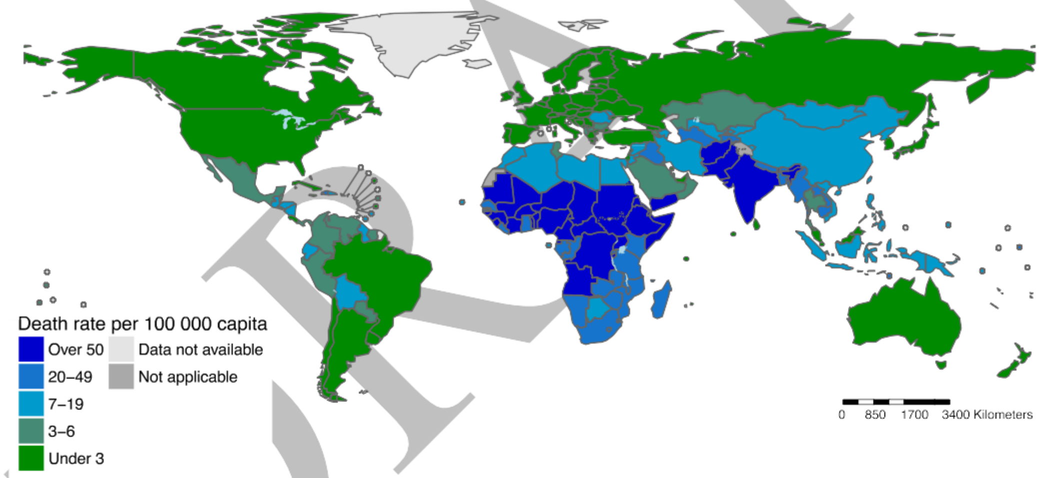
LMIC, low- and middle-income country; HIC, high-income country.

ALRI, acute lower respiratory infection; HAP, household air pollution; AAP, ambient air pollution.

Burden of disease due to AAP: In 2016, AAP was responsible for approximately 261 000 deaths from ALRI and almost 24 million disability-adjusted life years (DALYs) among children under 5 years. The numbers of deaths from ALRI due to AAP in children under 5 years of age are shown in Fig. 2.

The numbers of DALYs due to AAP in children under 5 years and children aged 5–14 years are shown in Annex 2 in Fig. 15 and Fig. 16, respectively.

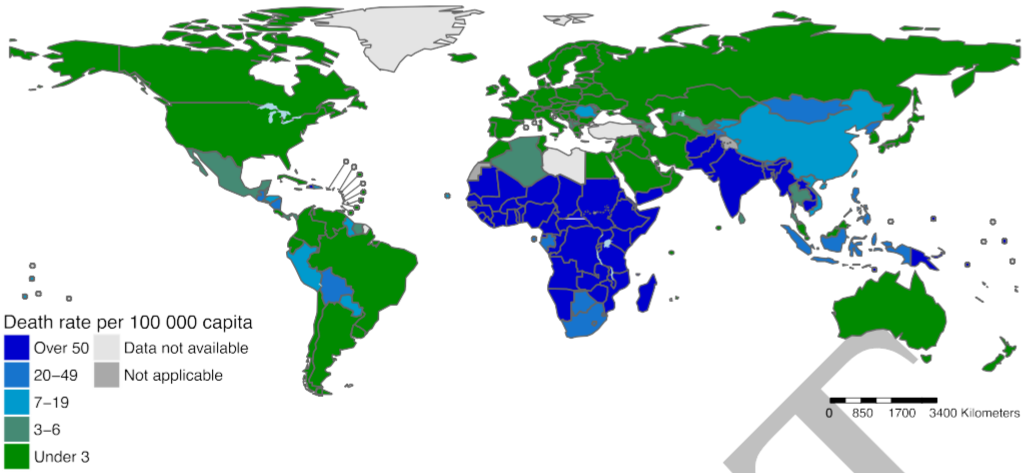
Fig. 2. Death rate per 100 000 per population from ALRI due to AAP in children under 5 years, 2016



Source: see Annex 2

Burden of disease due to HAP: In 2016, HAP was responsible for approximately 403 000 deaths from ALRI and 37 million DALYs among children under 5 years (Fig. 3).

Fig. 3. Death rate per 100 000 per population from ALRI due to HAP in children under 5 years, 2016

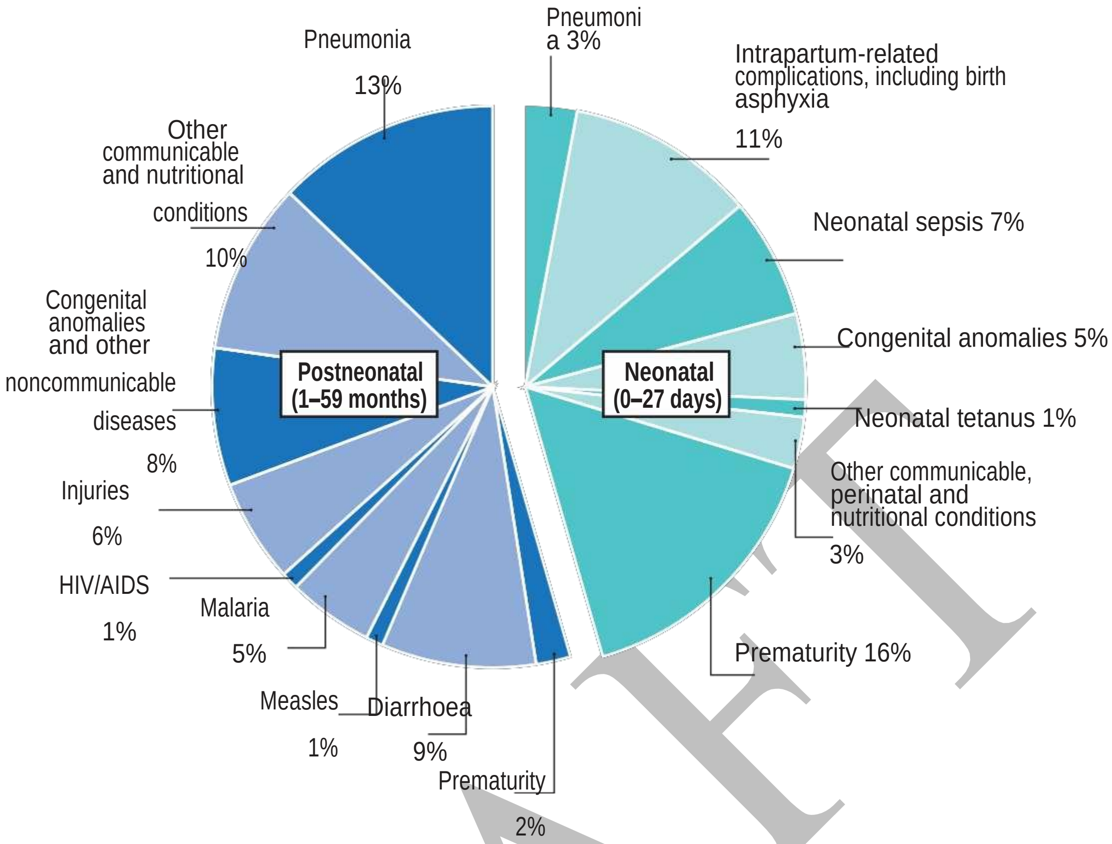


Source: see Annex 2

This tragically high toll is for just one disease, ALRI. The total burden of mortality and morbidity among children due to exposure to AAP and HAP is much greater. Evidence of the many different adverse health effects of exposure to air pollution is discussed below.

Exposure to air pollution contributes to more than half of all deaths from ALRI in children under 5 years in LMICs, making it one of the leading killers of children worldwide. The five leading causes of death in children under 5 years globally are prematurity, acute respiratory infections, intrapartum-related complications (including birth asphyxia), other group 1 conditions and congenital anomalies *(6)*. Premature birth is the only factor that kills more children under 5 years globally than acute respiratory infections (Fig. 4). In the African Region, acute respiratory infection is the leading cause of death of children under 5 years.

Fig. 4. Causesof deaths among children under 5 years, 2016



Source: Reference *(6)*.

Several global strategies and initiatives to improve child health have included targets, policies and interventions related to air pollution. These include the Global Action Plan for the Prevention and Treatment of Pneumonia and Diarrhoea, the Every Newborn Action Plan and the Nurturing Care Framework for Early Childhood Development (see Annex 1).

Sources of air pollution

Ambient air pollution: health toll, sources and solutions

AAP caused about 4.2 million premature deaths in 2016 (*2*). It is estimated that, in 2016, 286 000 children under 15 years of age died from exposure to unhealthy levels of AAP (see Annex 2). Ambient air is polluted from many different sources, both anthropogenic and natural, which differ in urban to rural areas. In urban settings, the main sources are fossil fuel combustion for energy production, transport, residential cooking, heating and waste incineration. Rural communities in LMICs are exposed to pollution emitted primarily from household burning of kerosene, biomass and coal for cooking, heating and lighting, from agricultural waste incineration and from certain agro-forestry activities *(7)*. These processes produce complex mixtures of pollutants that can interact chemically. They typically include carbon monoxide (CO), nitrogen oxides (NO_x), lead, arsenic, mercury, sulfur dioxide (SO_2), polycyclic aromatic hydrocarbons (PAHs) and particulate matter (PM). The last affects more people than any other air pollutant, and it is commonly used as a proxy indicator of air pollution more broadly.

Addressing AAP is a high priority for governments and multilateral agencies around the world. Many proven solutions are available to reduce emissions of dangerous pollutants, including cleaner transport, cleaner cooking and heating fuels and technologies, energy-efficient housing and urban planning, low- or zero-emission power generation, cleaner, safer industrial technologies and better municipal waste management *(8)*. The WHO air quality guidelines *(8)* provide recommended thresholds and limits for key ambient air pollutants that must be met in order to protect health; an updated version will be published in 2020.

Household air pollution: health toll, sources and solutions

HAP – the single largest environmental health risk factor worldwide – is produced mainly by the incomplete combustion of polluting fuels for cooking, heating and lighting *(3, 7)*. In 2016, WHO estimated that about three billion people – 41% of the world's population –used polluting cooking sources, most of them in LMICs *(3)*. This number has remained largely unchanged for the past three decades. The damage to health caused by such widespread dependence on polluting energy sources is severe and extensive: in 2016, HAP from solid fuel use resulted in an estimated 3.8 million premature deaths. This toll is equivalent to 6.7% of global mortality, greater than that from malaria, tuberculosis (TB) and HIV/AIDS combined. Of these deaths, 403 000 were among children under 5 years of age *(4)*. HAP is also an important source of AAP, as residential cooking contributes as much as 12% of global $PM_{2.5}$ to ambient air *(7)*.

In many parts of the world, children are especially vulnerable to HAP because they spend a great deal of time in the home and with their mothers as the latter tend the hearth. Smoke emitted from burning biomass, coal, charcoal and kerosene to meet the basic needs of cooking, heating and lighting is the primary contributor to HAP *(3)*. Burning these fuels in inefficient devices produces complex mixtures of contaminants. In dwellings with poor ventilation, emissions of fine particulate matter and other pollutants from stoves can reach 100 times the maximum exposure level recommended by WHO *(7)*.

In 2014 WHO issued *Guidelines for indoor air quality: household fuel combustion (9)*, the first guidelines to define fuels and technologies for cooking, heating and lighting that are clean for health at the point of use, including electricity, liquefied petroleum gas (LPG), biogas, ethanol and solar stoves, as well as some high-performing biomass stoves. The guidelines discourage household use of kerosene and unprocessed coal because of the serious associated health hazards. Unfortunately, kerosene is still used for lighting by many of the about one billion people who lack access to electricity. Achieving universal access to clean, safe household energy is a top priority on the global sustainable development agenda, reflected in SDG 7: "ensure access to affordable, reliable, sustainable and modern energy for all".

Other indoor sources

Many other air pollutants that are risks to health are beyond the scope of this report. These include volatile organic compounds from household products and building supplies, asbestos, pesticides, mercury (e.g. from broken thermometers), radon and biological pollutants. Tobacco smoke is another significant source of indoor air pollution and a health risk for children; the health effects of tobacco smoke have been reviewed extensively in other WHO documents.

Social determinants of children's health

Poverty is strongly correlated with exposure to air pollution. Children in LMICs and in low-income communities within HICs disproportionately suffer the effects of air pollution. Poverty causes people to rely on polluting energy sources for their basic needs, and poverty compounds the health risks associated with their use. Poverty also limits people's capacity to improve the environment in which they raise their children. Air pollution is often a chronic problem in poor-quality housing and temporary settlements. The exposure of people living in refugee camps can be particularly high, as they are forced to scavenge for nearby wood and other fuels or to rely on kerosene stoves for heating and cooking.

Women and girls are the primary users and procurers of household energy around the world. Dependence on the energy sources that produce the most HAP (e.g. wood and other solid fuels) used in inefficient stoves also poses other important health and safety risks. In many LMICs, children have the daily or weekly task of fuel collection, often walking long distances with heavy loads of wood and other fuels. A WHO analysis of survey data from 16 African countries in 2016 found that girls in households that used polluting fuels and technologies spent about 18 hours each week collecting wood or water, whereas girls in households in which clean fuels and technologies were used primarily spent 5 hours each week in those tasks *(7)*. This work robs children of time spent for playing and studying. It also leads to musculoskeletal disorders and can expose children, particularly girls, to higher risk of violence as they venture far from their household *(7, 10)*.

Health effects

There is compelling evidence that exposure to air pollution damages the health of children in numerous ways. The evidence summarized in this report is based on a scoping review of relevant studies published within the past 10 years and input from dozens of experts around the world. It covers adverse birth outcomes, infant mortality, neurodevelopmental disorders, childhood obesity, lung function, ALRI, asthma, otitis media and childhood cancers.

Adverse birth outcomes. Numerous studies have shown a significant association between exposure to AAP and adverse birth outcomes, especially exposure to PM, SO_2, NO_x, O_3 and CO. There is strong evidence that exposure to ambient PM is associated with low birth weight. There is also growing evidence that maternal exposure, especially to fine PM, increases the risk of preterm birth. There is emerging evidence for associations between exposure to air pollution and other outcomes, such as stillbirth and infants born small for gestational age.

Infant mortality. There is compelling evidence of an association between air pollution and infant mortality. Most studies to date have focused on acute exposure and AAP. As pollution levels increase, so too does the risk of infant mortality, particularly from exposure to PM and toxic gases.

Neurodevelopment. A growing body of research suggests that both prenatal and postnatal exposure to air pollution can negatively influence neurodevelopment, lead to lower cognitive test outcomes and influence the development of behavioural disorders such as autism spectrum disorders and attention deficit hyperactivity disorder. There is strong evidence that exposure to AAP can negatively affect children's mental and motor development.

Childhood obesity. A limited number of studies have identified a potential association between exposure to AAP and certain adverse metabolic outcomes in children. The findings include positive associations between exposure to air pollution in utero and postnatal weight gain or attained body-mass index (BMI) for age, and an association has been reported between traffic-related air pollution and insulin resistance in children.

Lung function. There is robust evidence that exposure to air pollution damages children's lung function and impedes their lung function growth, even at lower levels of exposure. Studies have found compelling evidence that prenatal exposure to air pollution is associated with impairment of lung development and lung function in childhood. Conversely, there is evidence that children experience better lung function growth in areas in which ambient air quality has improved.

ALRI, including pneumonia. Numerous studies offer compelling evidence that exposure to AAP and HAP increases the risk of ALRI in children. There is robust evidence that exposure to air pollutants such as $PM_{2.5}$, nitrogen dioxide (NO_2) and O_3 is associated with pneumonia and other respiratory infections in young children. Growing evidence suggests that PM has an especially strong effect.

Asthma. There is substantial evidence that exposure to AAP increases the risk of children for developing asthma and that breathing pollutants exacerbates childhood asthma as well. While relevant there are fewer studies on HAP, there is suggestive evidence that exposure to HAP from use of polluting household fuels and technologies is associated with the development and exacerbation of asthma in children.

Otitis media. There is clear, consistent evidence of an association between AAP exposure and the occurrence of otitis media in children. Although relatively few studies have examined the association between non-tobacco smoke HAP and otitis media, there is suggestive evidence that combustion-derived HAP may increase the risk of otitis media.

Childhood cancers. There is substantial evidence that exposure to traffic-related air pollution is associated with increased risk of childhood leukaemia. Several studies have found associations between prenatal exposure to AAP and higher risk of retinoblastomas and leukaemia in children.

While relatively few studies have focused on HAP and cancer risk in children, HAP is strongly associated with several types of cancer in adults and typically contains many known classified carcinogens.

Relation between early exposure and later health outcomes. Children exposed to air pollution prenatally and in early life is more likely to experience adverse health outcomes as they mature and through adulthood. Exposure to air pollution early in life can impair lung development, reduce lung function and increase the risk of chronic lung disease in adulthood. Evidence suggests that prenatal exposure to air pollution can predispose individuals to cardiovascular disease later in life.

Altogether, there is clear, compelling evidence of significant associations between exposure to air pollution and a range of adverse health outcomes. The evidence suggests that the early years, starting in pregnancy, are the best time to invest in a child's health, through action to improve their environment and reduce their exposure to pollutants. This window of time offers, in effect, a great opportunity: precisely because children are most vulnerable and sensitive to environmental influences in their earliest years, action taken during this critical phase can yield immense health benefits.

Recommended actions for health professionals

The scientific evidence outlined above suggests many clear, concrete steps that can be taken now to reduce the exposure of pregnant women, children and adolescents to air pollution.

Health professionals are trusted sources of information and guidance. They play an important role not only in treating ill health caused by air pollution but also in educating families and patients about risks and solutions and communicating with the broader public and decision-makers (Fig. 5). The role of health professionals in the management of childhood exposure to air pollution must be amplified, through improved methods of care and prevention and collective action. Health professionals can provide evidence to shape public health policy and advocate for effective policies to reduce children's exposure to air pollution. The broader health sector must become more engaged in developing a comprehensive approach to addressing this crisis.

Fig. 5. Critical role of health professionals

Be informed. Recognize exposure and related health conditions. Research, publish and disseminate knowledge. Prescribe solutions and educate families and communities. Educate colleagues and students. Advocate solutions to other sectors, policy- and decision-makers.

Be informed. All health professionals should consider air pollution a major risk factor for their patients and understand the sources of environmental exposure in the communities they serve. They should be informed about existing and emerging evidence on the ways in which air pollution may affect children's health.

Recognize exposure and health related conditions. Health professionals have an important role in identifying causative risk factors in order to prevent disease. A health care provider can identify air pollution-related risk factors by asking pertinent questions about the child's or pregnant mother's environment.

Research, publish and disseminate knowledge. Health professionals can conduct research on the effects of air pollution on children's health. They can conduct and publish studies of the causes, mechanisms and effects of environmental exposure of children, as well as potential treatment, prevention and management. They can also use this evidence to inform social and behaviour change communication strategies.

Prescribe solutions and educate families and communities. Health professionals can "prescribe" solutions to air pollution-related problems, such as switching to clean household fuels and devices. In contexts in which there are significant barriers to adopting clean household energy, health care professionals can recommend "transitional" solutions that offer some incremental health benefit, and they can provide resources and information on relevant government and non-profit programmes to help reduce exposure.

Educate colleagues and students. By training others in the health and education fields, health professionals can increase the reach of their messages on the health risks of air pollution and strategies to reduce exposure. Health professionals can engage their colleagues in their workplace, local health care centres, conferences and professional associations. They can support the inclusion of children's environmental health in curricula in post-secondary institutions and particularly in medical, nursing and midwifery schools.

Advocate solutions to other sectors, policy- and decision-makers. Health professionals are well positioned to share their knowledge with decision-makers, including members of local governments and school boards and other community leaders. Health professionals can accurately convey the health burden of air pollution to decision-makers, conduct health-based assessments, support improved standards and policies to reduce harmful exposures, advocate for monitoring and emphasize the need to protect children at risk.

The need for collective action, equity and access

Low-income families have limited options to improve the air quality in their homes. Because of market and other forces beyond their control, clean fuels and technologies may not be affordable, available or accessible. Outside the household, individuals and families have even less control over what is emitted into the air that surrounds them. Individual protective measures such as use of clean stoves for cooking may mitigate HAP and improve the health of the whole family; however, reducing AAP requires wider action, as individual protective measures are not only insufficient, but neither sustainable nor equitable. To reduce and prevent exposure to both HAP and AAP, public policy is essential.

> ***Lifting lifelong burdens*: Exposure to air pollution can alter children's trajectory through life, pushing them onto a path of suffering, illness and challenge. But this is preventable. Informed action by health professionals can help reduce the tremendous burden of disease in children caused by the exposure to air pollution.**

Air pollutants do not recognize political borders but travel wherever the wind and prevailing weather patterns take them. Therefore, regional and international cooperative approaches are necessary to achieve meaningful reductions in children's exposure. Approaches to preventing exposure must be complementary and mutually reinforcing, on every scale: houses, clinics, health care institutions, municipalities, national governments and the global community. Health care professionals can push together for strong action from decision-makers to protect the most vulnerable, voiceless citizens: children who have little or no control over the air they breathe. Individual efforts can add up to collective action that changes minds, changes policies and changes the quality of the air around us. Such actions would go far towards ensuring that children can breathe freely, without the terrible burdens imposed by air pollution.

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1. Introduction

Every day around the world, billions of children are exposed to unsafe levels of air pollution. The result is a global public health emergency. Air pollution, whether encountered outdoors or indoors, poses serious risks to children's health. In 2016, 93% of the global population under 18 years of age – including 630 million children under 5 – were exposed to ambient levels of fine PM ($PM_{2.5}$) pollution that exceed the annual mean WHO air quality guideline (see Annex 2). About three billion people were exposed to HAP from the use of polluting fuels for cooking in 2016 *(1)*.

The health burden of air pollution on the world's children is immense. Environmental factors are responsible for an estimated 26% of all child deaths worldwide *(2)*. ALRI are the second leading killer of children under 5 years worldwide *(3)*. Together, AAP and HAP cause more than 50% of all ALRI in children under 5 in LMICs *(4)*. In 2016, AAP and HAP were together responsible for approximately 543 000 deaths among children under 5 from ALRI, accounting for almost 10% of all child deaths that year *(5)*. Over 99.9% of those deaths were in LMICs. In 2016, ALRI caused by HAP was responsible for 441 000 deaths and around 40 million DALYs in children under 15 *(6)*. Among children aged 5–15 years, 52 000 deaths were attributed to the joint effect of HAP and AAP in 2016 *(7)*. These deaths and lost years of healthy life could largely be prevented by improving the environmental conditions to which children are exposed.

> *Air pollution causes over half of all deaths from acute lower respiratory infections in children under 5 in low- and middle-income countries.*

The heaviest burden on the smallest shoulders

Air pollution cuts so many lives short, but it can also lead to health burdens that last a lifetime. Exposure increases the risks of adverse birth outcomes, neurodevelopmental disorders and reduced lung function. In addition to respiratory infections, it is also clearly linked to a higher risk of developing asthma, a major cause of morbidity in children.

The toll is perhaps most severe on the very youngest. Fetuses and infants have long been recognized as especially vulnerable to the effects of exposure to environmental agents such as air pollutants, with possible lifelong consequences *(8)*. The earlier children's exposure, the greater their potential loss of healthy years of life *(9)*. A child exposed in the first months of life can suffer lifelong effects, including increased risks of heart disease, stroke and cancer. A growing body of evidence suggests that air pollution can adversely affect cognitive and behavioural development in children and that early exposure might lead to the development of chronic disease in adulthood *(4)*. Better understanding of the effects of air pollution on fetal and childhood growth and disease development is critically important to inform actions and policies to protect public health.

Children live, learn and grow in various contexts and environments: the home, school, the playground, the neighbourhood, the community, the country and the world at large. In these settings, they encounter pollutants from a wide range of sources, with varying effects on their health. For instance, young children in LMICs often spend much of their time with their mothers around the home and hearth and are thus exposed to high levels of smoke emitted from cooking and heating stoves. In poorly ventilated homes, they may breathe polluted air at levels that far exceed WHO guidelines, while their sensitive airways, lungs and immune systems are still developing *(10)*. Compounding these risks is the fact that children are at the mercy of their environment, with little to no control over their living conditions. Air pollution has not only effects on physical health effects but can add psychological burdens of stress and anxiety *(10)*.

Clear and mounting evidence

There is a large body of research on the effects of air pollution on child health, which is reviewed in this report, including effects on fetal growth and birth outcomes, lung development and function, asthma, respiratory infection and otitis media. The links between air pollution and neurodevelopmental disorders (including autism spectrum disorder and attention deficit hyperactivity disorder) are also reviewed, as are associations between air pollution and obesity or insulin resistance in children (conditions that can develop into metabolic syndrome or diabetes mellitus in later life).

The report focuses on exposure to AAP and HAP from the combustion of polluting fuels. It does not include the evidence for all sources of indoor air pollution, such as second-hand tobacco smoke, which are beyond the scope of this document. The evidence of the harm done by tobacco smoking and second-hand smoke to people of all ages is well established. The WHO Framework Convention on Tobacco Control and other initiatives (e.g. the Tobacco Free Initiative) were created to reduce exposure to tobacco smoke. The final section of this document gives suggestions for actions by clinicians and other health care professionals to address the health effects of air pollution, some of which include actions to reduce exposure to tobacco smoke.

Since publication of the monograph on the effects of air pollution on children's health and development by the WHO Regional Office for Europe in 2005 *(11)*, many studies have been published that strengthen the evidence of links between AAP and HAP and health effects in children. This report summarizes the findings of the latest peer-reviewed research on a number of health effects. As there are many studies, the report is based on systematic reviews, meta-analyses and recent studies (published in the past 10 years).

Evidence of causal links is lacking for many exposures, as epidemiology cannot prove causation. Action is warranted, however, when there is sufficient evidence from epidemiological studies and experimental research that strongly suggests causality. A significant number of studies have established associations between air pollution and various health outcomes. For outcomes for which the evidence of links is inconsistent, "knowledge gaps" and questions for further research are suggested.

For certain health outcomes, studies provide strong evidence of the effects of exposure to AAP, but there are relatively few studies of the links with HAP. As the sources of AAP and HAP often overlap significantly, the evidence for AAP could be considered indirect evidence for the health effects of HAP. Minimizing children's exposure to both forms of pollution, especially during the most sensitive, developmental stages of early life, should take precedence over establishing near-certainty about the full extent of the risk and the mechanisms involved. Preventive strategies could be based on the evidence for AAP on the assumption that HAP has similar effects.

Informing action

Scientific understanding of the serious risks posed by air pollution early in life is robust and growing. This knowledge must be translated into action. Taken together, the body of evidence provides ample support for strong action and effective policy measures. The closing section of this review accordingly suggests specific, concrete actions for paediatricians, obstetricians, health care providers, communities and families responsible for protecting fetuses, infants and children.

Recent WHO publications on environmental risk factors for health reveal the scope of the problem. This document builds on and adds to the evidence in those reports: the atlas on children's health and the environment *(12)*, "Burning opportunity" *(10)*, the guidelines for indoor air quality associated with household fuel combustion *(13)* and the guidelines for ambient air quality *(14)*.

Scope and purpose of the report

Environmental health – and particularly paediatric environmental health – is experiencing accelerated growth. Health care providers who work daily with children, adolescents and their families and communities are on the front line of assessment, treatment and prevention of environment-related diseases and are in a key position to educate the public and provide guidance to parents of young children on ways to mitigate the health risks from air pollution in their home environment.

This document provides health professionals with a summary of up-to-date evidence based on an extensive literature review on the relations between air pollution and various health outcomes in children, including the impact of exposure during pregnancy, child growth and birth outcomes, lung development and function, asthma, respiratory infections, otitis media, neurodevelopmental disorders and childhood cancers. The review includes not only the best available scientific evidence but also expert input on knowledge gaps and research needs. Case studies of successful policies and cost–effective interventions are highlighted as examples of action that could be taken at various levels. The aim is to provide health professionals with concrete actions to protect children from the health risks of exposure to air pollution.

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2. Routes of exposure to air pollution

Fetuses, infants and children have unique vulnerability and susceptibility to the risks of exposure to air pollution, including subsequent development of adverse health outcomes. These heightened risks are due to a combination of behavioural, environmental and physiological factors. (Note: detailed information on the sources of ambient and HAP can be found in Section 4 below.)

2.1 Inhalation

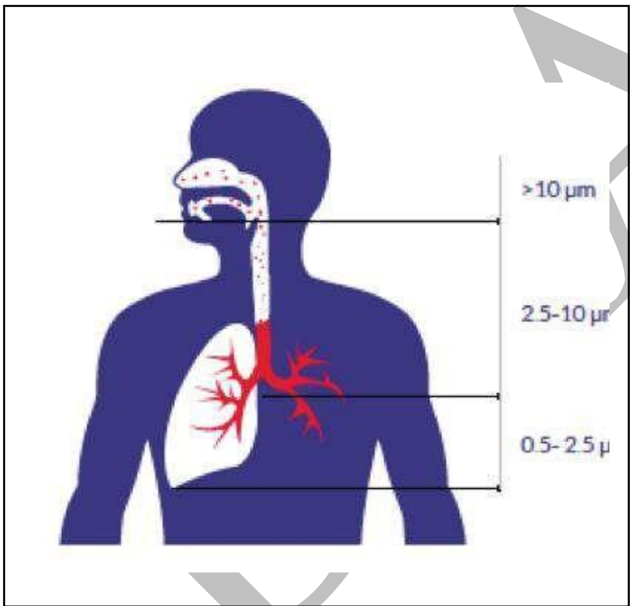
Inhalation is the primary means by which air pollutants enter the human body, through the lungs and alveoli (tiny air-filled sacs located at the end of the bronchioles in the lungs where oxygen exchanges with carbon dioxide in the blood). During the first few years of life, the numbers of alveoli increase rapidly, after which the volume begins to increase; this is therefore a critical window of growth, which may be affected by inhaled pollutants *(1)*. The lungs grow throughout childhood and adolescence and may be exposed to many airborne pollutants that harm growth and function *(1)*. As children breathe at twice the rate that adults do, they inhale larger amounts of air pollutants *(2)*.

Particles are also moved through the respiratory system faster, allowing them to reach the lungs, the alveoli and the bloodstream more rapidly *(3)*. In addition, children are more physically active than adults, so that their ventilation is even greater; and they are closer to the ground, where the levels of pollutants are often more concentrated *(4)*. In the case of particulate pollution, the size of the particle determines how far into the body it penetrates and where it is deposited. Particles < 10 µm in diameter (PM_{10}) are typically filtered out through the nose, whereas smaller particles, such as $PM_{2.5}$ (particles < 2.5 µm in diameter) can penetrate deeper and reach the lower airways. As children typically breathe through their mouths, the nasal filtration mechanism is often bypassed, so that more particles move into their lungs than is the case for adults *(3)*. During pregnancy, a woman's ventilation rate also increases *(5,6)*, increasing both her own exposure and that of her fetus.

Childhood exposure to air pollution by inhalation is associated with disease later in life. Exposure to various pollutants, including black carbon, NO_2, $PM_{2.5}$ and PM_{10}, is linked to the development of asthma in children *(7–9)*, presumably due in large part to the generation of oxidative stress and airway inflammation *(10)*. Research also indicates that PM may cause systemic inflammatory and immunological responses and remodelling in the lung *(11)*.

Other authors have found that ultrafine particles (< 0.1 µm in diameter) can cross the alveoli, enter the bloodstream and cause cardiovascular and cerebrovascular disease *(12–15)*. Research shows that PM_{10} stimulates alveolar macrophages to release the prothrombotic cytokine IL-6, which can cause accelerated arterial thrombosis and increase the risk of cardiovascular events *(16)*.

Fig. 6. Smaller particles of particulate matter penetrate deeper into the lungs



Source: Reference *(17)*

Inhalation of CO can also have significant health consequences (Boxes 1 and 2). Once absorbed, CO quickly binds the haemoglobin of red blood cells (which have a high affinity for CO), creating carboxyhaemoglobin, which displaces oxygen, potentially leading to tissue hypoxia *(18)*. Environmental exposure to CO has been linked to cardiovascular illness and elevated levels of carboxyhaemoglobin in adults. Evidence suggests that chronic exposure to CO may cause changes to the structure and function of the heart that could leave it more susceptible to stress *(19)*.

Box 1. Dangers of carbon monoxide

CO is a colourless, odourless, tasteless toxic gas produced by incomplete oxidation during the combustion of fuels. It can be emitted from household cooking and heating systems, vehicle exhaust, industrial processes and fires *(20)*. CO inhalation can be deadly. Breathing is the only pathway for CO to enter the body, where it combines with haemoglobin in the blood and reduces oxygen-carrying capacity of the blood. Children are most susceptible to CO toxicity due to their higher metabolic rates *(21)*. Symptoms of CO intoxication can include headaches, irritability, dizziness, fatigue, weakness, drowsiness, nausea, vomiting, loss of consciousness, skin pallor, dyspnoea, palpitations, confusion and irrational behaviour *(21)*.

Low levels of CO can be found in ambient air near roads and parking areas. Common indoor sources of CO vary across high-, low- and middle-income countries. In high-income countries, the main indoor source of CO is emissions from defective appliances for cooking or heating. If they are not properly maintained, gas burners, wood-burning fireplaces, clogged chimneys and supplementary heaters can all be potential sources of CO. High levels of CO have also been measured in both public and residential garages. In low- and middle-income countries, the most important sources are the burning of biomass fuels, especially in poorly ventilated kitchens, and tobacco smoke *(22)*.

Box 2. Case study: Carbon monoxide: an invisible threat at home

After moving into a new house, a 9-year-old child began experiencing recurring headaches and gastrointestinal discomfort. These symptoms were followed by an episode of loss of consciousness at home. Several medical examinations yielded no conclusive diagnosis. His teachers reported poorer school performance. Some months later, during the winter, the whole family suffered an episode of loss of consciousness. The ultimate diagnosis was CO intoxication. An extended study of the family's house found the source: a wood-burning stove used for heating during winter.

Case report by Amalia Laborde, Professor of Toxicology, University of the Republic, Uruguay

2.2 In utero

The placenta plays a crucial role in the growth and development of the fetus, providing nutrients and oxygen and removing waste and toxicants throughout pregnancy *(23–25)*. Because the placenta is so important in the exchange of substances between the mother and the fetus, it is also a pathway for exposure of the fetus when the mother is exposed to air pollution *(26, 27)*.

Certain inhaled or ingested pollutants that are small enough to penetrate the alveolar wall, including ultrafine PM and heavy metals, can enter the mother's bloodstream *(26,28–31)*. They can then cross the placental barrier and reach the fetus, affecting growth and development by a variety of mechanisms *(29,32,33)*. They can cause oxidative stress, damage DNA and reduce absorption of nutrients by the fetus *(30,34)*. One study suggested that alteration of placental mitochondrial DNA content may be the mediator between exposure to air pollution and low birth weight *(35)*. Exposure to air pollutants in utero can alter the newborn's immune cell population and may predispose children to allergies and asthma *(29)*. Maternal exposure to lead has been linked to increased fetal lead levels and adverse effects on neurodevelopment later in life *(36)*. A recent study also shows that maternal exposure to HAP during pregnancy leads to chronic hypoxia in the placenta; fetal development under these conditions may be associated with adverse pregnancy outcomes *(37)*. Inflammation is another important mechanism, as both maternal and intrauterine inflammation have been observed in response to air pollution, a factor that is believed to play an important role in adverse birth outcomes and poor neurodevelopment *(38,39)*.

The direct consequences of air pollution on maternal health present additional risks to the fetus. For example, both AAP and HAP have been linked to hypertension in pregnancy *(40–42)*. Hypertensive disorders in pregnancy are a leading cause of maternal mortality worldwide *(43)* and are associated with adverse birth outcomes, including preterm birth and low birth weight *(44,45)*. Children whose mothers experience preeclampsia during pregnancy are also at increased risk of health complications later in life, including endocrine, nutritional, and metabolic diseases *(46)*.

2.3 Ingestion

Air pollutants can settle on surfaces in the home, where an infant or child can ingest them. Because pollutants can persist in the environment for some time after their release, their impact is not always short-lived. Some substances that are released into the air, such as mercury and pesticides, can enter the hydrological cycle as a result of atmospheric dispersion and precipitation and can then be ingested during contact with contaminated water, food, soil or vegetation *(20,47)*.

Breastfeeding is the best source of nutrition for infants, as it provides them with an optimal balance of nutrients while strengthening their immune systems and forming a bond between the mother and the child *(48)*. There is, however, evidence that air pollutants accumulate in breast milk, resulting in exposure of the child. Pollutants from industrial sources, such as pesticides, fossil fuels, chemical by-products, flame retardants, heavy metals and volatile organic compounds, can enter the mother's circulation by inhalation or, more commonly, ingestion before being passed into breast milk *(49,50)*. For instance, PAHs have been reported at high levels in breast milk samples in the Mediterranean *(51)*. PAHs are classified as carcinogenic, and exposure through breastfeeding may result in adverse developmental outcomes *(52,53)*. Nevertheless, the advantages of breastfeeding still far outweigh any risks from most contaminants. WHO recommends exclusive breastfeeding for up to 6 months of age, with continued breastfeeding and appropriate complementary foods up until 2 years of age *(50,54)*.

Exposure to air pollutants during the pre-conception period may also affect the health of both the mother and the fetus. A recent study showed that maternal exposure to NO_x and SO_2 in the months before pregnancy is associated with an increased risk for gestational diabetes mellitus, a condition that is associated with adverse birth outcomes and risks to maternal health *(55)*. Studies also indicate that exposure to SO_2 before pregnancy may play a role in the formation of orofacial clefts *(56)*. Paternal exposure is also important. A study of persistent organic pollutants indicated that exposure of the mother and/or the father before conception resulted in lower birth weight *(57)*.

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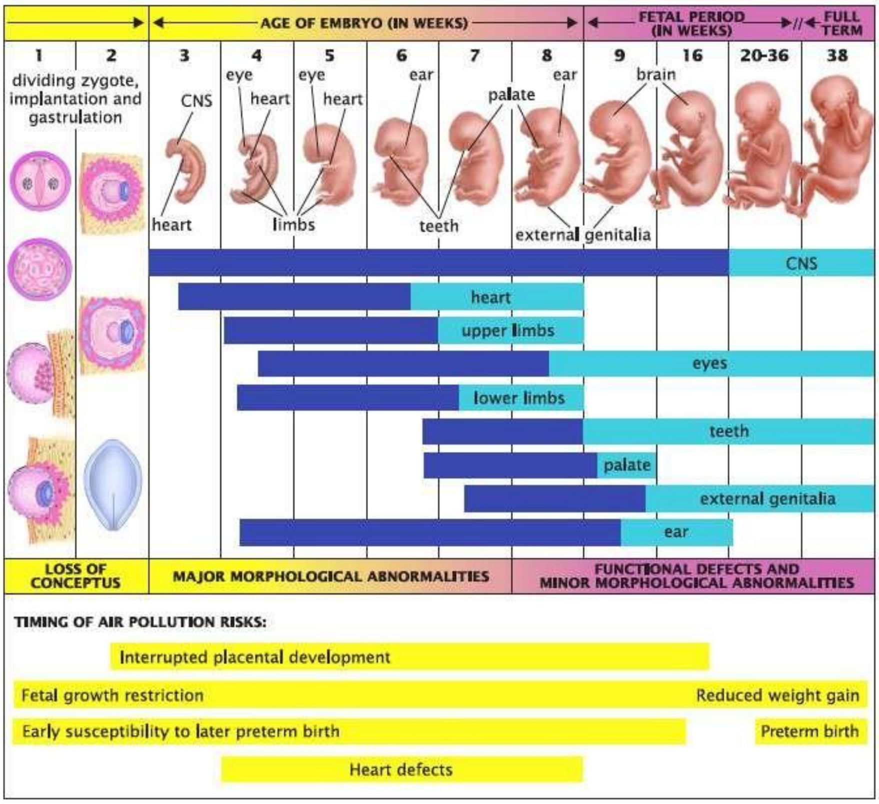
3. Vulnerability and susceptibility of children

A number of studies have established that fetuses, infants and children are particularly susceptible and vulnerable[2] to air pollutants (Fig. 7) *(1–9)*. Children breathe more rapidly than adults, because of their higher resting metabolic rate; as a consequence, they inhale more air – and more air pollutants – relative to their body weight *(2,6,10)*. Children also have a larger lung surface area per kilogram of body weight than adults *(1,2)*. During early life, the respiratory system grows and develops rapidly, and the lung surface area and number of alveoli increase significantly until around 5–8 years of age *(11)*; a higher ratio of lung surface area to volume facilitates absorption of particles. Lung growth continues until about 20 years of age *(12)*. Lung development trajectories are set in early life, so that damage during the prenatal and postnatal stages is potentially irreparable *(2,6,10,11,13)*.

Fig. 7. Fetal development and timing of air pollution risks

[2] Vulnerable: exposed to the possibility of being harmed by something. Susceptible: being likely or liable to be influenced or harmed by something.



Note: Blue bars indicate time periods when major morphological abnormalities can occur, while light blue bars correspond to periods at risk for minor abnormalities and functional defects.

Figure 1. Fetal development and timing of air pollution risks.

Source: Reference *(14)*

During critical windows of gestation and childhood, when organ systems are developing rapidly, children are more vulnerable to permanent damage. At birth, the immune, respiratory and central nervous systems are immature and highly sensitive to environmental stimuli *(15)*, and many mechanisms have been proposed whereby exposure to air pollutants is linked to health effects in children. Oxidative stress and inflammation are predominant and probably play an important role in perinatal outcomes and childhood asthma *(16,17)*. Air pollutants may also impact endothelial function, coagulation, and maternal hemodynamic responses during pregnancy *(16)*.

Exposure to air pollution during pregnancy, a particularly critical period of development, has been linked to various health outcomes. Exposure before 18 weeks of gestation has been linked to diminished development. Various pollutants are passed from mother to fetus with oxygen and nutrients. A mother's exposure to air pollutants during pregnancy can result in permanent damage to the respiratory and cardiovascular systems, cognitive impairment, intrauterine growth restriction and even compromise the development of vital organ systems *(2,18–20)*. Exposure during this critical period has also been linked to permanent changes in the structure of the lungs, which can have lifelong health consequences *(11,21)*. The timing of environmental exposure during pregnancy determines the effect on the developing fetus: earlier exposures tend to affect development of the airway tree and major pulmonary vessels, whereas later exposure can influence lung volume, alveoli and pulmonary capillaries *(11)*.

Children's airway passages are narrower than those of adults. Thus, any irritation and subsequent inflammation from exposure to air pollutants can result in proportionately greater airway obstruction *(2,6,10,22)*. Exposure to air pollutants can exacerbate existing health conditions in children and cause additional complications *(4,23)*. Children with respiratory or cardiovascular conditions are at particular risk *(24)*.

Children may also be more susceptible than adults to the effects of air pollution because of their behaviour. Children spend their days closer to the floor than adults, and some pollutants in household and ambient air are found in the highest concentrations in this zone, where children breathe and play *(25,26)*. The concentration of nitric oxide has been reported to be significantly higher at children's height near heavy traffic *(23,27)*. In the home, children are often with or near their mothers as they cook, exposing them to additional air pollutants. Infants are often unable to move away from sources of air pollution, and older children may not recognize the hazards, further compounding the risks *(26)*. Older children spend more time outside, running, playing and breathing hard, and this increased ventilation exposes them to larger doses of AAP *(28)*. Infants are likely to place objects in their mouth, placing them at risk of ingestion of air pollutants *(28)*. Children with pica behaviour, who compulsively put objects in their mouths, are at particular risk.

Children have a longer life expectancy than adults, rendering them more vulnerable to the potential health effects of air pollution in yet another way *(8,12,29)*. They have more time to manifest a disease with a long latency period and will potentially live longer with negative health consequences *(15)*. Thus, the earlier their exposure, the longer the potential chronic illness or disability they will experience. This kind of cumulative exposure to air pollution can become a life sentence, imposed just as life is beginning.

For the same reasons, the early years, starting in pregnancy, are the best time to invest in a child's health by acting to improve their environment and reduce their exposure *(30)*. This is therefore a window of opportunity to improve their lives. Precisely because children are most vulnerable and sensitive to environmental influences in their earliest years, action to protect them during this critical phase can yield immense benefits.

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4. Sources of air pollution

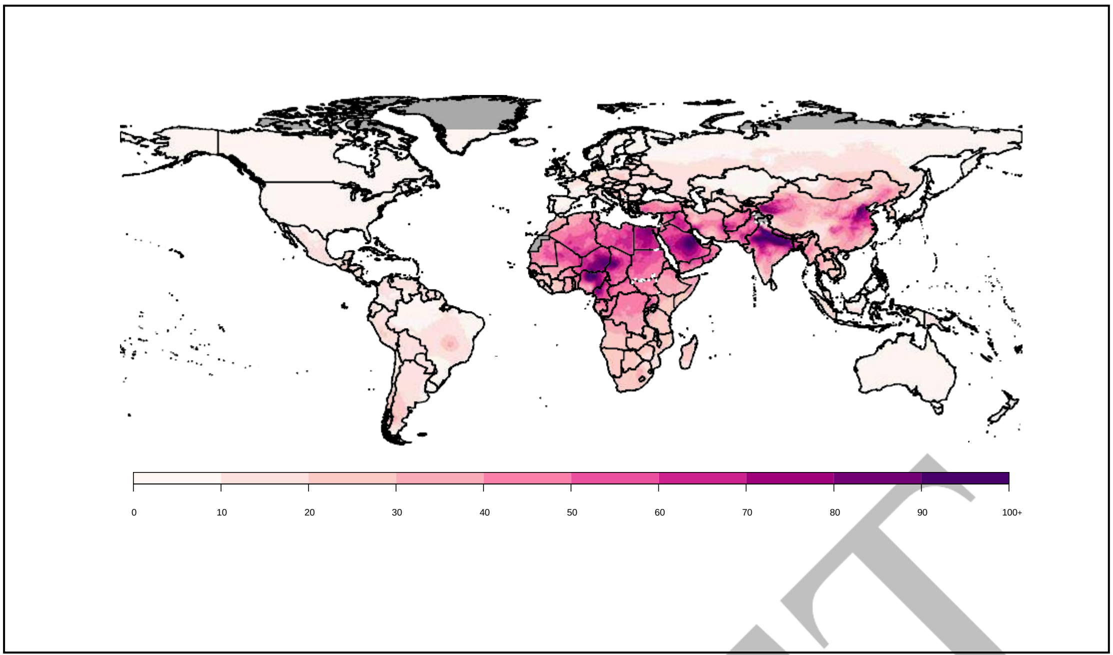
Air pollution from particulate matter is a problem that transcends geographical and political boundaries. It affects people in all countries, in every type of human settlement. It flows between nations and over oceans, from outdoors to indoors to outdoors, from the upwind countryside into the city and then on to the countryside again. Pollutants can be found equally in high, unsafe concentrations in the most remote, rural village and on the busiest, high-traffic urban streets. Children are threatened by this pollution in every region of the world.

HAP and AAP are strongly interconnected: the former is a major, often underestimated source of the latter *(1,2)*. In this section, AAP and HAP are treated separately, as they have been considered distinct phenomena by both scientists and policy-makers. HAP consists of emissions from all household energy, including lighting and heating. Because most of the relevant research to date has focused on cooking and much of the data on energy use are from surveys on cooking fuel and technology, HAP is generally perceived as a risk mostly for rural LMICs *(3)*. While this is broadly true, reliance on polluting household fuels also persists in many urban areas as well. For instance, with growing awareness of the health threat posed by AAP, heating fuels are gaining attention as an important source of air pollution, including in HICs.

4.1 Ambient air pollution

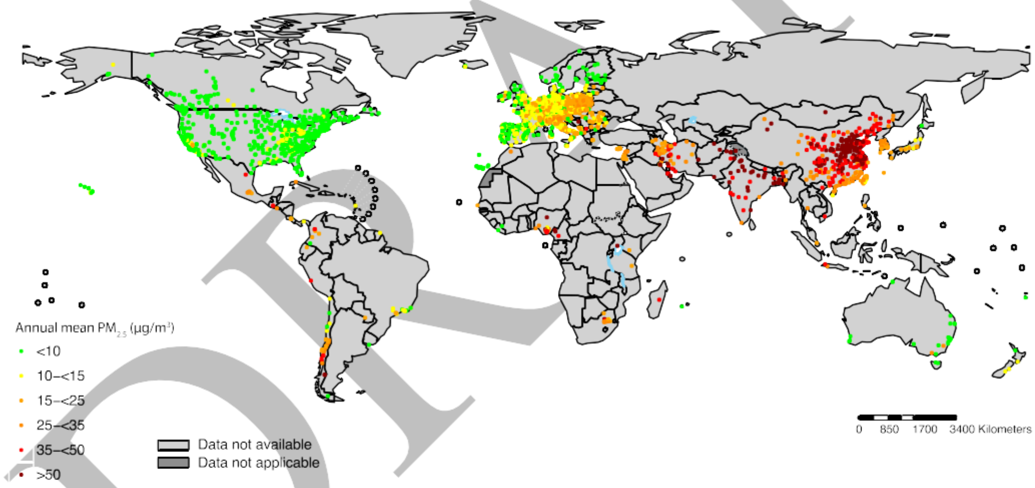
AAP is a global health crisis. The vast majority of people live in places where it is unsafe to breathe the air. Today, 91% of the world’s population – and 93% of its children – are exposed to fine PM at levels that exceed the WHO-recommended limit (Fig. 8 and 9) *(4)*. The distribution of the crisis is also becoming less equal: in more than 4300 settlements monitored by WHO, pollution levels have improved in cities in some HICs but worsened in poorer regions *(5)*.

Fig. 8. Annual average concentrations of ambient $PM_{2.5}$ in µg/m^3, 2016.



Source: WHO global ambient air quality database (update 2018). http://www.who.int/airpollution/data/en/

Fig. 9. PM$_{2.5}$ concentrations in more than 4300 human settlements, 2010–2016.



Source: WHO global ambient air quality database (update 2018). http://www.who.int/airpollution/data/cities/en/
The map shows sites for which data were available. Few data were available for some areas, including highly polluted settlements.

AAP caused about 4.2 million premature deaths in 2016 *(6)*. In 2016, an estimated 286 000 children under 15 years of age died from exposure to AAP (see Annex 2). The sources of pollution differ in urban and rural contexts *(7)*, the main sources in urban settings being fossil fuel combustion for energy production, transport, residential cooking and heating (household fuel use) and waste incineration *(8)*. Use of polluting fuels persists in some higher-income countries; in some countries in Europe and the Arabian Gulf, for example, coal is still used for household heating, posing a risk of CO poisoning for both children and adults *(9)*. The main source of pollution in rural communities in LMICs, however, is burning of kerosene, biomass and coal for cooking, heating and lighting, agricultural waste incineration and certain agro-forestry activities *(8)*.

Interventions to improve the quality of the air in rural areas must target these and other major sources, including excessive use of agrochemicals like fertilizers and pesticides, deforestation, small-scale industries such as charcoal production and spontaneous forest fires, fog and dust storms *(10,11)*. Geographical and meteorological factors influence the transport and chemistry of air pollutants.

Urban areas can affect downwind rural areas, just as rural activities – such as agricultural burning – can affect air quality in nearby cities. For these reasons, interventions to improve air quality in any locality require cooperation at many levels, including regional and international (*1,12*).

Poverty is closely associated with high exposure to air pollution. LMICs generally experience higher levels of exposure to PM, particularly in the WHO African, South-East Asian and Western Pacific regions *(4)*, where the annual mean levels of $PM_{2.5}$ are 5–10 times greater than the WHO guideline limit *(13)*. Even in regions in which $PM_{2.5}$ levels are lower and closer to the WHO limit values, such as Europe and Latin America, the levels in LMICs are almost twice those in HICs. It should be noted that national estimates of exposure to $PM_{2.5}$ are averages and that, even within HICs, low-income communities have disproportionately higher exposure to air pollution, as they tend to be located closer to major sources, such as industrial facilities, high-traffic roads and power plants *(14)*. Box 3 gives an example of a successful programme to reduce HAP.

Box 3. Better stoves, better sleep – lessons from a poverty alleviation programme in Peru *(15)*

Exclusive use of cleaner-burning biomass stoves was linked to better sleep and alleviation of respiratory symptoms in children in a village in Peru.

As a part of the Peruvian Government's "Juntos" national poverty alleviation programme, residents of the small village of Lliupapuquio, Andahuaylas, were given cleaner-burning biomass cooking stoves. These "Inkawasi" stoves have been demonstrated to reduce PM emissions by up to 75% and wood use by 50% as compared with traditional stoves.

Respiratory symptoms in children were assessed while they were sleeping before and after introduction of the stoves. The study subjects were 82 children under 15 years of age who had been exposed to smoke from biomass fuels throughout their lives. During the initial assessment, the population reported a wide prevalence of respiratory symptoms, and more than 33% of the children reported waking during the night, daytime sleepiness and falling asleep at school.

Statistically significant improvements in symptoms were found after introduction of the cleaner-burning stoves; in some cases, the symptoms disappeared. The researchers concluded that exclusive use of the new stoves was probably an important factor in the improvement in health. This study adds to evidence of the health gains made with proper, sustained, exclusive use of clean cooking, as opposed to "fuel stacking", in which a household continues to use polluting energy sources for some tasks.

The sources of AAP vary from manmade to natural, from fossil fuel combustion to crop burning to wildfires, all of which produce a complex mixture of pollutants that can interact chemically. They usually include CO, nitrogen oxides (NO, NO_2, NO_x), lead, arsenic, mercury, SO_2, PAHs and PM ($PM_{2.5}$, PM_{10}, and ultrafine particulate matter) *(16)*. Air pollution from a combination of agricultural activities, urban emissions and atmospheric conditions contributes to annual periods of extreme air pollution in parts of South-East Asia *(2)*.

Certain pollutants react in the atmosphere and in high temperatures to form secondary pollutants, such as O_3. Ground-level O_3 is created when pollutants such as NO_x and volatile organic compounds react with sunlight *(16,17)*. Whereas O_3 in the upper atmosphere is beneficial, as it blocks incoming ultraviolet radiation, exposure to ground-level O_3 can cause breathing problems, trigger asthma, reduce lung function and cause various lung diseases *(16,17,18)*.

It is difficult to measure the changing components of this complex mixture precisely. Certain pollutants have direct toxic effects and are also used as indicators of total exposure by researchers and national government agencies that set and enforce air quality standards. PM (PM_{10}, $PM_{2.5}$) is one of the most commonly used markers of exposure to air pollution in general; other common indicators are SO_2, O_3, NO_2, CO and lead *(19,20)*. The WHO air quality guidelines, updated in 2005 *(16)* were proposed as a basis for regulatory changes to reduce emissions of pollutants and for policy to reduce the health impacts of air pollution. The guidelines propose recommended thresholds and limits for these key ambient air pollutants. Setting science-based air quality standards for important pollutants is one of the most important steps that decision-makers can take to protect the health of their citizens, including children. Governments should adopt the WHO air quality guidelines (e.g. an annual mean threshold of 10 $\mu g/m^3$ for $PM_{2.5}$) or set their own stringent emissions limits. Monitoring and identifying areas that exceed the recommended maximum air pollution levels is essential for effective interventions to protect health. Box 4 gives examples of initiatives to help people reduce air pollution.

Box 4. Digital tools to help citizens fight air pollution and improve health

Regional and global initiatives that leverage the trend of increasing digital connectivity in societies around the world provide citizens with access to regularly updated, online data about the quality of the air where they live.

BreatheLife is an initiative of WHO and UN Environment to raise global awareness about the health risks posed by air pollution. Evidence-based information and resources are provided to mobilize individuals and cities to take action to clean up the air they breathe. BreatheLife's network of participating cities is growing, allowing urban decision-makers to demonstrate support for and share lessons about solutions to improving air quality. On the programme's website (www.breathelife2030.org), individuals can access updated information on the pollution levels in their cities and countries and about the related burden of disease and human cost of air pollution.

Country-level initiatives to make data on air quality more accessible and user-friendly include the Air Quality Health Index in Ontario, Canada (www.airqualityontario.com), which rates air quality on a scale from 1 to 10 and is updated daily. The index indicates action people can take to protect themselves when local pollution levels exceed the recommended limits.

Working towards solutions

Addressing AAP is an increasingly important priority for governments and multilateral agencies. Many proven solutions are available to reduce emissions of dangerous pollutants in cities, including cleaner transport, cleaner cooking and heating fuels and technologies, energy-efficient housing and urban planning, low- to zero-emission power generation, cleaner, safer industrial technologies and better municipal waste management *(21)*.

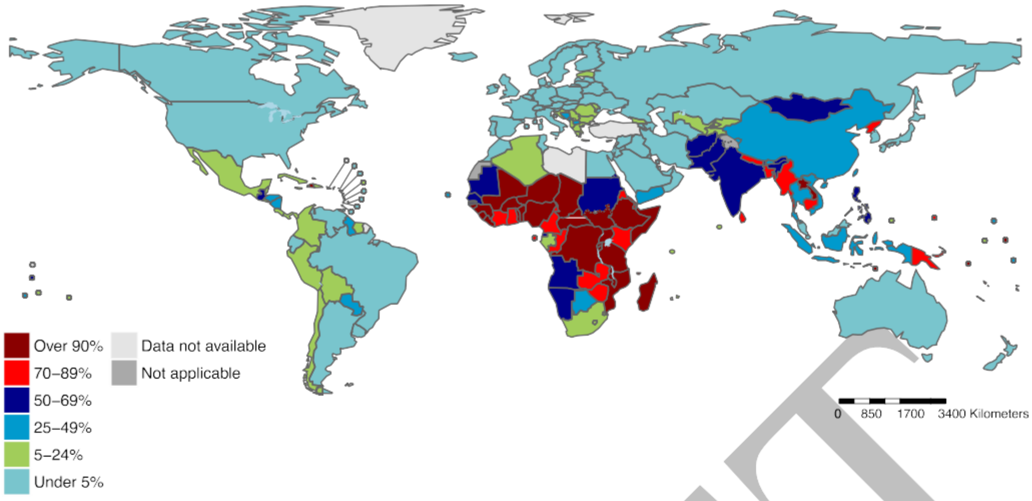
WHO has been publishing reports on air pollution and its health effects since 1958, including work that led to the first air quality guidelines, in the mid-1980s *(22)*. Since the release of the current version of the WHO air quality guidelines in 2005, more evidence has become available on the health effects of ambient air pollutants, even at relatively low concentrations. The guidelines are therefore being revised to reflect the latest available evidence, and an updated version with recommended thresholds for key air pollutants will be published in 2020.

4.2 Household air pollution

Polluted air inside homes, schools, workplaces and recreation facilities – spaces where pregnant women, mothers, infants and children spend much of their time –cause and contribute to a wide range of negative health outcomes. Tragically, excessive air pollution can turn the very places that are meant to shelter and nurture children into places of risk.

HAP is produced mainly by incomplete combustion of polluting fuels used for cooking, heating and lighting and is the single largest environmental health risk factor worldwide *(8)*. HAP is also an important source of AAP *(23)*. In 2016, WHO estimated that about three billion people – 41% of the world's population – still used polluting fuels for cooking, mostly in LMICs (Fig. 10) *(24)*, and this number has remained largely unchanged for the past three decades. The damage to health caused by dependence on polluting energy sources is severe and extensive: in 2016, HAP from solid fuel use resulted in 3.8 million premature deaths, equivalent to 6.7% of global mortality, greater than the toll due to malaria, TB and HIV/AIDS combined. Of these deaths, 403 000 were among children under 5 years of age *(8,18)*. The risks of children are not limited to direct exposure, as there is emerging evidence that pregnant mothers' exposure to high levels of HAP is linked to higher risks of adverse birth outcomes such as low birth weight *(25)*.

Fig. 10. Proportions of households that used polluting fuels for cooking, 2016



Source: Reference *(28)*

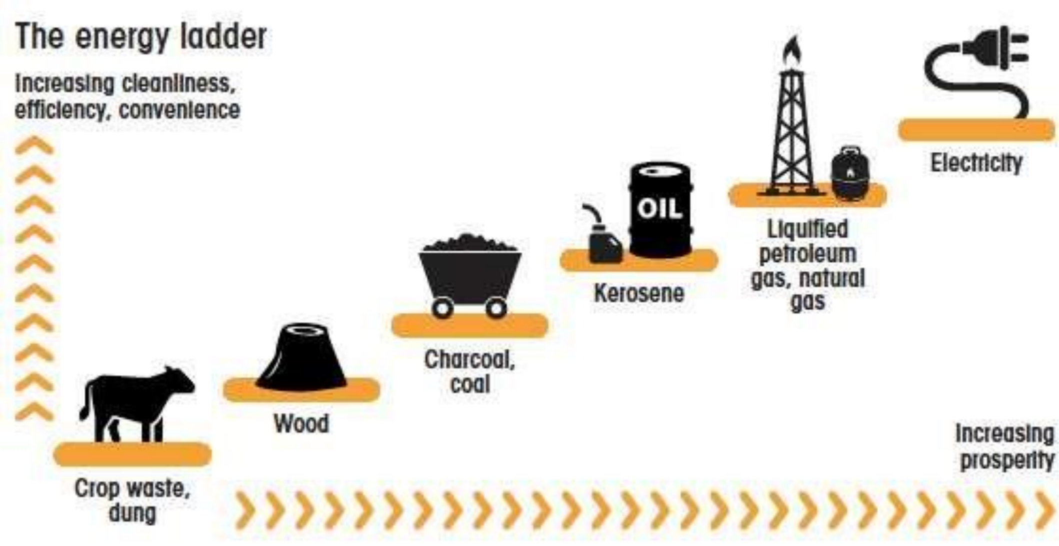
Families' daily acts of survival can undermine the health of their own children. Smoke emitted from burning biomass (wood, dung and crop residues), coal, charcoal and kerosene for cooking, heating and lighting is the primary contributor to HAP; other significant sources are tobacco smoke, candles, incense and mosquito coils *(8)*. Burning produces complex mixtures of contaminants, the composition of which depends on the type of fuel used and on the temperature and phase of combustion *(26–29)*. For instance, emissions from the combustion of coal can contain PM, CO, NO_x, SO_2, benzene, PAHs, carbon and several heavy metals *(30)*. Kerosene combustion can emit CO, NO_x, PM, SO_2, formaldehyde and PAHs *(31)*. Kerosene smoke is also extremely rich in black carbon, a major component of fine PM and a potent climate-warming pollutant *(32)*.

In some regions, children are especially vulnerable to HAP because they spend so much time in the home and with their mothers as they tend the hearth. Women and girls are the main users of household energy around the world. They also spend significant time and effort gathering, transporting, preparing and using fuels like biomass, coal and charcoal to cook food in inefficient stoves or open hearths and to heat their homes. In dwellings with poor ventilation, emissions of fine PM and other pollutants from these stoves can exceed the maximum exposure recommended by WHO by 100 times *(8)*.

Cooking is not the only use of household energy use that poses risks to children's health. The WHO guidelines for household fuel combustion *(31)* classify kerosene as a polluting fuel and discourage its use as a household fuel. Nevertheless, kerosene is still used for lighting by many of the around one billion people who lack access to electricity. Kerosene lamps are often the only means of lighting houses at night, allowing children and adolescents to study in areas without electricity. Use of kerosene not only pollutes the air inside houses but also increases the risks for fires, burns and CO poisoning.

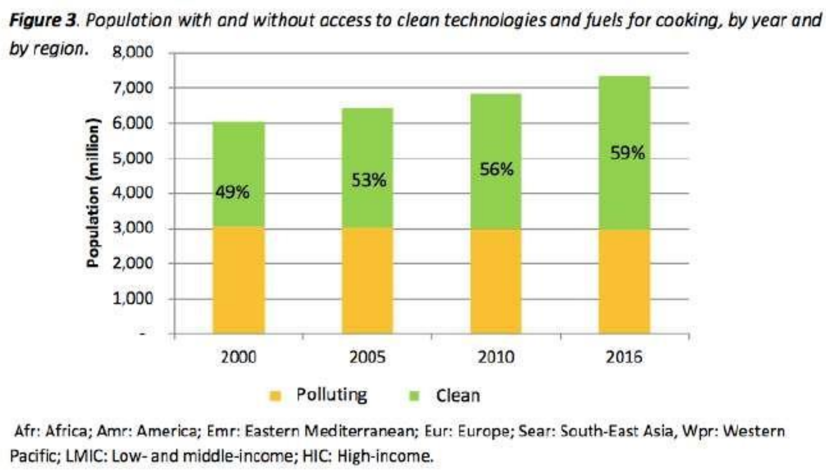
Although significant numbers of urban dwellers in LMICs still use polluting fuels and devices for cooking, heating and lighting, the vast majority of those who use polluting household energy live in rural areas (Fig. 11) *(3)*. Reliance on polluting fuels is especially prevalent in rural areas of the WHO African, South-East Asian and Western Pacific regions *(8)*. Persistent use of polluting cooking, heating and lighting fuels by more than three billion people – and the resulting health risks – is due largely to lack of access to clean, affordable, convenient alternatives *(33)*. Despite recent progress in all WHO regions in increasing access to clean fuels and technologies (Fig. 12), the number of people who use polluting fuels did not change appreciably between 1990 and 2016 (Fig. 13) *(24)*. Given this trend, better coordinated and concerted action is required to meet the SDG 7 target of achieving universal access to clean energy by 2030.

Fig. 11. The "energy ladder", showing increasing cleanliness, efficiency and convenience with increasing prosperity



Source: Reference *(34)*.
The combination of fuel and technology determines whether a stove is "clean for health"; e.g., some pellet-burning stoves achieve WHO guideline levels in laboratory testing.

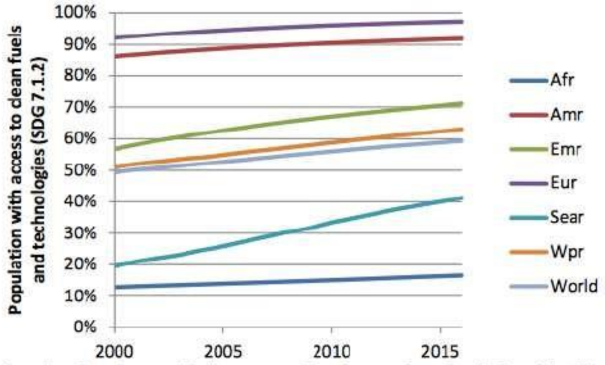
Fig. 12. Population with and without access to clean technologies and fuels for cooking, by year and by region.



Source: Reference *(24)*.

Fig. 13. Trends in access to clean fuels and technologies for cooking, 2000–2016, by region

Figure 2. *Trends in access to clean fuels and technologies for cooking for the years 2000-2016, by region.*



Afr: Africa; Amr: America; Emr: Eastern Mediterranean; Eur: Europe; Sear: South-East Asia, Wpr: Western Pacific; LMIC: Low- and middle-income; HIC: High-income.

Source: Reference *(24)*.
AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; SEAR, South-East Asian Region; WPR, Western Pacific Region

HAP and AAP are interconnected: the latter can make its way indoors, and the former contributes to poor air quality outdoors. Globally, an estimated 12% of ambient $PM_{2.5}$ comes from use of solid fuel for cooking *(35)*. This "leakage" of indoor pollutants outdoors is responsible for almost half a million premature deaths due to AAP *(36)*. Reducing cross-contamination between household and ambient air by reducing reliance on polluting fuels in both rural and urban areas throughout the world is an urgent priority for health sector professionals and for those working in energy and sustainable development. Accelerating the transition to clean household energy for billions of people is a critically important means for protecting children's health.

Working towards solutions

In 2014, WHO issued the first set of guidelines on fuels and technologies for cooking, heating and lighting that are clean for health *(31)*. The guidelines include recommendations on combinations of fuel and technology that are clean for health at the point of use, including electricity, LPG, biogas, ethanol and solar stoves, as well as high-performing biomass stoves that meet the emission rate targets in the guidelines. The guidelines discourage household use of kerosene and unprocessed coal because of the serious health hazards they pose.

Achieving universal access to clean, safe household energy is a high priority on the global sustainable development agenda, reflected in SDG 7 ("ensure access to affordable, reliable, sustainable and modern energy for all"). Box 5 presents the human rights issues involved. WHO has resources to help health professionals and decision-makers to integrate health concerns into planning, programmes and policies on household energy and air quality. These include the Clean Household Energy Solutions Toolkit, which contains modules on needs assessment, standards and testing for household energy devices, monitoring and evaluation and materials, to help the health sector in tackling HAP. (See also Annex 1.)

Box 5. Air pollution is a child rights issue

No group is more vulnerable to environmental harm than children. Yet, a healthy environment is essential for children to fully enjoy their right to health. The Convention on the Rights of the Child *(37)*, the universally ratified human rights treaty, requires States Parties to pursue full implementation of the right to health by appropriate measures that include the provision of nutritious foods and clean drinking-water, taking into consideration the dangers and risks of environmental pollution (Art. 24 (2) (c)). Air pollution in particular jeopardizes children's right to health. Countless children suffer disease and disability from air pollution, often with lifelong effects, as it can disrupt their physical and cognitive development.

States have heightened their obligations to respect, protect and fulfil the rights of children, who are often unable to protect themselves from environmental harm, including air pollution. The obligations include:

- ensuring that educational programmes increase children's understanding of environmental issues and strengthen their capacity to respond to environmental challenges;
- assessing the effects of proposed measures on children's rights before the measures are taken or approved;
- collecting information on sources of environmental harm to children and making the information publicly available and accessible;
- facilitating the participation of children in environmental decision-making and protecting them from reprisals for their participation or otherwise expressing their views on environmental matters; and
- removing barriers to children's access to justice for environmental harm so that can fully enjoy their rights.

States should adopt and implement environmental standards that are consistent with the best available evidence and relevant international health and safety standards. Thus, States should implement recommendations from expert agencies, such as WHO, on specific measures to protect children's health and well-being from environmental harm. A good example of concrete guidance is the report of the United Nations Special Rapporteur on Human Rights and the Environment, John H. Knox, on the threat posed to children's health and well-being in Mongolia by air pollution *(38)*. The Rapporteur noted that, in 2017, the Committee on the Rights of the Child expressed serious concern about the effects of air pollution on Mongolian children, particularly in the capital, Ulaanbaatar. Each winter, the city has some of the most heavily polluted air in the world, as residents of *gers* burn coal in household stoves to stay warm. Knox observed that children are at particular risk, jeopardizing their rights to life and health.

Other sources of indoor air pollution

Many other air pollutants are also important health risks, but fall beyond the scope of this report, which addresses primarily sources of air pollution arising from combustion. Contaminants present in urban and rural indoor air include volatile organic compounds, asbestos, pesticides, mercury (e.g. from broken thermometers), radon and biological pollutants. Volatile organic compounds produce vapours readily at room temperature and are emitted by thousands of household products, including paints, varnishes, solvents, building materials, disinfectants, personal care products, air fresheners, art and hobby supplies and vehicles used in attached garages *(20)*.

Tobacco smoke is a significant source of indoor air pollution and a health risk for children *(39)*. As many as 4000 chemicals may be present in tobacco smoke alone *(40)*. Asbestos is a known occupational carcinogen, and its use in residential and education buildings can contaminate indoor air *(30)*. Pesticides such as insecticides and antimicrobial disinfectants are often sprayed near the ground and can persist in indoor air or settle on surfaces *(41)*. Radon, a radioactive carcinogenic gas naturally present in some soil and rock, can enter houses, buildings and other enclosed spaces *(42-44)*. This document primarily addresses sources of air pollution arising from combustion.

Various biological pollutants are present in indoor air: dust mites, droppings and urine from pests, insects and rodents, pollen from indoor plants and outdoor air, viruses and bacteria and fungi, including mould and mildew, or their by-products *(41,44,45)*. Build-up of certain biological pollutants can trigger asthma or cause allergic reactions *(46,47)*, and others are linked to the spread of infectious diseases *(45)*.

Working toward solutions

WHO has published a series of indoor air quality guidelines (Table 3) *(22)*. There are many solutions to reducing exposure to other air pollutants. In general, indoor environments can be made healthier by a few key actions: avoiding tobacco smoking, improving ventilation and reducing humidity in houses (to reduce mould and mites), storing chemicals safely and avoiding the use of unnecessary chemicals and pesticides. Asbestos and lead paint should no longer be used in building or renovating houses *(21,43,48,49)*.

Table 3. Common air pollutants: sources of exposure and WHO air quality guidelines

Pollutant	Common sources of exposure.	WHO guideline values[a]	Reference
Benzene	Ambient: Building materials, furniture, attached garages. Motor vehicle exhaust. Refineries and petrol stations. Household: Heating and cooking with kerosene. Activities such as cleaning, painting, mosquito repellents, photocopying and printing. Tobacco smoke.	No safe level of exposure is recommended. Unit risk of leukaemia per 1 μg/m^3 air concentration is 6×10^{-6}. The concentrations of airborne benzene associated with excess lifetime risks of 1/10 000, 1/100 000 and 1/1 000 000 are 17, 1.7 and 0.17 μg/m^3, respectively.	*43*
Carbon monoxide (CO)	Ambient: Incomplete combustion from burning charcoal or biomass and burning fossil fuels in motor vehicles, electric generators and other machinery.	100 mg/m^3 – 15-min 35 mg/m^3 – 1-h 10 mg/m^3– 8-h 7mg/m^3 – 24-h	*43*
	Household: Heating and cooking. Tobacco smoke. Vehicle exhausted from attached garages. Electric generators. Incense burning.	Emission rates from household fuel combustion should not exceed CO (unvented) 0.16 (g/min) CO (vented) 0.59 (g/min)	*31*
Lead	Vehicle and industry emissions, waste incineration, natural processes (e.g. volcanic eruptions)		
Mercury	Vehicle and industry emissions, waste incineration, natural processes (e.g. volcanic eruptions).		
Naphthalene	Ambient air Crystalline (pure) naphthalene moth repellents and disinfectants, herbicides, charcoal lighters and hair sprays, unvented kerosene heaters, tobacco smoke, rubber materials Wood smoke, fuel oil and gasoline.	0.01 mg/m^3 – annual average	*43*
Nitrogen dioxide (NO_2)	Ambient: Combustion processes (heating, power generation, and engines in vehicles and ships). Household: Heating and cooking – gas, wood, oil, kerosene and coal; tobacco smoke Outdoor air. Occupational use of vehicles indoors.	200 μg/m^3 – 1-h average 40 μg/m^3 – annual average	*43*
Ozone (O_3)	Vehicle and industry emissions, solvents.	100 μg/m^3 – 8-h mean	*16*
Particulate matter (PM)	Ambient: Motor vehicle emissions. Combustion of fossil fuels and solid fuels. Dust. Various sources.	$PM_{2.5}$ 10 μg/m^3 – annual mean 25 μg/m^3 – 24-h mean PM_{10} 20 μg/m^3 – annual mean 50 μg/m^3 – 24-h mean	*16, 50*
	Household: Combustion of solid fuels in open fires or traditional stoves. Kerosene.	Emission rates of $PM_{2.5}$ from household fuel combustion should not exceed 0.23 mg/min – unvented 0.80 mg/min – vented	*31*

Polycyclic aromatic hydrocarbons (PAH)	Ambient: Motor vehicles. Burning of coal and oil for electricity and industrial use. Incomplete combustion of organic materials. Household: Heating and cooking with dung, wood, agricultural residues, coal. Tobacco smoke. Incense and candles.	No threshold can be determined, and all indoor exposures are considered deleterious to health. Unit risk for lung cancer estimated to be 8.7×10^{-5} per ng/m^3 of benzo(*a*)pyrene. The corresponding concentrations from lifetime exposure to benzo(*a*)pyrene that result in excess lifetime cancer risks of 1/10 000, 1/100 000 and 1/1 000 000 are approximately 1.2, 0.12 and 0.012 ng/m^3, respectively.	*43*
Sulfur dioxide (SO_2)	Ambient: Industrial activities, power generation, motor vehicles. Household: Burning of fossil fuels (coal and oil).	20 μg/m^3 – 24-h mean 500 μg/m^3 – 10-min mean	*16*
Volatile organic compounds	Ambient: Petrochemical solvents, vaporization of unburnt fuel, pesticides. Combustion processes and vehicle exhaust. Household: Cooking, solvents, building materials, household products indoors at room temperature.	No guidelines, although there are recommendations for certain volatile organic compounds, such as benzene, which is carcinogenic to humans; there is no safe threshold for exposure to benzene.	*20*

This list is of important pollutants in indoor air; it is not exhaustive.

[a] Some countries and states within countries (e.g. California in the USA) have adopted guideline levels lower than those of WHO.

4.3 Social determinants of exposure and health

Social determinants of health play a central role in the effects of HAP and AAP on health. The circumstances in which we live powerfully influence our lives, beginning at conception *(51)*. Social inequalities negatively affect infant health and are associated with increased rates of infant mortality rates *(52)*. Studies suggest that social status, especially poverty, influences the risk of environmental exposure. Thus, less affluent populations are at greater risk of a variety of exposures; for example, the combined effects of socioeconomic inequality and reduced air quality can contribute to increased infant mortality *(53)*. It has been estimated that, in 2010, 2.7–3.4 million preterm births globally were associated with exposure to $PM_{2.5}$ during gestation *(53)*.

Poverty and pollution are closely linked. Poverty may force people to rely on polluting fuels for their basic needs, and poverty compounds the health risks associated with their use. Poverty also limits people's choices and their ability to improve the environment in which they raise their children; for example, low-income families cannot just decide to move away from a heavily polluting industrial site. Air pollution is often a chronic problem in poor-quality housing and temporary settlements. The exposure of people living in refugee camps can be particularly high, as they have to scavenge for wood and other fuels or rely on kerosene stoves for heating and cooking.

> *Poverty and pollution are closely linked. The poor often have higher exposure to air pollution and more limited access to treatment and interventions.*

Dependence on the energy sources that produce most HAP – solid fuels such as wood – also contributes to other important health risks. Children, often at the expense of their schooling or playtime, are sometimes given the tasks of cooking on inefficient stoves or gathering fuel. Fuel collection obliges them to walk long distances with heavy loads. This work can lead to musculoskeletal disorders and can put children, particularly girls, at higher risk of violent attack, rape or injury as they venture far from the household *(8,34)*. The risk of attack while gathering fuel is especially high for girls living in refugee camps *(54,55)*. An analysis of survey data in 16 African countries in 2016 showed that girls in households in which polluting fuels were used spent about 18 hours each week collecting wood or water, whereas girls in households in which clean fuels were used primarily spent 5 hours each week in such tasks *(8)*.

Gender also determines exposure of children to HAP and AAP. As they move through childhood, their exposure to HAP and AAP may change according to their gender. In some cultures, girls are kept in the kitchen with their mother for longer than boys because of social and cultural attitudes towards the role of women *(56)*. Girls are therefore more exposed to HAP and boys potentially more exposed to AAP *(57)*. This obviously varies, as some parents have a social preference for male children and spending more time looking after them, so that they have greater exposure to HAP *(58)*. The role of gender in exposure to HAP and AAP is complex and depends on social and cultural attitudes.

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5. Effects of air pollution on child health

Since publication of the monograph on the effects of air pollution on children's health and development by the WHO Regional Office for Europe in 2005 *(1)*, further evidence has been published of the links between AAP and HAP and the health of children.

This document provides a summary of the latest and best available science, to inform and aid healthcare professionals' efforts to protect children's health. For each of the 10 sections on health effects below, two experts did an initial scoping review and reviewed the available evidence; because of the extensive relevant published literature, they gave priority to systematic reviews, meta-analyses and recent studies, mainly those published within the past 10 years. A second in-depth review was conducted to identify additional studies, with a round of extensive peer review by a geographically diverse group of experts in air pollution and child health. The document also cites WHO publications on air pollution that are relevant to child health. It should be noted that this document is neither a full systematic review nor a set of official guidelines, and, because of constraints of space and time, the review does not cover every potential effect of air pollution on children's health.

The health effects discussed are adverse birth outcomes, infant mortality, effects on neurodevelopment, childhood obesity, effects on lung function, acute lower respiratory infection, asthma, otitis media and childhood cancers, demonstrating the diverse range of impacts that air pollution can have on children, often with long-lasting consequences.

5.1 Adverse birth outcomes

Key findings:

- Numerous studies show significant associations between exposure to AAP and adverse birth outcomes, especially in association with the pollutants PM, SO_2, NO_x, O_3 and CO.
- A growing body of evidence shows that air pollution, particularly $PM_{2.5}$, is associated with low birth weight, and AAP is associated with preterm birth.
- Few studies have examined the role of HAP, but there is moderate evidence of an association between solid fuel combustion and low birth weight.

The health impacts of exposure to air pollution during the prenatal period are often overlooked but can be quite significant. A growing body of research provides evidence of an association between maternal exposure to air pollution and adverse birth outcomes, including stillbirth, preterm birth, low birth weight and being small for gestational age (SGA) *(2–19)*. Exposure before conception can also affect the fetus, with emerging evidence of a link between exposure to air pollution from traffic and other sources of AAP and reproductive disease in women. A systematic literature review provides suggestive evidence of associations between exposure to AAP and the incidence of reproductive and gynaecological diseases, including infertility and endometriosis, although the number of studies to date is limited *(20)*.

WHO defines stillbirth as fetal death occurring at a birth weight of ≥ 1000 g or at ≥ 28 completed weeks of gestation *(21)*. In 2015, an estimated 2.6 million infants were stillborn, and 98% of the deaths occurred in LMICs *(22)*. Preterm birth is defined by WHO as infants born alive before 37 weeks of gestation; an estimated 15 million infants are born preterm worldwide each year *(7)*. Health complications resulting from preterm birth are the leading cause of death among children < 5 years of age, resulting in over one million deaths in 2016 *(7, 23, 24)*.

Low birth weight is a major public health issue worldwide and is associated with a range of short- and long-term health effects. Low birth weight is defined by WHO as a weight at birth of < 2500 g *(2)*. It has been estimated that 15–20% of all infants born worldwide have a low birth weight, corresponding to more than 20 million births per year *(3)*. SGA is commonly defined as having a weight below the 10th percentile of the recommended sex-specific birth weight for gestational age *(10)*. SGA and low birth weight are also associated with preterm birth *(18)*. Thus, preterm birth and SGA can occur independently or together and can result in low birth weight *(18, 25)*. These outcomes have been associated with increased risks for premature death and disability, including cardiovascular morbidity, chronic lung disease, obesity and metabolic syndrome *(18, 26)*. There is also emerging evidence suggestive of an increased risk for developmental delays and poorer cognitive performance *(11, 18)*. Children who had adverse birth outcomes may require more health care after birth, placing demands on health facilities and resources, with wider social impacts *(18)*.

The evidence for links between air pollution and stillbirth, preterm birth, low birth weight and SGA is discussed below.

Stillbirth

Ambient air pollution

Several studies have been published on the effect of AAP, particularly $PM_{2.5}$, and stillbirth. In a meta-analysis *(27)*, one study on the effect of $PM_{2.5}$ on risk of stillbirth found a statistically nonsignificant increase in risk of stillbirth per 10 μg/m^3 increase in $PM_{2.5}$ *(28)*. Green and colleagues identified a small, statistically significant increase in risk per 10 μg/m^3 increase in $PM_{2.5}$ in a birth cohort in California, USA *(29)*. Other studies reported modest increased risks associated with exposure to $PM_{2.5}$ throughout pregnancy *(30)* or at specific stages, such as the third trimester *(31)* or the week before delivery *(32)*. Ebisu and colleagues *(33)* recommended that the chemical components of $PM_{2.5}$ and the specific cause of stillbirths (fetal growth, maternal complications) be determined to ensure accurate results.

Other studies have reported increased risks of stillbirth with exposure to total AAP *(34)*, $PM_{2.5}$ *(30)*, PM_{10} *(30, 35, 36)*, CO *(28, 30)*, SO_2 *(28, 30, 36)*, NO_2 *(28–30)* and O_3 *(29, 37)*. Some publications reported nonsignificant or no associations *(38, 39)*, and some were limited by distance at which air pollution monitors were located from birth address or by failure to adjust for change of address during pregnancy *(28)*. The strongest effect for PM_{10}, SO_2, CO, and O_3 in most studies was in the third trimester *(29, 30, 35, 36, 40)*. As for $PM_{2.5}$, evidence indicates that exposure to NO_2 throughout pregnancy increases the risk of stillbirth *(29, 30)*.

Acute exposure to AAP in the week before delivery has been the subject of relatively few studies. New evidence suggests that such exposure increases the risk of stillbirth. Faiz and colleagues *(32)* found an increased risk of stillbirth when mothers were exposed to high levels of CO, SO_2, NO_2 or $PM_{2.5}$ in the 6 days before delivery. In a retrospective cohort study of 223 375 births in the USA, exposure to O_3 during the week before delivery increased the risk of stillbirth by 13–22% *(37)*.

Household air pollution

Pope et al. *(41)* identified four studies of the relation between HAP from solid fuel use and stillbirth: three in India *(42–44)* and one in Pakistan *(45)*. Three of the studies found a significant association between exposure to HAP and increased risk of stillbirth; the fourth found an increased risk, which was not statistically significant. The review *(41)* found an overall 51% increase in risk of stillbirth with exposure to HAP. The studies differed in design, particularly with respect to the method for exposure assessment. Two of the studies considered kerosene to be a "low pollution" fuel *(43, 44)*, and one considered that exposure to kerosene led to medium exposure to HAP *(45)*, which contradicts current understanding of the adverse health effects of kerosene. WHO guidelines for indoor air quality associated with household fuel combustion *(46)* discourage use of kerosene in the home. The review of health effects for the guidelines concluded that the findings of these four studies were consistent and that a causal association was possible but could not be confirmed, given the small number of studies. A more recent review *(47)* included an additional study and found a 29% increase in the risk of stillbirth but found that kerosene was categorized inconsistently in the studies, with one categorizing it as resulting in "high pollution" *(48)* and two as "low pollution" *(43, 49)*; in two studies, information on kerosene use was not collected. Different classification of kerosene may affect the interpretation of these results and also the findings of studies on other health effects.

Preterm birth

Ambient air pollution

Maternal exposure to individual air pollutants during pregnancy has been linked with preterm birth *(8, 9, 14)*. A number of studies have found a positive association between maternal exposure to $PM_{2.5}$ and preterm birth *(50–52)*, and it has even been estimated that, in 2010, 2.7–3.4 million preterm births globally were associated with exposure to $PM_{2.5}$ during gestation *(53)*. One review found a nonsignificant association between exposure to PM_{10} and preterm birth *(52)*. Preterm birth has been consistently associated with SO_2 levels *(54, 55)*, while the evidence for associations with CO, NO, NO_2 and O_3 remains inconclusive *(50, 53)*.

It is important to distinguish between very early and later preterm birth (e.g. before 26 weeks, 26–32 weeks and after 32 weeks), because each has different effects on health and probably different causes. Many studies do not distinguish between very early and later preterm birth, although this distinction would be useful, particularly for evaluating the effects of different levels of AAP.

Household air pollution

Very few studies have been undertaken of HAP and preterm birth. A systematic review by Amegah and colleagues *(47)* covered three studies *(44, 49, 56)* and found an increased risk of preterm birth with household solid fuel use. One of the studies *(44)*, conducted in India, gave an adjusted odds ratio of 1.43 for preterm birth in houses in which solid fuel was used as compared with those in which LPG or kerosene was used. The literature review for the WHO guidelines on indoor air quality associated with household fuel combustion did not include an assessment of the quality of the evidence for associations between polluting fuel use and preterm birth, because of the small number of studies *(46)*.

Box 6. Air pollution and congenital anomalies

Congenital anomalies, also known as birth defects, are structural or functional abnormalities that occur during intrauterine life *(57)*. They may be identified before birth, at birth or later in life. Congenital anomalies, including metabolic disorders, account for an estimated 11% of global neonatal deaths, 6% of infant deaths and lifelong morbidity *(24)*. Examples of congenital anomalies linked to environmental factors include congenital heart disease, limb reduction, kidney or urinary tract malformation, cleft lip and palate defects, cryptorchidism and hypospadias. While there is evidence that certain birth defects are associated with exposure of nonsmoking pregnant women to second-hand tobacco smoke, the results of studies of AAP and HAP have been inconsistent.

There is a growing body of literature on the relations between AAP and congenital anomalies, and associations of varying strength have been found. A cohort study conducted in Wuhan, China *(58)*, found a significant association between maternal exposure to atmospheric $PM_{2.5}$ during early pregnancy and congenital heart defects in the offspring. This study of 105 988 live births, stillbirths and fetal deaths was based on 1-week average concentrations from nearby air pollution monitors and showed a significant association with risk of congenital heart defects, which increased monotonically as $PM_{2.5}$ concentration increased. A study of traffic pollutants (PM_{10} and benzene) in a community in northern Italy showed an association between exposure to PM_{10} and birth defects *(59)*. A systematic review of 10 epidemiological studies that included a meta-analysis of four studies of associations between the risk of congenital anomalies and concentrations of various air pollutants found statistically significant increased risks of coarctation of the aorta and of tetralogy of Fallot with exposure to NO_2 and SO_2 *(60)*. It also showed an association between exposure to PM_{10} and an increased risk of atrial septic defects. Another systematic review and meta-analysis showed a significant association between exposure to NO_2 and coarctation of the aorta *(61)*.

Because of the paucity of studies, there is insufficient evidence of an association between congenital anomalies and HAP other than tobacco smoke. A population-based case–control study in Shanxi Province, China *(62)* on the link between neural tube defects and HAP from coal combustion demonstrated a dose–response trend, whereby the risk of a child having neural tube defects increased with the mother's exposure to household coal combustion pollutants.

Low birth weight

Ambient air pollution

Evidence has emerged in the past decade that ambient PM affects birth weight *(5, 6, 15–17, 63)*. Several meta-analyses performed between 2012 and 2016 consistently showed positive associations between exposure to $PM_{2.5}$ during pregnancy and low birth weight and suggest that late pregnancy may be a critically vulnerable time *(50, 52, 64–66)*.

Individual chemical elements of PM may be involved in its toxic effect. In a large study of eight pooled European cohorts, an increased amount of sulfur in $PM_{2.5}$ was associated with an increased risk of low birth weight *(17)*. As the chemical components of PM differ widely by source, this may explain some of the inconsistencies in the findings of different studies *(64)*. In an extensive systematic review of studies in China *(55)*, SO_2 was consistently associated with low birth weight. There is less evidence of associations between exposure during pregnancy to PM_{10}, PAH (benzene, toluene, ethyl benzene, M- and p-xylene, and o-xylene) and other elements of AAP, such as CO and NO_2, and low birth weight *(4, 52, 65)*.

Household air pollution

Several studies have tested the association between HAP, particularly from use of solid fuels, and a lower mean birth weight. These studies found an increased risk of low birth weight between 21% and 35% with exposure to HAP *(25, 41, 47, 67, 68)*.

The review of health effects for the 2014 WHO guidelines led to the conclusion that there was moderate evidence of an association between exposure to solid fuel combustion and low birth weight *(46)*. The review comprised seven studies, which had consistent findings *(44, 49, 69–73)*. An earlier review by Pope and colleagues *(41)* included many of the same studies from Guatemala, India, Pakistan and Zimbabwe, all of which reported higher risks of low birth weight after maternal exposure to solid fuel combustion in the home. The review found that maternal exposure to HAP increased the risk of low birth weight by 38%, for an average reduction in birth weight of 96.6 g. A recent systematic review by Amegah and colleagues *(47)* found a 35% increase in risk and an average reduction in birth weight of 54 g, after adjustment for publication bias.

Box 7. Air pollution and adverse birth outcomes: new evidence from cohort studies in India

Air pollution is one of the leading risk factors for the national burden of disease in India *(74)*. Exposure to $PM_{2.5}$ in AAP and HAP has been associated with low birth weight in many studies but in few studies in the high-exposure settings that are common in LMICs such as India. Balakrishnan et al. *(75)* investigated whether exposure to $PM_{2.5}$ during pregnancy was associated with low birth weight in an integrated rural–urban, mother–child cohort in Tamil Nadu. The researchers recruited 1285 women in the first trimester of pregnancy in primary health care centres and urban health posts and followed them until the birth of their child to collect data on maternal health, prenatal care, exposure to air pollution during pregnancy and the birthweight of the child. They found that a 10 μg/m^3 increase in exposure to $PM_{2.5}$ during pregnancy was associated with a decrease in birth weight of 4 g and a 2% increase in the prevalence of low birth weight (after adjustment for gestational age, sex, maternal BMI, maternal age, history of a previous low-birth-weight child, birth order and season of conception). By applying the exposure–response estimates of the median differences in $PM_{2.5}$ concentration (of ~175 μg/m^3) between households in which biomass and clean fuel were used, a 70 g decrease in birth weight was estimated to be associated with solid fuel use *(76)*. This study provided some of the first quantitative estimates of the effects of exposure to $PM_{2.5}$ in India to birth weight. It contributed evidence of this association that is relevant for high-exposure settings in LMICs that experience the dual health burdens of AAP and HAP. The findings indicate that maternal exposure to $PM_{2.5}$ should be considered with other risk factors for low birthweight in India. The study also provided baseline information for a new multi-country HAP intervention trial under way in Guatemala, India, Peru and Rwanda on the effects of clean fuel (in this case, LPG) use on maternal and child health (www.hapintrial.org).

Small for gestational age

Ambient air pollution

Few studies have explored the association between exposure to air pollution and infants born small for gestational age (SGA), defined as birth weight below – 2 standard deviations of the mean or below the 10th percentile according to local intrauterine growth charts *(77)*. Maternal exposure to $PM_{2.5}$ and PM_{10} has been associated with SGA births *(15, 50)*. Le and colleagues *(8)* investigated the association between SGA at term and exposure to SO_2, CO, NO_2, O_3 and PM_{10} during the first month and the third trimester of pregnancy. They found an association between SGA at term and exposure to high CO and NO_2 levels in the first month and with exposure to O_3 and $PM_{10} > 35$ μg/m^3 during the third trimester. Additional evidence confirms the link between elevated NO_2 levels and SGA. A study of 2.5 million births in Canada between 1999 and 2008 found that exposure to NO_2 during pregnancy was significantly associated with infants born SGA at term. The association was independent of $PM_{2.5}$, and a dose–response relation was found. This information and evidence that NO_2 is a key component of traffic-related air pollution led the authors to suggest that exposure to traffic is an important factor in adverse pregnancy outcomes such as SGA *(54)*.

Social situation strongly affects birth outcome. A population-based study in the USA linked exposure to both O_3 and $PM_{2.5}$ to SGA. The authors noted that more socially disadvantaged populations are at greater risk of infants born SGA, particularly in the case of exposure to $PM_{2.5}$ *(12)*. Overall, there is growing evidence of an association between SGA and ambient air pollution.

Household air pollution

Associations between HAP and infants born SGA have been identified in several studies. In India, infants born to women who used biomass fuels such as wood and/or dung as the primary cooking fuel in the home during pregnancy were more likely to be SGA *(44)*. In a study of pregnant women in Zambia, household air monitors were used to measure exposure to $PM_{2.5}$ and volatile organic compounds during the first trimester *(78)*. The authors found that increasing levels of pollutants were associated with poor birth outcomes, and both $PM_{2.5}$ and VOCs were associated with SGA. The primary sources of pollution identified were biomass fuels (wood, charcoal, crop residues and cow dung) used for cooking. Garbage burning was also common.

Biological mechanisms

It is difficult to determine the association between air pollution and adverse birth outcomes because so many factors can influence the sensitive periods of development. Several plausible mechanisms have been proposed, including oxidative stress, which may affect the embryo directly in its early stages of development or induce DNA damage, pulmonary and placental inflammation, changes in fetal blood coagulation or endothelial function, and altered maternal haemodynamic response *(79)*.

The placenta is central to the health of the fetus, and airborne pollutants that reach the placenta may cause significant damage. PAHs and CO can cross the placenta, triggering a number of effects *(63, 80)*. Researchers found that maternal exposure to fine particulate matter ($PM_{2.5}$) and CO in household air during pregnancy increases the risk of fetal thrombotic vasculopathy, a disorder characterized by clots on the fetal surface of the placenta that block vascular flow, and also stillbirth and low birth weight *(81)*.

Studies have identified epigenetic changes in the expression of maternal and fetal DNA in cases in which air pollution has been indicated as a factor in preterm birth, suggesting a new mechanism of action *(82)*. Increased methylation of umbilical cord blood and placental DNA has been noted, although more research is needed *(82)*. Studies in experimental animals showed that high maternal exposure to $PM_{2.5}$ during pregnancy can cause epigenetic changes that interfere with the cerebral development of the embryo *(83)*.

PM can also stimulate maternal inflammatory responses, reduce maternal immunity and increase the risk of infection *(84)*. Infection may cause intrauterine growth restriction or preterm labour *(84)*. Maternal health is critical to fetal health; therefore, if the mother's respiratory health is jeopardized by air pollutants, the transport and delivery of oxygen and nutrients to the fetus may be reduced *(85)*.

Box 8. Clarion call: the FIGO opinion on the effects of exposure to toxic environmental chemicals on reproductive health.

"Exposure to toxic environmental chemicals during pregnancy and breastfeeding is ubiquitous and is a threat to healthy human reproduction." That is the conclusion of the International Federation of Gynaecology and Obstetrics (FIGO), the leading voice of reproductive health professionals, with member societies in 125 countries and territories. In 2015, FIGO published an opinion by an international group of obstetricians, gynaecologists and scientists, formally endorsed or supported by 12 reproductive health professional organizations worldwide *(86)*, that there is "accumulating, robust evidence" for an association between exposure to environmental chemicals, such as those in air pollution, and reproductive health. "Preventing exposure to environmental chemicals is a priority for reproductive health professionals everywhere", the opinion states. FIGO recommends that health professionals advocate for policies to prevent exposure to toxic chemicals in the environment, including air pollution.

Conclusions

Pregnancy is a highly vulnerable time. A growing body of evidence shows a link between exposure to air pollution and adverse birth outcomes, which may have lasting health consequences. There is robust evidence that exposure to air pollution, especially ambient PM, is associated with low birth weight. Likewise, there is growing evidence that maternal exposure to AAP, especially to fine PM, increases the risk of preterm birth. While the reported strength of association between stillbirth and exposure to air pollutants (e.g. PM, CO) depends on the individual pollutant, several studies have shown an increased risk of stillbirth linked to higher exposures. There is evidence suggestive of a link between exposure to ambient and household air pollution and infants born SGA. While additional research will advance knowledge, the harmful effects of air pollution on fetal development and birth are clear, and efforts must be made to protect future generations.

Knowledge gaps and research needs

- A substantial number of studies have examined the link between air pollution and various birth outcomes. The studies differ widely in the populations studied, the method and the levels of exposure to air pollution.
- More studies should be conducted on the association between exposure to ultrafine PM and birth outcomes and also on exposure to air pollution and preterm birth.
- As many studies on birth outcomes and air pollution are based on general estimates of exposure, studies should be conducted with state-of-the-art techniques for measuring and modelling air

quality to increase the validity of the links between exposure to various air pollutants and birth outcomes and to improve the evidence base for environmental health policies to ensure the health of mothers and children.

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5.2 Infant mortality

Key findings:

- While there are few studies, those on the link between exposure to PM and infant mortality have provided compelling evidence of a positive association globally.
- Most studies have addressed acute exposure to AAP with relatively few on the effects of HAP on the risk of infant mortality.

Infant mortality refers to deaths that occur in the first year of life. In 2016, the global infant mortality was 4.2 million, representing 75% of all deaths of children under the age of 5 years *(1)*. While many studies have shown a link between air pollution and mortality in adults, less research has been done on infants. As infants' lungs are highly susceptible to pollutants, they are particularly vulnerable to airborne exposure, and more research is required. The available evidence indicates a link between infant mortality and exposure to HAP and AAP. The links between climate change, air pollution and infant and child health are also increasingly being studied, with growing concern for the health and well-being of future generations *(2)*.

Ambient air pollution

Early studies of the effect of AAP on infant mortality consistently found associations of different strengths. Several studies included in a systematic review in 2005 *(3)* found strong correlations between air pollution and infant mortality. The studies were conducted in many geographic areas, on a range of pollutants, including total suspended particles: SO_2, O_3, NO_2, NO_x, $PM_{2.5}$ and PM_{10}. A similar review in 2004 found that the results differed by subgroup of infants *(4)*. While inconsistent findings were noted for PM and both total infant mortality and neonatal mortality, the authors found a positive association between exposure to PM and post-neonatal mortality. This was especially pronounced for deaths due to respiratory causes and sudden infant death syndrome. Although the reason for this trend was not clear, the authors suggested links between exposure to particulate air pollution and some causes of infant death.

Several studies examined the effects of AAP on infant mortality in more detail. A large study in Japan was conducted of infant deaths in urban Tokyo between 2002 and 2013 to examine the association with acute exposure to $PM_{2.5}$, suspended PM (< 7 µm in diameter) and coarse particles ($PM_{7–2.5}$) *(5)*. The mortality rates associated with increases in the concentration of each pollutant of 10 $\mu g/m^3$ were compared. Infant mortality was categorized by age at death (infant, neonate and post-neonate) and cause of death. Infant and post-neonatal mortality increased with each 10 $\mu g/m^3$ increase in $PM_{2.5}$ and was linked with respiratory diseases. An increase in exposure to coarse particles was associated with a 21% increase in the risk of post-neonatal mortality; and the risks of post-neonatal mortality and mortality due to respiratory diseases increased by 10% and 25%, respectively, with increased concentrations of suspended PM. The risk of infant mortality was increased even when PM concentrations were below the Japanese air quality guideline of a daily average of 35 $\mu g/m^3$ for $PM_{2.5}$. These results highlight the importance of evaluating infants separately from other age groups, as they may be uniquely susceptible to air pollution.

A study with satellite estimates and data from household surveys on the location and timing of almost 1 million births in 30 countries in Africa was conducted to estimate the effect of exposure to ambient $PM_{2.5}$ on infant mortality *(6)*. The authors found that infant mortality increased by 9% with a 10 $\mu g/m^3$ increase in $PM_{2.5}$ and estimated that exposure to $PM_{2.5}$ above minimum threshold levels was responsible for 22% of infant deaths in those 30 countries in 2015.

In an affluent, densely populated area of Flanders, Belgium in close proximity to traffic, industry and agriculture, researchers investigated acute exposure to PM_{10} and infant mortality between 1998 and 2006 *(7)*. Daily infant mortality, pollutant level and cause of death were recorded. Neonates aged 2–4 weeks were the most vulnerable to air pollution, with an 11% higher risk of death with every increase of 10 $\mu g/m^3$ in PM_{10}. When PM_{10} levels exceeded 50 $\mu g/m^3$, these neonates were 1.75 times more likely to die. This finding is important, because the WHO guidelines recommend levels < 20 $\mu g/m^3$ and daily averages < 50 $\mu g/m^3$ on more than 3 days per year (*8*). Thus, adherence to local pollution standards may significantly affect infant mortality rates. In this study, infant mortality due to perinatal circumstances (e.g. maternal conditions, complications of pregnancy and birth, adverse birth outcomes) and congenital and chromosomal abnormalities also increased with rising daily PM_{10} levels.

Most studies measured exposure to air pollution immediately before an infant's death, and relatively few considered longer exposures, although the extent of exposure to pollutants in the weeks and months before death may be critical. For example, a correlation has been found between the average level of $PM_{2.5}$ during the time between birth and post-neonatal death *(9)*. In a study in a highly polluted part of California, USA, the average CO, NO_2, O_3 and PM_{10} levels experienced by infants 2 weeks and 1, 2 and 6 months before death were measured *(10)*. In infants 28 days to 3 months old, the risk of death from respiratory causes increased significantly with rising CO levels in the 2 weeks before death; a moderate increase in risk was seen for infants 4–12 months old with increasing PM_{10} levels in the 2 weeks before death; and, for infants 7–12 months old, the risk more than doubled when they had been exposed to high levels of PM_{10} in the 6 months before death. In another study in the same region, the risk of sudden infant death syndrome increased by 15–19% when average NO_2 levels were elevated during the 2 months before death *(11)*. In a cohort study in the Republic of Korea of the association between long-term exposure, including during pregnancy and postnatally, to PM and infant mortality *(12)*, gestational exposure to increasing levels of PM_{10}, total suspended particulates and $PM_{2.5}$ increased the risk of infant mortality from all causes and from respiratory causes in infants with a normal birth weight. The first trimester was the only period during which this pattern was found independently, indicating an effect of air pollution in early pregnancy on infant development and mortality.

Policy affects human health and perhaps most significantly that of infants. In a quasi-experiment, Tanaka *(13)* studied changes in infant mortality in 175 Chinese prefectures before and after the introduction of stringent air pollution regulations. In 1998, the power industry, which was heavily reliant on coal and a major source of emissions (particularly SO_2), dramatically reduced its emissions. This reduction was associated with a 20% decrease in the rate of infant mortality, with a 63% reduction during the neonatal period, particularly from deaths associated with the nervous and circulatory systems. The author proposed that the drastic improvement in neonatal survival with reduced maternal exposure to pollutants benefitted fetal development and increased probability of survival.

Household air pollution

Most of the research on HAP has been on the effects of ambient air pollutants, although infants spend most of their time indoors. In a study in rural India, the risk of infant mortality was 21% higher in households with indoor burning of biomass fuels (wood or dung) than in those in which kerosene or biogas was used *(14)*. In Ecuador, the infant mortality rate increased with the amount of biomass fuels burnt *(15)*. In these studies, households in which biomass fuels were used were compared with those in which fuels considered by the authors as "cleaner", such as biogas, LPG or kerosene, were used. (As noted above, this categorization contradicts current understanding of the adverse health impacts of kerosene use.) In another study, infants born to women exposed to polluting cooking fuels (kerosene, charcoal, coal, wood, straw, crop waste and dung) during pregnancy were found to be at increased risk of neonatal mortality within 0–2 days of birth *(16)*, indicating the danger of exposure to HAP both in utero and in the domestic environment.

Biological mechanisms

The biological mechanisms through which air pollution increases infant mortality are not clearly understood. It has been proposed that infants are likely to die when exposed to air pollution because their immature lungs and immune system leave them unable to cope with the reactive inflammation that occurs in response to such exposure *(17)*. Pope et al. *(18)* proposed that PM damages the lung, resulting in respiratory distress and hypoxaemia. Neonatal rats exposed to PM had reduced cell proliferation and increased oxidative stress in the lungs *(19)*, but toxicological evidence for humans is lacking. CO poisoning is a well-known cause of infant death *(20)*.

The association between exposure to PM and adverse birth outcomes, including low birth weight, preterm delivery and intrauterine growth restriction, is relevant to infant mortality. The possible mechanisms of these outcomes have been studied in more detail. They may include adverse effects on the cardiovascular system, such as oxidative stress, inflammation, impaired coagulation and endothelial function and faulty haemodynamic responses *(21)*. These adverse effects add to the challenges faced by vulnerable infants as they grow and develop during their first year of life.

Conclusion

A correlation has been found between exposure to HAP and AAP and infant mortality, which increases with increasing pollution levels. Infants are at particular risk from exposure to PM and toxic gases. Although inconsistent classification of kerosene in studies of HAP and infant mortality may affect the interpretation of certain findings, HAP is clearly a risk factor for child mortality.

Knowledge gaps and research needs

- Most of the studies addressed acute exposure, and more research is needed to understand the long-term cumulative effects of air pollution, from gestation to death.
- Few studies to date have been conducted on HAP. Better understanding of the effects of indoor pollutants on infant mortality will improve understanding of the interaction between exposures and risk. Studies of the different constituents of air pollution and the biological mechanisms by which they act will improve understanding of how air pollution affects infant mortality.

- Although sufficient data are available to support preventive action, further research on the components of air pollution and their mechanisms of action would provide input for additional preventive policy actions and interventions.

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5.3 Neurodevelopment

Key findings:

- Exposure to air pollutants can negatively affect neurodevelopment, resulting in lower cognitive test outcomes (such as global intelligence quotient) and the development of behavioural disorders such as autism spectrum and attention deficit hyperactivity disorders.
- Research suggests that both prenatal and postnatal exposure to air pollution represent threats to neurodevelopment.

Overview

Neurodevelopment is a fundamental phase of human growth and development, which begins in the early prenatal period with the proliferation of radial glia and neurons. While neurodevelopment continues well into the second decade of life, the first three years of age are especially important. Various processes occur during this period, including proliferation, migration, differentiation, synaptogenesis, myelination and apoptosis of neuronal cells *(1, 2)*. If neurodevelopment is interrupted or impaired by environmental pollutants, the health consequences for the child can be serious, as this may lead to a number of conditions and symptoms, including cognitive impairment, attention disorders and autism spectrum disorder, which are difficult to diagnose and treat and may have lifelong consequences.

Ambient air pollution

Three systematic reviews concluded that there is an association between exposure to AAP, especially pollutants emitted from vehicles, and impaired neurodevelopment in children *(2–4)*.

Several studies have evaluated the relation between prenatal exposure to air pollution and neurodevelopment in children and suggested that air pollution can negatively affect their mental and motor development. Lertxundi et al. *(5)* found that prenatal exposure to $PM_{2.5}$ and NO_2 was associated with significant decreases in cognitive development and motor development in children at the age of 15 months. In a study of birth cohorts in the Republic of Korea, prenatal exposure to PM_{10} and NO_2 had significant effects on cognitive development and motor development at 6 months of age but not at 12 or 24 months *(6)*.

The findings of studies on the effects of prenatal exposure to air pollution on cognitive function and behaviour have been inconsistent *(2)*. While one meta-analysis of cohort studies in Europe found no association between cognitive development and exposure to NO_2 and PM from traffic-related air pollution, an association was seen between prenatal exposure to NO_2 and deficits in overall psychomotor function in children aged 1–6 years *(7, 8)*.

Prenatal exposure to air pollutants can have various effects on development throughout childhood. In Japan, Yorifuji and colleagues *(9)* reported an association between prenatal exposure to air pollution and deficits in verbal and fine motor development at the age of 2.5 years. They also found an association with problems of attention, inhibition and impulsivity at 5.5 years. In the same cohort, the risks of attention problems and aggressive behaviour were found to have increased by 8 years of age *(10)*. Other studies indicate that exposure in specific periods during pregnancy is associated with certain stages of neurodevelopmental deficit, with differences by gender. Chiu et al. *(11)* reported an association between exposure to $PM_{2.5}$ at 31–38 weeks of gestational age and reduced intelligence quotient among boys and an association between exposure to $PM_{2.5}$ at 12–20 weeks of gestational age and decreased general memory index among girls.

Where children live and grow has a powerful effect on their lives. There is increasing evidence that, postnatally, childhood exposure to traffic-related air pollution is linked to neurodevelopmental outcomes such as anxiety and depression *(12)* and impaired cognitive function *(13, 14)*. In a study of 2715 children aged 7–10 years in Barcelona, Spain, Sunyer and colleagues *(15)* found that children who attended schools in highly polluted areas had slower growth in cognitive function, measured as working memory, than those in less polluted areas.

In a prospective study of birth cohort, Suglia et al. *(16)* used black carbon as an indicator of traffic-related air pollution and found that increased exposure was associated with lower scores on intelligence, memory and learning tests in children aged 8–11 years. In a one-year longitudinal study in Spain, Freire et al. *(17)* observed that high exposure to traffic-related air pollution was associated with a modest decrease in cognitive and motor development. A longitudinal study in Spain showed that students exposed to higher levels of traffic-related NO_2, elemental carbon and ultrafine particles in school classrooms and courtyards had "slower growth in all cognitive measurements" and negative performance on tests of working memory and attentiveness than those exposed to lower levels. In another longitudinal study, Chiu et al. *(18)* found a nonlinear relation between exposure to air pollution and attention in children aged 7–14. They also found that children in the second and third quartile of exposure to black carbon made more errors and had a slower reaction time on a continuous performance task than those in the lowest quartile, although the association was less strong for those in the highest quartile. Significant associations were found for both boys and girls, but stronger associations were found for boys.

In the first large study of the effect of air pollution on brain morphology, Guxens et al. *(19)* analysed brain imaging scans and cognitive function tests of 783 children in a Dutch birth cohort. Prenatal exposure to $PM_{2.5}$ was found to cause structural alterations to the cerebral cortex, which partially mediates inhibitory control, of children age 6–10 years. Impaired ability to control impulses at this age may affect educational achievement and increase the risk of mental disorders.

Household air pollution

The review of evidence of health effects for the 2014 WHO guidelines for indoor air quality associated with household fuel combustion *(20)* identified the association between solid fuel use in houses and neurodevelopment as an emerging area of research. One study in rural Guatemala found an association between exposure to CO during pregnancy and reduced neuropsychological performance in children *(21)*. In another study, memory and building block skills (as indicators of cognitive development) in children aged 3–9 years in Belize, Kenya, Nepal and American Samoa were found to be lower in those who were exposed to open-fire cooking *(22)*. The reviewers concluded that, while research to date suggests a relation between exposure to HAP and impaired cognitive development, no clear association could be concluded from two studies. Indoor exposure to CO from cooking with gas or solid fuels may be independently associated with adverse neurodevelopmental outcomes in children *(23)*, but this conclusion is also based on a limited number of studies.

Autism spectrum disorders

Autism spectrum disorders (ASD) cover a wide range of conditions, which are usually identified by the age of 5 years. They are characterized by asocial behaviour and difficulties in communication and language *(24)*. WHO has estimated that one in 160 children currently lives with ASD *(24)*.

Ambient air pollution

Several studies have addressed associations between prenatal and postnatal exposure to traffic-related air pollution and ASD in children. Becerra et al. *(12)* reported an increased risk of ASD with increasing prenatal exposure to NO_x, O_3, and $PM_{2.5}$ in Los Angeles, California, citing traffic as the primary source *(12)*. Three other studies found associations, with an increased risk of ASD and pre- and postnatal exposure to $PM_{2.5}$ *(13, 14, 25)*, PM_{10}, NO_2 and traffic-related air pollution *(14)*. In a prospective cohort study, Jung and colleagues *(26)* identified an increased risk of ASD with rising levels of CO, NO_2, O_3 and SO_2 in the 1–4 years before diagnosis. In a systematic review of 23 studies, Lam et al. *(27)* found an increased risk of autism with increased exposure to air pollution but rated the quality of the evidence as moderate, with a low risk of bias. They concluded that there is limited evidence of toxicity.

In contrast, two studies in Europe found no association between autistic traits and prenatal exposure to NO_2, $PM_{2.5}$ or PM_{10} *(28)* and no link between pre- and postnatal exposure to NO_x and $PM_{2.5}$ and ASD *(28, 29)*. Furthermore, a study of birth cohorts in Sweden *(30)* found no association between pre- and postnatal exposure to NO_x and PM_{10} and ASD or attention-deficit hyperactivity disorder, a brain disorder marked by a continuous pattern of inattention and/or hyperactivity–impulsivity that interferes with functioning or development *(31)*. Lyall et al. *(32)* suggested that the differences in the results obtained in Europe and the USA were due to differences in exposure measurements, methods for assessing ASD and the age at which assessments were done.

Overall, systematic reviews of studies on ASD have shown relatively consistent evidence of an association between AAP, especially prenatal exposure to PM, and autism *(27, 33–36)*. More research should be conducted to clarify the effects of individual components of AAP. There is inconsistent evidence of an association between the critical period of exposure (pre- or postnatal) and the occurrence of ASD *(2, 36, 37)*.

Household air pollution

The review revealed no published studies on HAP from use of polluting fuels and the development of ASD. ASD were not included in the review of the evidence of health effects for the WHO guidelines on indoor air quality with respect to household fuel combustion in 2014 *(20)*.

Biological mechanisms

Although neurodevelopment is a complex process, studies are beginning to elucidate the mechanisms by which air pollution interferes with the normal physiology. A study with magnetic resonance imaging (MRI) of children aged 7–9 years who had been exposed in utero to PAHs showed a dose–response relation with reductions in white matter surface *(38)*. The changes were found almost exclusively in the left hemisphere of the brain and were associated with specific symptoms, including more severe externalizing behavioural problems, symptoms of attention-deficit hyperactivity disorder and conduct disorders.

Pujol et al. *(39)* used MRI to document brain structure, membrane metabolites, functional connectivity in major neural networks and activation/deactivation dynamics during a sensory task. Other authors concluded that higher exposure to traffic-related air pollution in childhood slowed brain maturation *(13)*. Other research suggests that exposure during fetal life to high levels of air pollution causes structural changes in the cerebral cortex *(19)*.

MRI also revealed significant differences in white matter volume and cognitive deficits between children living in highly polluted areas and those living in less polluted areas *(40)*. The authors also saw increased serum inflammatory mediators in these children, suggesting a role for neuroinflammation, and proposed that structural brain alterations are a potential response to high levels of air pollution. Other work showed an association between long-term exposure to air pollution (including ultrafine PM and $PM_{2.5}$) and neuroinflammation, in addition to an altered innate immune response in children and young adults *(41)*. The authors also noted disruption of the blood–brain barrier, ultrafine particulate deposition and accumulation of amyloid β-42 and α-synuclein, suggesting that long-term exposure to air pollution should be considered a risk factor for degenerative diseases such as Alzheimer and Parkinson diseases.

Conclusions

There is growing evidence of an association between exposure to AAP in the prenatal and postnatal periods and impaired childhood neurodevelopment. There is strong evidence that exposure to AAP can negatively affect children's mental and motor development. There is suggestive evidence of a link between prenatal exposure to traffic-related air pollution and cognitive and psychomotor function and behavioural problems, but the findings have been inconsistent. Some studies showed an association between exposure to HAP and impaired cognitive develoment, but further research is needed. Outdoor air pollution has been linked to an increased risk of ASD, especially in studies in the USA in which consistent methods were used.

Knowledge gaps and research needs

- Further research should be conducted on the biological pathways of the effects of air pollution on neurodevelopment. Use of more precise methods for measuring exposure to air pollution, the composition of PM and the sources, long-term evaluations and identification of critical periods of exposure would strengthen the evidence of neurodevelopmental effects.
- Long-term neurobehavioural follow-up of children exposed to air pollution in early life is required to assess the consequences of early exposure later in life in view of the emerging literature on particulate pollution and dementia in adults.

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5.4 Overweight and obesity

Key findings:

- Some studies suggest an association between exposure to air pollution in utero and postnatal weight gain or attained BMI for age. Other studies suggest an association between traffic-related air pollution and insulin resistance in children.
- Air pollution may disrupt the normal development of children, resulting in increased weight-for-length gain and mean BMI and differences in attained BMI at specific ages. Potential mechanisms for these effects include regulation of lipid metabolism, fat storage and appetite.

"Overweight" and "obesity" are defined as abnormal or excessive fat accumulation that may impair health, with weight-for-height greater than two or three standard deviations above the median WHO child growth standard *(1)*. In practical terms, this means that overweight or obese children are too heavy for their height.

Childhood obesity is increasing worldwide and is now recognized as a major public health challenge *(2, 3)*. The prevalence of obesity among young people is high in many countries, but the rate of obesity is increasing at a faster rate in developing than in developed countries *(3, 4)*. The problem has reached the proportions of an epidemic: in 2017, 38.3 million children < 5 years and 340 million aged 5–19 years worldwide were overweight or obese *(4 ,5)*. Childhood obesity is likely to continue into adulthood, with increased risks of cardiovascular or metabolic disorders, including diabetes and heart disease. Increasingly, obese children are presenting with these diseases early in life. The rapid global rise in obesity is due to a variety of factors, including overconsumption of energy-dense foods and less physical activity. The environment in which children are raised can also strongly influence their risk of becoming overweight or obese *(6, 7)*. The effects of the mother's environment during pregnancy must be also be considered. The Commission on Ending Childhood Obesity has recognized the importance of ensuring that pregnant women are protected from environmental hazards to reduce the risk of childhood obesity *(3)*. There is growing interest among researchers and policy-makers in determining the effects on childhood obesity of environmental conditions such as air pollution *(2)*.

Ambient air pollution

As indicated in section 5.1, exposure to air pollution in utero may affect birth weight through placental damage, epigenetic changes and maternal inflammatory responses. Longer-term effects on energy balance, weight-for-length gain and BMI for age in early childhood have also been identified in some studies. In a study of children in the USA, Rundle et al. *(8)* reported that prenatal exposure to PAHs in AAP was associated with increased BMI and obesity in childhood. Pregnant women in this study wore personal air monitoring devices for 2 days during the third trimester of pregnancy. In comparison with the group with lowest exposure, children born to mothers most heavily exposed to PAH had a higher BMI at 5 and 7 years of age and relative risks of obesity of 1.79 and 2.26, respectively. Adjustment was made for several potentially confounding variables, such as the child's sex, ethnicity and birth weight, but did not account for physical activity. Fleisch et al. *(9)* measured the weight and length of infants in the Project Viva cohort at birth and at 6 months and determined the association between prenatal exposure to $PM_{2.5}$ and black carbon and fetal growth and infant weight gain. Infants in the highest quartile of exposure to black carbon in the third trimester had less fetal growth than those in the lowest quartile, and an association was found between exposure to black carbon or $PM_{2.5}$ and weight-for-length gain between 0 and 6 months. Account was taken of potentially confounding variables, including weight gain, maternal smoking and abnormal glucose tolerance.

There is some evidence that air pollution affects different stages of gestation separately. A cohort study was conducted to determine sensitive periods of exposure and sex-specific effects by modelling the day and week of exposure to $PM_{2.5}$ during pregnancy *(10)*. Exposure to $PM_{2.5}$ during 10–29 weeks of gestation resulted in increased waist–hip ratios in girls at the age of 4 years. Exposure in weeks 8–17 and 15–22 of gestation increased the BMI z score and fat mass in boys at the age of 4 years. Studies in experimental animals also indicate specific differences. A study in rodents found significant sex-specific differences in weight gain after exposure to diesel exhaust in utero *(11)*.

Maternal health plays an important role in infant and child health and can modify the effects of environmental exposure. In a study of a cohort of children in the USA, maternal body mass before pregnancy and exposure to ambient $PM_{2.5}$ during pregnancy were measured. Children born to mothers with a high pre-pregnancy BMI and who were exposed to $PM_{2.5}$ during pregnancy and in the first 2 years of life had a higher risk of being overweight or obese between 2 and 9 years of age. In addition, children whose mothers were exposed to $PM_{2.5}$ at levels above the median were at higher risk of being overweight or obese, regardless of their mother's pre-pregnancy BMI *(12)*.

Although there have been few epidemiological studies on the link between exposure to air pollution and childhood obesity, seven studies were identified in a recent review in which an association was found between AAP and obesity and metabolic outcomes in children *(13)*. Two prospective birth cohort studies on air pollution and insulin resistance in children found positive associations between exposure to traffic-related NO_2 and PM_{10} and insulin resistance in 10-year-old children *(14)*. An increase in proximity to the nearest major road by 500 metres increased insulin resistance by 7.2%. Obese or overweight children are thus at increased risk for insulin resistance and other metabolic complications. Insulin resistance is associated with risks for type 2 diabetes and cardiovascular disease, which can have profound lifelong effects. In a 4-year longitudinal study, Jerrett et al. *(15)* investigated the relation between exposure to traffic-related air pollution and changes in BMI in children aged 5–11 years in 13 communities in southern California. NO_x levels were used as an indicator of traffic-related air pollution (which can contain black carbon, ultrafine particles and many PM components). Exposure had a significant effect on BMI growth and BMI level at the age of 10 years. The average annual rate of BMI growth was associated with exposure to NO_x in children with the highest exposure. In another longitudinal study in California *(16)*, children exposed to higher levels of NO_x from traffic-related air pollution had significantly increased BMI growth over 8 years and a higher attained BMI at 18 years of age as compared with the group with lower exposure.

In a cohort study in Italy *(17)*, no association was found between exposure to NO_2, NO_x, PM_{10}, $PM_{2.5}$, coarse PM or total traffic load within 100 metres of the residence and characteristics including BMI at the age of 4 years, cholesterol levels and waist circumference at 8 years of age.

Household air pollution

There has been no peer-reviewed publication on a link between sources of HAP and childhood overweight or obesity.

Biological mechanisms

While air pollution's relation to childhood obesity is a relatively new area of research, some studies have identified mechanisms by which air pollution may influence childhood obesity and metabolic dysfunction. Air pollution may influence metabolic development prenatally, as elevated levels of leptin and adiponectin were found in the umbilical cord blood of infants whose mothers were exposed to NO_2, $PM_{2.5}$ and NO during pregnancy *(18, 19)*, and these adipokines have been linked to obesity-related outcomes in childhood *(18)*. In another study, increased levels of leptin and adiponectin were associated with increased weight gain in infant girls at 6 months of age, suggesting a pathway for air pollution-mediated risk of obesity in children *(19)*.

The causes of metabolic dysfunction in childhood are complex. In a metabolic profiling study of overweight or obese young people aged 8–18 living in a highly polluted urban environment, air pollution was associated with higher insulin resistance and secretion and higher glycaemia *(20)*, indicating air pollution is a risk factor for type 2 diabetes. In another study, it was reported that children living in Mexico City, where the levels of air pollution (particularly $PM_{2.5}$ and O_3) are high, had altered appetite-regulating peptides, high blood leptin and endothelin-1 and vitamin D deficiency *(21)*. Even when the BMI-for-age of the children was below the cut-off for obesity, the analysis indicated potentially increased risks of insulin resistance, obesity, type 2 diabetes, addiction-like behaviour and premature cardiovascular disease in adulthood.

Box 9 provides information on stunting and air pollution.

Box 9. Air pollution and stunting

A child who has a low height-for-age is considered to be stunted. In 2012, WHO adopted a global target to reduce the number of stunted children under the age of 5 by 40% by 2025 *(22)*. In 2017, 150.8 million children under the age of 5 years were stunted *(5)*. Stunting has both immediate and long-term effects on health and well-being, as, in addition to poor physical growth, stunted children are more susceptible to infections and have an increased risk of neurodevelopmental effects, which can affect their school and work performance *(23)*. Children who are stunted often remain shorter than their peers in adulthood and are at increased risk of becoming overweight as they grow older. Stunted growth is due mainly to prolonged insufficient caloric intake or other nutritional deficiencies, but a link with exposure to air pollution has also been proposed in a growing body of literature on the association between AAP and stunting.

A study of maternal exposure to AAP in Bangladesh showed a strong link between AAP and child stunting *(24)*. The study was based on outcome data from four waves of the nationally representative Bangladesh Demographic and Health Survey, conducted between 2004 and 2014. Maternal exposure to AAP ($PM_{2.5}$) was estimated from high-resolution satellite data. Over half of all children in the study were exposed to an annual ambient $PM_{2.5}$ level > 46 µg/m^3, which is over four times the WHO air quality guideline value of 10 µg/m^3. These children were significantly more likely to be stunted. It was concluded that reducing AAP in Bangladesh could significantly reduce child stunting.

HAP is also strongly linked to stunting. A population-based cohort study of exposure to indoor biomass fuel and tobacco smoke and the risks of various adverse health outcomes in newborn infants in south India *(25)* found that infants exposed to HAP were at a 30% higher risk of being stunted at 6 months of age. The link between HAP and child stunting is further supported by the results of a systematic review and meta-analysis of the link between HAP and various adverse health outcomes, including stunting *(26)*. A statistically significant protective association was found between reduced exposure to HAP and stunting in children under 5 years. The authors suggested that switching from polluting to clean fuels could substantially reduce the risk of child stunting and other adverse health outcomes.

Conclusions

Some studies indicate a potential association between exposure to AAP and certain adverse metabolic outcomes in children. They support the plausibility of the "obesogen" hypothesis, which posits that exposure to chemical compounds during development can increase susceptibility to gaining weight, and also the links between childhood obesity, insulin resistance and exposure to air pollution. Because of the limited number of epidemiological studies of exposure to air pollution and obesity and insulin resistance, it would be premature to draw conclusions about causality.

Knowledge gaps and research needs

- A review of the literature suggests an association between exposure to AAP and childhood obesity or insulin resistance, but relatively little research has been done on the associations between childhood overweight and obesity, insulin resistance and air pollution.
- The effect of HAP on childhood overweight and obesity has not been studied, even though children spend a significant amount of time indoors.

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5.5 Respiratory effects

Lung function

Key findings:

- Elevated AAP, particularly traffic-related pollution, impairs lung function and lung function development in children, even at exposures below United States national ambient air quality standards.
- Prenatal exposure to air pollution is associated with impairment of lung development and lung function in childhood.
- There is evidence that lung function development improves in children in urban areas where ambient air quality has been improved.

Lung function is a measure of how effectively the lungs move air in and out of the body in order to exchange oxygen with the blood and remove CO_2. More simply, lung function indicates how well a person breathes. The lungs go through dramatic changes during the embryonic and fetal stages and continue to develop after birth, until late adolescence. Anything that affects the structure of children's still-maturing lungs can affect their lung function later in life. Children exposed to air pollution in utero or in early childhood are thus at risk of compromised lung function for the rest of their lives.

Ambient air pollution

Many studies have shown that exposure to air pollution has negative effects on lung function, although the effects vary. In the European Study of Cohorts for Air Pollution Effects (ESCAPE), Gehring et al. *(1)* found an association between $PM_{2.5}$ levels at the current address and a small decrease in lung function in children aged 6–8 years. A prospective cohort study of children in Taiwan showed that increased exposure to ambient $PM_{2.5}$ was associated with lower rates of development in some measures of lung function, including forced vital capacity (FVC) and forced expiration volume in 1s (FEV1) and with reduced development of FVC *(2)*. Reduced lung function was also seen in schoolchildren in Hong Kong who had long-term exposure to higher levels of AAP *(3)*. In four cities in China, Chongqing, Guangzhou, Lanzhou and Wuhan, exposure to ambient PM was associated with decreased development of lung function in children *(4)*.

The magnitude of the effects on lung function differs by study, perhaps because of spatial differences in the mass, number and composition of PM. In a study of five European birth cohorts, Eeftens et al. *(5)* found a more consistent association between increased PM mass and reduced lung function than with individual components of PM. They also found small adverse effects associated with exposure to nickel and sulfur in PM. Overall, these findings suggest that PM mass, rather than specific components, is more useful for assessing risks from exposure to air pollution to lung development and function in children.

Traffic-related pollution is a subject of widespread concern. NO_2 is commonly used as a reliable marker of traffic-related air pollution. In a meta-analysis of 13 studies, increased levels of NO_2 were associated with a higher prevalence of children with abnormal lung function (measured in terms of FEV1) *(6)*. In the Children's Health Study cohort, independent negative associations were found between regional and traffic-related air pollution and lung function *(7)*. These authors suggested that the differences in the strength of the associations reported among studies was due to differences in the exposure assessment methods used, which included roadway proximity, traffic count and density measures instead of validated methods.

Some studies reported adverse effects on lung function of pollution at levels below the national ambient air quality standards of the Environmental Protection Agency in the USA. In a study of the effect of relatively low exposure to pollution on childhood lung function *(8)*, 614 mother–child pairs in the Boston area were studied. Long-term exposure to AAP (fine particulate matter and black carbon) during pregnancy was associated with lower lung function in mid-childhood.

There is evidence that children with asthma are more vulnerable to the effects of air pollution. In some subgroups of asthmatic children, prenatal and early-life exposure to CO, PM_{10} and NO_2 had negative effects on pulmonary function *(9)*. A study of children with asthma in two cities in Canada *(10)* showed that exposure to air pollution was linked to elevated airway oxidative stress and reduced small airway function. In another study in North America *(11)*, exposure of children with asthma to air pollution had adverse effects on both lung function and methacholine responsiveness, which is a measure used to evaluate the degree of bronchial response to external stimulation.

Prenatal exposure to air pollution can impair organogenesis and lung growth, leading to long-term complications *(12)*. Newborns whose mothers were exposed to high levels of PM_{10} during pregnancy had increased minute ventilation and higher respiratory rate and tidal breathing flow *(13)*. Jedrychowski et al. *(14)* found that children aged 5 years whose mothers had been exposed to high levels of $PM_{2.5}$ during pregnancy had reduced FVC and FEV1. Morales and colleagues *(15)* reported lung function deficits in preschool-age Spanish children who had been exposed to traffic-related NO_2 and benzene during the second trimester of pregnancy.

In southern California, pollution levels have been decreasing steadily over the past several decades as a result of air pollution control policies, and there are indications these long-term reductions may improve the respiratory health of children. A study of lung function measured annually in 2120 children in three cohorts in three separate periods (1994–1998, 1997–2001 and 2007–2011) indicated an association between reduced exposure to NO_2, $PM_{2.5}$ and PM_{10} and improved lung function (measured as FEV1 and FVC) over 4 years *(16)*. The study also showed that the proportion of children with low FEV1 values decreased as air pollution levels fell. In a study of the same cohort *(17)*, children who moved from the study area to areas with higher air pollution had lower lung function growth at follow-up, and children who moved to areas with lower pollution had increased lung function growth.

Household air pollution

Fewer studies have been published on HAP and lung function or lung function development in children. A randomized controlled trial was performed in rural Guatemala in households with pregnant women or infants to measure the effects of an intervention to improve indoor air quality on childhood respiratory health *(18)*. Households in which cooking was traditionally done over an open fire were randomly selected to receive a chimney stove to improve ventilation of combustion products from cooking, at the beginning or at the end of the 18-month trial. At the end of the trial, children in houses that had received the chimney stove had significantly lower longitudinal peak expiratory flow growth and a large but non-significant decrease in FEV1 growth. Box 10 describes an intervention in Nigeria to improve the respiratory health of women and children by the introduction of improved cookstoves.

Box 10. Cleaner stoves, easier breaths *(19)*

In Nigeria, more than 70% of the population uses solid fuel stoves for cooking. Most household cooking is done by women, often in poorly ventilated kitchens. This results in high exposure of both women and children to HAP. A community-based pilot study was conducted in which low-emission stoves were substituted for traditional biomass stoves in three rural communities: Ajibade, Eruwa and Olorisaoko. Assessments were conducted before and 1 year after the intervention in households with a mother aged 20–60 years and one or more children aged 5–17 years. Before substitution of the stove, the $PM_{2.5}$ levels were found in several cases to be 60 times greater than the WHO standard, and almost half the mothers and children had diminished respiratory function. After the intervention, a remarkable decrease was found in the frequency of exposure-related respiratory symptoms, such as cough, chest tightness, difficulty in breathing and rhinitis, as well as headaches, fever and dizziness.

In cohorts of children in Chongqing, Guangzhou, Lanzhou and Wuhan, use of coal in houses without appropriate ventilation was associated with deficits in lung function growth *(20)*. The FVC and FEV1 of exposed children were 27% and 61%, respectively, below the average annual growth levels of the cohort.

In a small study of lung function in women and children aged 7–15 years in Ecuador, who were exposed to biomass fuel smoke in the home *(21)*, exposed children had reduced FVC and FEV1.

Biological mechanisms

Inhaled particles can be deposited in the bronchioles and the alveoli, where they may affect gas exchange *(22)*. Small particles, particularly $PM_{2.5}$, are of interest because their size allows them to penetrate deep into the lungs, where they cause irritation and induce oxidative stress and inflammation, damaging lung cells *(23)*. PM is a mixture of physical and chemical components (e.g. nitrates, sulfates, ammonium, PAHs, allergens, microbial compounds, metals) that can contribute to lung dysfunction *(22, 24)*.

Prenatal exposure to air pollution can alter lung function and development by various plausible mechanisms, by causing epigenetic changes in the fetus and negatively affecting the mother's respiratory health *(25)*. A prospective birth cohort study of children exposed prenatally to PAHs indicated that lung function was better when antihistamine medication was used *(26)*, which supports the theory that the mechanism of fetal PAH-induced alterations in lung function is initiated by the allergic inflammatory response to pollutants in the lungs.

Conclusion

There is robust evidence that exposure to air pollution damages children's lung function and impedes their lung function growth. Even at lower levels of exposure, children – whose lungs are still maturing and therefore especially vulnerable to pollution – can have lasting deficits in their lung function. There is also compelling evidence that policies and interventions to improve ambient or household air quality can lead to improvements in children's lung function. Compromised lung function negatively affects quality of life and is associated with long-lasting chronic conditions such as asthma and chronic obstructive pulmonary disease *(27–29)*.

Knowledge gaps and research needs

- Even at exposures to levels below local recommended guidelines, air pollutants significantly reduced children's lung function in some studies. More research is required to identify the levels of pollutants that adversely affect lung function in order to influence policies on air quality.
- More studies are required on the effect of HAP on childhood lung function.

Acute lower respiratory infections, including pneumonia

Key findings:

- Air pollutants such as $PM_{2.5}$, NO_2 and O_3 increase the risk of pneumonia and other respiratory infections in young children.
- Household use of biomass use increases the risk of acute lower respiratory infection, including pneumonia, in children.
- HAP is the leading cause of acute lower respiratory infection in children under 5 years.

Lower respiratory infections, including pneumonia, bronchitis, bronchiolitis and other acute respiratory diseases, are the second leading cause of child mortality worldwide. Lower respiratory infections caused 878 829 deaths in children under 5 years in 2016, accounting for 15.55% of all child deaths *(30, 31)*. HAP from cooking with solid fuels, AAP and second-hand tobacco smoke were the causes of 57% of the burden of disease (in DALYs) from lower respiratory infections in children under 5 years in 2012 *(32–34)*. HAP is the leading risk factor for lower respiratory infections in children in LMICs, and 13% of lower respiratory infections are attributable to HAP and AAP in HICs, where the levels of exposure are lower *(32)*.

Pneumonia is an acute respiratory infection caused by viruses, bacteria, fungi or chemicals and is characterized by inflammation of the air sacs of the lungs *(31, 35)*. While the major environmental risk factors for pneumonia in children are HAP, AAP and second-hand smoke *(35)*, different pollutants contribute to respiratory infections in various ways.

Ambient air pollution

Short-term exposure to AAP exacerbates acute respiratory infections. Nhung et al. *(36)* conducted a meta-analysis of 17 studies on the acute effects of AAP on childhood pneumonia and concluded that short-term increases in AAP are significantly associated with increased hospital admissions for pneumonia. Positive associations were found with PM_{10}, $PM_{2.5}$, SO_2, O_3 and NO_2 in studies conducted in many counties. Darrow and colleagues *(37)* investigated the association between short-term changes in ambient air pollutant concentrations and visits to emergency departments for respiratory infections. They found that exposure to air pollutants such as $PM_{2.5}$, NO_2 and O_3 exacerbates upper respiratory infections and pneumonia in children under 5 years.

Long-term exposure to AAP may also increase the risk for pneumonia in early life. In a meta-analysis of 10 European birth cohorts, MacIntyre et al. *(38)* found an association between long-term exposure to traffic-related air pollution and the incidence of pneumonia. Vehicle traffic is one of the main sources of exposure to AAP. Rice et al. *(39)* examined the association between prenatal exposure to traffic-related air pollution in Boston, USA, and the risk of respiratory infection (including pneumonia, bronchiolitis and croup) in early life. Reduced distance from roadways and higher traffic density were correlated with a higher risk of respiratory infection, suggesting that living close to a major road during pregnancy heightens the risk for respiratory infections in early life.

There is increasing evidence that exposure to PM plays a significant role in acute respiratory infections. Jedrychowski et al. *(40)* assessed the effect of prenatal exposure to $PM_{2.5}$ on the occurrence of acute bronchitis and pneumonia between birth and 7 years and found that the incidence of recurrent pulmonary infections was significantly correlated with prenatal $PM_{2.5}$ exposure in a dose-dependent manner. Fuertes et al. *(41)* combined the results for seven birth cohorts to investigate the effects of various components of PM on the development of pneumonia in early childhood. All the components (iron, potassium, copper, nickel, sulfur, silicon, vanadium) except zinc from PM_{10} were associated with a higher risk of pneumonia in early life.

Household air pollution

HAP is not only the largest environmental health risk factor worldwide but is also the leading cause of acute lower respiratory infection, particularly pneumonia, in children *(42)*. Systematic reviews show consistent evidence of an association between exposure to HAP and ALRI, especially pneumonia, in children. A meta-analysis of published observational studies showed that the rate of ALRI in young children exposed to smoke from household biomass fuel was twice that of children who were not exposed or who lived in households in which cleaner fuels were used *(43)*. Bruce and colleagues *(44, 45)* reviewed 26 studies on non-fatal, severe and fatal ALRI and found an association with exposure to HAP.

Other systematic reviews have reported higher risks associated with exposure to solid fuel emissions. These include a comparative risk assessment by Smith et al. *(46)*, a meta-analysis of 10 studies by Misra et al. *(47)* and a review of six studies of deaths among children with ALRI in LMICs by Sonego et al. *(48)*. In a study of acute respiratory infection and ALRI, Po and colleagues *(49)* reported a strong association with exposure to solid biofuel in rural children. Although many reviews noted that the heterogeneity of the studies included was a limitation, the consistency of the findings suggests an association. Box 11 describes a randomized controlled trial on a clean cookstove intervention in Guatemala.

A systematic review prepared for the 2014 WHO guidelines for indoor air quality associated with household fuel combustion *(31)* concluded that there is substantial evidence that solid-fuel HAP increases the risk of ALRI and that the risk of severe and fatal ALRI may be more than doubled. The authors concluded, however, there is relatively limited evidence on the mechanisms by which HAP causes pneumonia in children.

Box 11. Breathing lessons: a randomized control trial in Guatemala yields insights on clean cooking and children's health

The RESPIRE study, the first randomized controlled trial on the health effects of cooking interventions, was conducted in the rural highlands of San Marcos in Guatemala between October 2002 and December 2004. The region's inhabitants typically used open wood fires for cooking and heating, resulting in long-term exposure to HAP, particularly for women and children. The aim of the study was to determine whether reducing smoke from a *plancha* chimney stove would reduce the risk of pneumonia in children < 18 months of age. After visiting more than 5000 households, those in which there was a pregnant woman or children under 4 months of age were selected for the trial. The intervention consisted of providing some households with a closed chimney *plancha*. Levels of CO in the home were monitored, and the children were followed for 18 months at periodic visits by field workers and underwent medical examinations, which included monitoring of hypoxaemia and chest X-rays if pneumonia was diagnosed. The researchers found a 33% reduction in diagnosed cases of severe pneumonia in children living in households with the improved stoves, suggesting that exposure to pollution from household fuel combustion plays a role in the pathogenesis of pneumonia and that substitution of clean fuels and devices for cooking and heating may reduce the incidence of pneumonia in children *(50)*.

Several studies in the same cohort were performed in parallel. One found that exposure in utero to smoke from open wood stoves increased the risk of adverse neurodevelopment outcomes over that of children in households with a stove that had an enclosed combustion chamber, such as a *plancha (51)*. Another found a lower incidence of children born with low birth weight to mothers living in households with a *plancha (52)*.

Biological mechanisms

Pollutants contribute to respiratory infections by several mechanisms. Inhaled PM can damage the normal defence mechanisms of the respiratory tract by causing inflammation and oxidative stress, and breathing NO_2, which is a free radical, can also damage and inflame the respiratory tract. There is some evidence that combustion-derived PM interferes with alveolar macrophages, which have an essential role in the response of the immune system to viruses and bacterial infections, therefore increasing the susceptibility of individuals to infections. Laboratory analysis of human macrophages exposed to HAP showed impaired ability to phagocytose *Streptococcus pneumoniae* and

Mycobacterium tuberculosis and a lower oxidative burst capacity, suggesting reduced host defence against infection *(53)*. Box 12 discusses the association between air pollution and TB.

A laboratory study showed that exposure to black carbon alters the biofilm structure, composition and function of *Staphylococcus aureus* and *Streptococcus pneumoniae* and their tolerance to proteolytic degradation and response to antibiotics *(54)*. Furthermore, black carbon caused *S. pneumoniae* to spread from the nasopharynx to the lungs in an animal model. These results have important implications for the pathways by which air pollution may cause lung infections in children.

Box 12. Air pollution and tuberculosis

TB is an infectious disease caused by *Mycobacterium tuberculosis*. It affects mainly the lungs but can also spread to other body systems. It is transmitted from person to person through the air. Disease progression may be influenced by environmental factors, and air pollution has been identified as a potential risk factor for active TB in adults in several studies. There is a growing scientific evidence that both AAP and HAP are associated with TB in children, but no systematic reviews specifically on studies in children have been published, and the risk of childhood TB associated with exposure to AAP has not yet been evaluated. An ecological study conducted in North Carolina, USA, showed a significant association between pulmonary TB and long-term exposure to PM. Children and adolescents aged 0–24 years were included in the study, but their risk was not independently assessed *(55)*. Another study in adults in California, USA, also found a relation between residential exposure to $PM_{2.5}$ and the presence of smear-positive acid-fast bacilli *(56)*.

The association between exposure to HAP from solid fuel combustion and TB has been evaluated in a few studies. Exposure to biomass fuel combustion exhaust was found to prevent macrophages in the lung from functioning correctly *(57)*. As macrophages have a key role in the immune response to infection, these changes may increase the vulnerability of individuals to TB and other respiratory infections *(58)*. A meta-analysis of studies in children and adults performed in 2014 *(59)* showed a relation between HAP from solid fuel combustion and the risk of TB. Two of the studies included in the review were specifically of children, and both found positive but nonsignificant associations. A case–control study in India showed a correlation between exposure to HAP from solid fuel combustion and the risk of contracting TB in children < 5 years *(60)*. The evidence suggests a positive association between exposure to air pollution and TB infection in children, although further research is needed.

Conclusions

Many studies offer consistent, compelling evidence that exposure to AAP or HAP is a major risk factor for ALRI in children. It is clear that exposure to air pollution increases the incidence of ALRI, including pneumonia. While a range of pollutants has been found to exacerbate respiratory infections, there is growing evidence that PM has an especially strong effect.

Knowledge gaps and research needs

- There is a lack of studies on associations between exposure to specific chemical components of ambient particulate matter and ALRI such as pneumonia in young children.
- Research on the mechanisms through which air pollution induces lung infection will aid in identification of treatments and preventive measures to protect children from serious, life-threatening illness.

Asthma

Key findings:

- There is evidence of a causal relationship between exposure to AAP and the development and exacerbation of childhood asthma.
- There is suggestive evidence of a causal effect of exposure to HAP and the development and exacerbation of asthma in children.

Asthma affects an estimated 250 million people worldwide and is a common chronic illness in children *(61)*. Both AAP and HAP have long been suspected of contributing to childhood asthma, and a growing body of research suggests that exposure to air pollution both causes and exacerbates the condition. As children have narrower airways and higher breathing rates than adults, they are particularly vulnerable to airborne pollution. Furthermore, children tend to spend much time doing physical activity outdoors and breathe through their mouths more frequently than adults, allowing more unfiltered air pollutants to affect their still-developing lungs.

Asthma development

Ambient air pollution

In a meta-analysis of 19 studies conducted between 1996 and 2012, Gasana et al. *(62)* observed a positive association between exposure to NO_2 and the incidence of asthma and between exposure to PM and higher incidence of wheeze in children. In addition, they found a higher prevalence of wheeze in children exposed to SO_2 and a higher prevalence of asthma associated with exposure to NO_2, nitrous oxide and CO. A systematic review and meta-analysis by Khreis and colleagues *(63)* of 41 studies indicated significant associations between increased exposure to $PM_{2.5}$, PM_{10}, NO_2 and black carbon and the risk of asthma.

The longitudinal association between early childhood exposure to AAP and future asthma incidence has been evaluated in several cohort studies. In a meta-analysis of published birth cohort studies, Bowatte et al. *(64)* reported significant associations between long-term exposure to black carbon and $PM_{2.5}$ and the risk of asthma in childhood. They also reported an association between exposure to traffic-related air pollution in early childhood and a higher risk of developing asthma up to 12 years of age. Gehring et al. *(65)* evaluated the longitudinal association between prenatal exposure to air pollution and development of asthma throughout childhood and adolescence in four prospective birth cohort studies in Europe. They found that increased exposure to NO_2 and $PM_{2.5}$ at the birth address was associated with an increased risk for asthma throughout childhood and adolescence. Sbihi et al. *(66)* analysed a population-based birth cohort of 65,254 children in Vancouver, Canada, and found positive association between perinatal exposure to air pollution and asthma incidence during pre-school years.

Two systematic reviews reached similar conclusions on the role of long-term exposure to AAP in asthma development, further strengthening evidence of an association. A systematic review of 18 studies *(67)* found evidence of a significant link between prenatal exposure to NO_2, SO_2 and PM_{10} and the development of asthma. The authors found insufficient evidence that exposure to black carbon, CO or O_3 during pregnancy was associated with asthma in childhood. Andersen and colleagues *(68)* reviewed 17 cohort studies and found that 12 showed positive associations between exposure to air pollution and the incidence of asthma.

Household air pollution

Several studies found positive associations between indoor cooking with polluting fuels and asthma development in children. In a meta-analysis of 41 studies published before 2013, Lin et al. *(69)* found a positive association between gas cooking, exposure to NO_2 and childhood asthma or wheeze. In a study of over 512 000 children in primary and secondary schools in 47 countries, Wong et al. *(70)* found a link between cooking on an open fire and the risk of reported asthma in both boys and girls. Studies in India *(71)* and Nepal *(72)* also found statistically significant increases in the risk of asthma with indoor use of biomass fuel stoves, especially in the absence of appropriate ventilation. In contrast, a study in Malaysia found no association between exposure to household wood stoves and a first hospitalization for asthma of children aged 1 month to 5 years *(73)*. The authors also found no association with other factors, such as use of kerosene stoves, aerosol mosquito repellent or crowding.

Asthma exacerbation

Ambient air pollution

Numerous studies have found that exposure to PM_1, $PM_{2.5}$ and PM_{10} exacerbates asthma, aggravating the symptoms of wheeze and shortness of breath *(74, 75)*. A meta-analysis of 26 studies conducted in Australia, Canada, China, Denmark, Finland, Turkey and the USA *(76)* found a 4.8% increase in the risk of asthma-associated emergency department visits and admissions among children exposed to short-term increases in $PM_{2.5}$ of 10 μg/m^3. The effect was greater in studies conducted in Europe and North America than in Asia. Other meta-analyses have found similar results. A review revealed a 3.6% increase in risk of emergency visits and admissions for asthma of children per 10 μg/m^3 increase in ambient $PM_{2.5}$ *(77)*. Zheng and colleagues *(78)* also reported associations between exposure to $PM_{2.5}$, O_3, CO, NO_2, SO_2 and PM_{10}, and hospital admissions in 50 studies of children. Meta-analyses by Weinmayr and colleagues *(79)* showed associations with PM_{10}, and Orellano and colleagues *(80)* found associations with NO_2, SO_2 and $PM_{2.5}$.

Zhang et al. *(81)* conducted a meta-analysis of 26 studies conducted in the East Asian region and found associations between exposure to ambient NO_2, SO_2, CO, and PM_{10} and asthma-related use of general and emergency hospitals. The association between exposure to air pollution and asthma morbidity was generally stronger in children < 15 years than in other age groups. The results of studies in southern California, USA, where the levels of air pollution have been decreasing for several decades as a result of air pollution controls, show that decreases in AAP levels were associated with statistically significant decreases in bronchitic symptoms among children with asthma *(82)*. These meta-analyses together provide compelling evidence that exposure to a range of ambient air pollutants places children at higher risk of asthma-related hospitalization.

Box 13. Case study: Identifying AAP as a trigger for asthma exacerbation[3]

Megan, a 9-year-old living in Alberta, Canada, was diagnosed with asthma 5 years ago. Since then, her symptoms have been well controlled by a common treatment: inhaled steroids combined with a long-acting beta agonist, and a short-acting beta agonist as needed. In the past 2 weeks, however, she had had several episodes of breathlessness while training outside with the school track team, which she joined recently. On days spent at home, her symptoms diminished. She had no allergies, and spring had not yet arrived in the region. Her home was in a quiet suburban neighbourhood, with no highways or industrial areas nearby, and close to a park. Her parents didn’t smoke or keep pets, and the home did not have a solid-fuel stove.

Her school, however, was on a busy street. Drivers often left their engines running while picking up or dropping off passengers. The school playground was regularly sprayed with herbicides. Her paediatrician concluded that the exacerbation of her asthma was probably related to her exposure to herbicides in the school playground and to AAP from motor vehicles. The paediatrician recommended that the family check the Air Quality Health Index, Canada’s local air quality monitoring system, daily basis before Megan participated in outdoor activities. The doctor also advised that Megan be given an extra dose of her regular asthma medication before she engaged in sports. The school principal was notified and decided to implement a “no-idling” policy for vehicles. Parents advocated to stop herbicide being sprayed in the playground and discussed with teachers the possibility of training inside on days when AAP levels were higher than recommended for outdoor activities.

Asthma is a multifaceted condition. In Megan’s case, the exacerbation appeared to be related to poor air quality due to heavy traffic, use of herbicides and idling of vehicles near the training area. After a few weeks of alternating indoor–outdoor training when pollution levels were high, cessation of herbicide use and the no-idling policy, Megan’s episodes of breathlessness diminished, and her extra treatment for asthma was no longer necessary.

Household air pollution

Although the relation between exposure to AAP and exacerbation of childhood asthma has been well documented, there is less evidence on exposure to HAP from incomplete combustion of polluting fuels. The review for the WHO guidelines for indoor air quality associated with household fuel combustion *(31)* concluded that there is suggestive evidence for a causal effect of exposure to HAP and exacerbation of asthma in children. A cross-sectional study in rural Nigeria of 1690 school-age children *(19)* found that living in a household in which biomass fuel was used for cooking increased

[3] Presented at Workshop 6: Protect the children! What you can do to prevent environmental hazards from harming children. 28th International Congress of Pediatrics, 17–22 August 2016, Vancouver, Canada.

the risk of severe asthma symptoms. Schei and colleagues *(83)* concluded that use of open fires increased the risk of asthma symptoms in children aged 4–6 years living in an indigenous Maya community in Guatemala.

Box 14 describes a community activity for managing asthma in children.

Biological mechanisms

Many pathways have been studied through which air pollution may contribute to childhood asthma. Inflammation and oxidative stress are known harmful effects of air pollution. In a study of children with asthma living in a highly polluted environment, elevated levels of SO_2, NO_2 and benzene were associated with increased bronchial inflammation and biological markers of oxidative damage and asthma symptoms *(84)*. Research also indicates that epigenetic modification of DNA plays a role in the association between childhood asthma and air pollution *(85)*. The patterns of DNA methylation that contributes to lung damage in children with asthma in response to air pollution have been identified *(86)*, and another study indicated that DNA methylation associated with prenatal exposure to PAHs may contribute to the development of childhood asthma by altering gene expression early in life *(84)*, but more research is needed.

Box 14. "**You can control asthma now**".

An award-winning initiative demonstrates effective community engagement in managing asthma in children, at the Children's Hospital of Richmond, at Virginia Commonwealth University in the USA *(84)*. The hospital formulated a promising programme called "You can control asthma now" in response to the disproportionately high burden of disease attributed to asthma, compounded by poverty, in its region.

When a child is first diagnosed with asthma, the family is directed to the unit by their general practitioner or the emergency room. The unit is staffed by a pulmonologist, a nurse and social workers, who use a multidisciplinary approach for clinical assessments, education and providing support and resources to address barriers to treatment. Practitioners follow up families over the long term by text or phone communications. The home environment is assessed by the City of Richmond Health District, and families can be referred to a medical legal partnership programme to help them resolve any environmental problems in the home that might affect their child's asthma. The programme offers extensive practical information to families on the effect of environmental exposures on childhood asthma and how to make changes.

Since 2015, the programme has assisted more than 344 patients with family-focused management techniques. The programme has also made the region's health care system more cost-effective, saving US$ 691 per patient by fewer hospitalizations and emergency room visits, which adds up to a total cost reduction of US$ 163 958 since the programme began. The initiative was awarded the "Asthma award" of the Environmental Protection Agency in 2017 in recognition of a successful asthma management intervention that is integrated into health care services. The programme shows that, through collaboration and engagement with the community and the development of specific resources, families can reduce environmental exposures to protect the health of children.

Conclusion

The relation between air pollution and childhood asthma is clear. Many studies provide consistent, robust evidence of an association between exposure to air pollution and the risk of developing asthma in childhood. There is also ample evidence that breathing pollutants exacerbates asthma in children. Although the mechanisms are not as well understood, long-term exposure to PM and other pollutants can increase the probability that a child will develop asthma, with serious long-term implications for health and quality of life. While there are fewer studies on HAP, they provide sufficient evidence to support proactive approaches to limit children's exposure to both AAP and HAP to protect them from developing and exacerbating asthma.

Knowledge gaps and research needs

- Various epidemiological studies support the conclusion that AAP and traffic-related air pollution are related to exacerbation and development of asthma in children. The vulnerable period of exposure for childhood asthma remains to be defined, and more long-term birth cohort studies with regular, repeated follow-up are needed.

- Although there is suggestive evidence of an effect of exposure to HAP on asthma development and exacerbation, additional studies with consistent methods and exposure assessment and intervention studies are necessary to confirm a causal relation.

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5.6 Otitis media

Key findings:

- An increasing number of epidemiological studies indicate an association between exposure to AAP and the occurrence of otitis media in children.
- HAP from combustion may increase the risk of otitis media.

Otitis media, inflammation of the middle ear, is a common childhood infection *(1)*. Viral and bacterial ear infections are the primary causes of otitis media, which often occurs with upper respiratory tract infections *(2)*. Environmental exposures also play a role. Exposure to second-hand tobacco smoke is a known risk factor *(3, 4)*, and evidence suggests that exposure to AAP and HAP may have a similar effect on the development of otitis media. A child with recurrent otitis media can have long-term consequences, such as hearing loss, and potential difficulties in learning and communication *(5, 6)*.

Ambient air pollution

AAP has been strongly linked to otitis media in children. A review *(2)* of five cross-sectional, two time-series and three cohort studies found a higher prevalence of otitis media in children living in areas with high levels of AAP *(7–10)*. Traffic-related air pollution was associated with risk for otitis media *(2)* and with higher risks for ear, nose and throat infections *(11)*. In a study of over 7000 children in Germany *(12)*, the prevalence of otitis media decreased over a 7-year period in areas in which air quality improved. Strong conclusions could not be drawn from the review because of the limited number of studies.

A systematic review of 24 studies *(1)* found limited but increasing evidence of a link between exposure to AAP and otitis media in children. All the studies found evidence of a positive association with AAP, but the results were inconsistent for most pollutants, except NO_2.

Other studies have reported a higher incidence of otitis media among children exposed to air pollutants, especially NO_2 and $PM_{2.5}$. Brauer et al. *(13)* observed an association between exposure to traffic-related air pollutants (NO_2, $PM_{2.5}$ and elemental carbon) and the incidence of otitis media in the first 2 years of life in two large birth cohorts in Germany and the Netherlands. Zemak and colleagues *(3)* analysed emergency department visits by children aged 1–3 years for otitis media over 10 years in Canada and found an association with exposure to CO and NO_2. In another study in Canada *(14)*, 42,413 children born in British Columbia were followed until 2 years of age. The authors found that the average levels of exposure to pollutants (NO, CO, $PM_{2.5}$ and wood smoke) in their residence 2 months before hospital visits were associated with the occurrence of otitis media. In a study in Spain, Aguilera et al. *(15)* reported a significant association between otitis media in early childhood and exposure to NO_2 and benzene during pregnancy. A meta-analysis of 10 European birth cohort studies of the effects of traffic-related air pollution (NO_2, NO_x, $PM_{2.5}$, PM_{10} and $PM_{2.5\text{-}10}$) on otitis media *(16)* showed an association with the annual average ambient NO_2 concentration during the first year of life.

Time-series and case-crossover studies have also reported positive associations between exposure to AAP and visits to an emergency department for otitis media. In an analysis of 4815 such visits by children aged < 3 years in Ontario, Canada *(17)*, the number of visits increased in the days after an increase in the ambient levels of O_3 and PM. A study of 422 268 emergency department visits for otitis media between 2002 and 2008 in Georgia, USA, found associations with exposure to CO, NO_2, O_3, PM_{10}, $PM_{2.5}$, element carbon, organic carbon ammonium and SO_4^{2-} *(18)*.

The evidence indicates a consistent association between exposure to air pollution and otitis media.

Household air pollution

An association between parental tobacco smoking and otitis media in young children has been well documented *(4, 19–21)*; however, few studies have been conducted on the associations with other sources of HAP, particularly in low-income countries *(20)*.

A systematic review of risk factors for chronic and recurrent otitis media *(20)* identified only one study on HAP *(22)*, in which indoor cooking was associated with chronic suppurative otitis media. Older studies in high-income countries gave inconsistent results. In a case–control study of 125 otitis media patients and 237 controls in a private paediatric practice in New York, USA, between October 1986 and May 1987, exposure to a wood-burning stove was associated with otitis media *(23)*. A study of more than 900 infants in two states in the USA *(24)* found no significant association between otitis media and secondary heating sources (fireplace, wood stove, kerosene heater and air conditioning).

Among the few studies from LMICs is a case–control study in Maputo, Mozambique *(25)*, which showed an association between use of wood and charcoal as household fuels and the occurrence of otitis media. A study of 189 children living in urban areas in two Nigerian states *(26)* indicated that indoor cooking was significantly associated with the occurrence of chronic suppurative otitis media; however, the type of fuel used was not specified.

Multiple sources of exposure

It is important to consider the timing of exposure to household and ambient air pollutants. Deng et al. *(26)* conducted a retrospective cohort study of 1617 children aged 3–4 years in Changsha, China. The lifetime prevalence of otitis media in preschool children was associated with prenatal exposure to an industrial air pollutant (SO_2) and postnatal exposure to indoor renovations. Both AAP from industrial activities and HAP from renovations were associated with development of early childhood ear infection.

Biological mechanisms

The biological pathways through which air pollution contributes to otitis media in children are not clear. Epithelial cells of the middle ear had significantly altered gene expression in response to exposure to PM *(27)*, and the authors noted that some of the genes affected are involved in cellular processes, including generation of reactive oxygen species, apoptosis, cell proliferation, cell differentiation and inflammatory response. These may therefore be triggered by exposure to PM.

In another study, increased mucin gene expression (which can contribute to chronic infection), decreased cell viability and an increased inflammatory response were observed as a result of exposure to diesel exhaust particles *(28)*. These findings were supported by the results of a study in experimental animals. Further research will help to confirm whether these processes play a role in the development of otitis media in children.

Conclusions

There is consistent evidence of an association between exposure to AAP and otitis media in children. The findings on the effects of individual pollutants are not consistent, and few studies of HAP are available.

Knowledge gaps and research needs

- Prospective observational epidemiological studies on the association between AAP exposure and otitis media occurrence should be undertaken.
- Evidence from studies of HAP is limited. As infants and children spend much of their time in the home, more studies should be conducted, with detailed measurements of HAP.
- Studies on the mechanisms by which air pollution contributes to the development of otitis media in children should be undertaken.

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5.7 Cancer

Key findings:

- There is substantial evidence that exposure to traffic-related air pollution is associated with childhood leukaemia.
- Several studies have found associations between prenatal exposure to AAP and higher risks of retinoblastoma and leukaemia in children.
- Relatively few studies have been conducted on HAP and cancer risk in children. Nevertheless, HAP is strongly associated with several types of cancer in adults and commonly contains a variety of classified carcinogens.

The incidence of cancer in children is increasing, as shown by data from 68 countries and over 100 population-based registries published by the International Agency for Research on Cancer (IARC) *(1)*. In the period 1990–2017, an average of 215 000 cases of cancers per year were diagnosed in children under 15 years of age, and 85 000 new cases were diagnosed among those aged 15–19 years *(1)*. In view of the lack of cancer registries in several low-income countries, however, these statistics may be underestimates of the actual incidence *(2)*.

The most prevalent types of cancer are different in children and adults *(3)*. Leukaemia and lymphoma are the most common in children, accounting for almost half of all childhood cancers, followed by central nervous system tumours and tumours originating in embryonic tissues, such as neuroblastoma, retinoblastoma and nephroblastoma. Children also develop carcinomas, but the incidence is low *(2)*.

Ambient air pollution

Children are exposed to a wide range of cancer-causing pollutants in ambient air. Diesel exhaust, AAP and particulate matter have been classified by working groups convened by IARC as Group 1 carcinogens. Nitroarenes, which are derived from diesel engine emissions, have been classified as Group 2 carcinogens, and gasoline exhaust has been classified as a Group 2B carcinogen (possibly carcinogenic to humans) *(4)*. Traffic exhaust also contains harmful contaminants, such as CO, PAHs, benzene, NO_x and PM *(5)*. Benzene has been classified in Group 1 (carcinogenic to humans) *(5,6)*.

Leukaemia is the most frequent childhood cancer *(2)*. Although the etiology of at least 90% of cases of leukaemia remains unknown in *(7)*, many studies have shown that exposure to traffic-related pollution (including diesel and gasoline exhaust) is associated with childhood leukaemia *(4, 8, 9)*. A meta-analysis indicated that the development of leukaemia in early childhood is associated with exposure to traffic during the postnatal period, with a risk increased by 1.5 times *(9)*. In addition, exposure to PM_{10} was independently associated with the risk for leukaemia. In a meta-analysis on the role of benzene in the pathogenesis of childhood leukaemia, traffic-related exposure to benzene increased the risk for acute myeloid leukaemia by a factor of 2.07 and the risk for acute lymphoblastic leukaemia by 1.49 *(10)*.

The relation between proximity to highways, urban AAP and childhood cancer has also been assessed. A study in a nationwide cohort in Switzerland found that the risk for leukaemia of children who lived < 100 M from a highway was 1.43 times greater than that of children who lived > 500 M away, especially for those < 5 years of age *(11)*. Box 14 illustrates differences in childhood cancer risk according to residence.

Box 14. Location matters: variations in air pollution and childhood cancer risk in a city in Turkey

A study in Turkey was conducted to assess the relation between exposure to benzene, toluene, ethyl benzene, xylenes, NO_2 and O_3 and childhood cancer risk in two areas of the city of Eskisehir *(12)*. Students at two schools participated: one in an urban area known to have high levels of air pollutants and one in a suburban location with lower levels of pollution. Benzene, toluene, ethyl benzene and xylenes are volatile organic compounds considered to be hazardous air pollutants; benzene is a Group 1 human carcinogen *(5)*.

Personal air sampling and indoor (school and home) and outdoor air sampling was conducted over a 24-h period. Children who lived in smoking and in non-smoking homes were identified. An activity diary was given to each child, with a questionnaire on socioeconomic status, family activities and house characteristics (e.g. floor type, renovations). Potential sources of pollutants at residences and schools were identified from a checklist. Personal, exposure to indoor and outdoor concentrations of all air pollutants except O_3 was higher for children in the urban school than at the suburban site. Personal concentrations were also strongly correlated with indoor concentrations (except for O_3). The responses to the questionnaire indicated that interactions with tobacco smoke, solvent-based products and proximity to petrol stations increased exposure to pollutants. The authors found a higher risk of cancer in the urban school group, particularly for children whose parents smoked, than in children in the suburban location.

The risk assessment in this study focused on chronic exposure to pollutants rather than acute toxic effects. The findings show that levels of pollution can differ significantly in different parts of a city, as can the health effects of ambient and indoor exposure on children in different areas.

A number of studies on prenatal exposure to air pollutants indicate associations with cancer. A study in California, USA, of more than 3000 children with various types of cancer *(13)* found a clear relation between exposure to traffic pollution during gestation and the first year of life and the risk of cancer by the age of 6 years, not only for acute lymphoblastic leukaemia but also for germ-cell tumours and retinoblastoma. A study in Texas, USA, indicated an increased risk of embryonal tumours in children whose mothers lived < 500 M from a major roadway during pregnancy *(14)*. The strongest association was found with retinoblastoma, the risk for which was increased 2.57 times. In a study of more than two million children followed-up from birth to 4 years of age in Canada *(15)*, prenatal exposure to AAP, particularly during the first trimester of pregnancy, was associated with increased risks of astrocytoma and acute lymphatic leukaemia. In another study in California, USA

(16), each 25 parts per billion increase in average maternal exposure to NO_x during pregnancy increased the risk for leukaemia in their offspring by 23%. Bilateral retinoblastoma was associated with exposure to NO_x during the second and third trimesters of pregnancy. Exposure to PAHs during pregnancy was associated with a 1.44-times increase in risk of medulloblastoma in early childhood *(17)*.

The exposures of both parents must be taken into account in assessing the risk of childhood cancer, in addition to exposure in utero *(4)*. In a case–control study in Australia *(18)*, both maternal exposure during pregnancy and paternal pre-birth occupational exposure to diesel and petrol exhaust were associated with an increased risk of acute childhood lymphoblastic leukaemia. A study in the United Kingdom found a small but statistically significant increased risk of leukaemia in children whose fathers were occupationally exposed to vehicle exhaust fumes and particulate hydrocarbons around the time of conception *(19)*.

Household air pollution

Emissions from household combustion of coal have been classified by IARC as a Group 1 carcinogen *(20)*, emissions from household combustion of biomass fuel, in particular wood, are probably carcinogenic, and the combustion of wood and other biomass fuels can produce toxicants including CO, PAHs, aldehydes and free radicals that are classified as Group 2A carcinogens (probably carcinogenic to humans). Metal compounds present in solid fuel emissions, such as arsenic and nickel, have also been classified as Group 1 carcinogens *(21)*. In some rural areas of China, up to the 60% of the population under 30 years of age are exposed to arsenic from household coal combustion, which may account for the higher incidence of cancer in these populations *(22)*.

HAP has been strongly associated with several types of cancer in adults, including lung cancer, upper aerodigestive tract cancer, kidney and cervical cancer *(20, 23–27)*, but few studies have been conducted on HAP and cancer risk in children. A study in Australia *(28)* found increased risks of childhood leukaemia by 1.41 times in association with use of a wood burner to heat the home during pregnancy and by 1.25 times when used after birth. A case–control study in California, USA, provided evidence of an association between lung cancer and exposure to coal-burning during childhood and adolescence *(29)*. Given the susceptibility of children, the known cancer risks of adults and the longer time available for cancer to develop in children, further research should be conducted on the risk of cancer associated with exposure to HAP during childhood.

Biological mechanisms

The pathogenesis of childhood cancer is complex, as it involves many genetic and environmental factors. In most cases, the primary causes remain unknown, although most of the scientific literature suggests that the immune system plays a role. A prominent hypothesis is that faulty functioning of the immune system in response to infections and allergies is the primary cause *(8)*, and this is supported by some studies that suggest that environmental exposure to certain chemicals and pollutants that are known to alter the immune system can lead to this aberrant response and, therefore, to the outcome of leukaemia *(30)*.

It has also been proposed that air pollutants contribute to carcinogenesis by damaging DNA. Particulate matter contains several genotoxic and mutagenic chemicals that cause single-strand breaks, micronuclei, sister chromatid exchange and oxidative DNA damage mediated by reactive oxygen species *(31)*. DNA adducts and micronuclei have been identified in the cord blood of women exposed to air pollution during pregnancy; these are important biomarkers of DNA damage that can result in mutations leading to cancer *(32)*. Furthermore, several studies have found that certain genes in xenobiotics pathways (e.g. *CYP2E1*, *GSTM1*, *NQO1*, *NAT2* and *MDR1*) increase the risk of leukaemia by themselves or in association with exposure to chemicals *(33)*.

Conclusion

The rising rate of cancer in children worldwide is deeply concerning. There is ample evidence that both prenatal and childhood exposure to AAP is associated with increased risk of leukaemia and other cancers. There is robust evidence of an increased risk for cancer in adults exposed to HAP, but few studies have examined the association between HAP and childhood cancers.

Knowledge gaps and research needs

- Few studies have been conducted on the association between exposure to HAP from polluting fuels and childhood cancers.

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5.8 Later health outcomes

Key findings:

- Exposure to air pollution early in life can impair lung development, reduce lung function and raise the risk of chronic lung disease in adulthood.
- Evidence suggests that exposure to air pollution during pregnancy can predispose the offspring to cardiovascular disease later in life.

The life course of children can be significantly affected by exposure to toxic air pollutants. Children who are exposed to air pollution during the prenatal period and early life are more likely to experience adverse health outcomes as they mature and throughout adulthood. Exposure not only has a direct impact on children's health and development but can also stimulate latent diseases to become evident only in later life. Air pollution can contribute to effects on all of the organs and systems of the human body. Children's physiological vulnerability and susceptibility to pollutants and the delayed emergence of certain adverse effects are an area of growing scientific interest. Several recent studies have addressed these factors and associated diseases.

Impairment of lung growth and development in childhood is an important risk factor for chronic lung disease in adulthood. A study of two European cohorts (n=12 862, age 28–73 years) *(1)* showed that exposure in early life was significantly associated with decreased FEV1 in adulthood, and the estimates were almost as large as those for personal smoking. In a study of a Swedish cohort, 2278 children were followed up *(2)*. It was found that exposure to traffic-related air pollution in infancy is associated with a lower FEV1 at the age of 16 years. Factors in early life predicted decreased lung function decades later, suggesting that some mechanisms related to lung ageing may be established in childhood or in utero.

One of the common outcomes of impaired lung function is chronic obstructive pulmonary disease, and the link between HAP and development of this disease has been addressed. A meta-analysis found that people with long-term exposure to HAP from solid fuel combustion had twice the risk of chronic obstructive pulmonary disease *(3)*. Exposure to AAP and HAP also plays a role in the development of lung cancer, as emissions from the combustion of solid fuels in the home and traffic-related pollution both contain well-known carcinogens *(4)*.

Exposure to high levels of air pollutants during pregnancy can predispose to cardiovascular diseases later in life. Exposure to pollution as the fetal organs develop during pregnancy can trigger susceptibility to weight gain and neuroinflammation in adulthood *(5, 6)*. Early exposure to air pollutants has also been associated with early cardiovascular phenotypes in young adults. Zhang et al. *(7)* reported an association between higher exposure to $PM_{2.5}$ during the third trimester of pregnancy and high blood pressure in children at 3–9 years of age. Breton et al. *(8)* found an association between prenatal exposure to ambient pollutants (PM_{10}, $PM_{2.5}$) and higher carotid arterial stiffness, a biomarker of endothelial function, in a population of university students. Iannuzzi et al. *(9)* evaluated 52 Italian children and found that those who lived closer to a main road had higher carotid arterial stiffness than those living further away. Thiering et al. *(10)* concluded that traffic-related air pollution may increase the risk of insulin resistance. In all these studies, confounding variables such as economic status, exposure to environmental tobacco smoke, onset of puberty and height and weight were accounted for.

Honda et al. *(11)* reported a probable relation between early exposure to air pollutants and development of anaemia later in life. This disorder is highly prevalent in elderly populations and is associated with numerous adverse health outcomes.

Conclusion

There is increasing suggestive evidence that exposure to air pollution early in life can influence the development of chronic lung disease, cardiovascular disease and other adverse health outcomes in adulthood. Early exposure can sow the seeds of serious long-term illness, in addition to heightening the risks of adverse outcomes in childhood. Thus, preventive measures to reduce exposure are likely to be extremely cost-effective in terms of reducing the overall burden of disease in populations.

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6. Recommended actions for health professionals

Air pollution is a global problem. Evidence of its negative health effects – which may have both lifelong and generational impacts – is clear and compelling.

The developing fetus and child are particularly vulnerable to the effects of air pollution and are at risk of both short- and long-term health outcomes. As summarized above, numerous studies have linked air pollution to adverse birth outcomes, infant mortality, neurodevelopmental disorders, childhood obesity, compromised lung function, pneumonia, asthma and otitis media, with associations of varying strength. In light of this evidence, major health professional organizations throughout the world are focusing increasingly on the adverse health impacts of air pollution on children. While further research is needed in a number of areas, the scientific evidence is already sufficient for taking clear, concrete steps now to reduce the exposure of pregnant women and children to air pollution.

Health professionals are trusted sources of information and guidance. Paediatricians, family doctors, gynaecologists, obstetricians, midwives, nurses and community health care workers who interact with children can all play significant roles in advocating for policies to reduce childhood exposure to air pollution. Health care professionals commonly treat the effects of exposure-related illness but rarely receive training in identifying and managing the underlying causes and are rarely involved in policy-making. Health professionals should expand their role in the management of childhood exposure to air pollution, with better methods of care and prevention and collective action.

The broader health sector must develop a comprehensive approach to this problem. Preventing the health impacts of air pollution on children requires action by both decision-makers and individual health care professionals, who are best positioned to educate both the public and policy-makers about the dangers of air pollution and to suggest the most promising solutions (Fig. 14).

Fig. 14. Critical roles of health professionals

Be informed.
Recognize exposure and the associated health conditions.
Conduct research and publish and disseminate knowledge.
Prescribe solutions and educate families and communities.
Educate colleagues and students.
Advocate to policy- and decision-makers.

6.1 Be informed.

Health professionals should be aware of the sources and patterns of air pollution in their communities and any tools that can be used to monitor air quality. Regulatory levels of air pollutants are established in almost all major cities. When these regulatory levels are exceeded, health professionals should be prepared and know what action to take to protect the health of their patients. All health professionals should understand the sources of environmental exposure in the communities they serve and should consider air pollution a major risk factor for their patients. They should remain aware of the existing and emerging evidence on the ways in which air pollution can affect children's health.

6.2 Recognize exposure and associated health conditions.

Health professionals are trained to prevent, detect, diagnose and treat health conditions. They also have an important role in identifying causative risk factors in order to prevent disease. Training in the prevention of early childhood exposure will reduce not only common childhood morbidity but also adult mortality. A health care provider can identify air pollution-related risk factors by asking pertinent questions about the child's or pregnant mother's environment. Primary health and community workers can take the opportunity to observe and assess exposure during home visits or when providing advice on infant feeding and during visits to schools and community centres.

Questions can be asked during a medical visit to evaluate the risk of exposure to hazardous air pollutants. Box 16 provides examples of questions that could be asked. For more specific guidance on evaluating environmental risks associated with air quality, see Children's health and the environment: a global perspective *(1)*. Primary health and community workers can take the opportunity to ask questions about the child's environment during Integrated Management of Childhood Illnesses. Alternatively, a comprehensive environmental risk assessment can be conducted during consultations with pregnant women or children who present with air pollution-related health effects, to assess and understand their current exposure and prevent further exposure. A concise version of taking a paediatric environmental history has been prepared and has been field-tested in Argentina; it is available with guidance materials on the WHO website (http://www.who.int/ceh/capacity/paedenvhistory/en/). The more questions that are asked about the child's environment, the more valuable the information collected, as it allows health professionals to identify causative risk factors for acute, recurrent and chronic conditions and helps them educate families on preventing further exposure. Box 17 gives examples of questions that can be asked to determine the risk of AAP.

Box 16. Examples of clinical questions for determining household air pollution risk *(2–4)*

Cooking

1. What fuel does this household use for cooking (including cooking food, making tea/coffee and boiling drinking-water)? *Please circle all cookstoves or devices used. If any technologies are used that are associated with health risk, explain that these stoves produce high levels of pollution that is harmful to health.*

   No cooking done in household·································· 0 SKIP to Q 5
   Electric stove···1 CLEAN FOR HEALTH SKIP to Q.5
   Solar cooker··2 CLEAN FOR HEALTH SKIP to Q.5
   Piped natural gas stove·· 3 CLEAN FOR HEALTH SKIP to Q.5
   Biogas stove································ ····························4 CLEAN FOR HEALTH SKIP to Q.5
   Liquefied petroleum gas (LPG)/ cooking gas stove··········……..5 CLEAN FOR HEALTH SKIP to Q.5
   Liquid fuel stove:
   ···· Using alcohol / ethanol··· 6 CLEAN FOR HEALTH SKIP to Q.5
   ···· Using gasoline / diesel···7 HEALTH RISK
   ···· Using kerosene/paraffin···8 HEALTH RISK
   Manufactured/artisanal solid fuel stove that meets standards for "advanced" (ISO Tier 4 or 5)······· 9 CLEAN FOR HEALTH SKIP to Q.5
   Manufactured / artisanal solid fuel stove (ISO Tier 0–3)··· ……...10 HEALTH RISK
   Traditional solid fuel stove··············· ······························ 11 HEALTH RISK
   Three stone stove/open fire·······································…· 12 HEALTH RISK

If the household uses polluting fuels or stoves for cooking (options with a HEALTH RISK), ask these follow-up questions:

2. Where is cooking usually done? *The exposure of the cook and others is greatest when cooking is done in the main house. Cooking with polluting fuels or stoves can release high concentrations of air pollution. Cooking outdoors or in areas with good ventilation may reduce exposure to air pollution.*

   In main house: no separate room·····························1
   In main house: separate room ································· 2
   Outside main house: in a separate room ·················3
   Outside main house: in open air·····························4
   On veranda or covered porch································· 5

3. Does the cookstove have a chimney or a hood? *If yes, this can reduce the air pollution from cooking or heating.*

   Yes··1 CAN REDUCE EXPOSURE
   No..2
   Don't know..3

4. Does your child / do your children spend time around the cookstove or fire? *If yes, the child can be exposed to high levels of harmful air pollution. It is suggested that children minimize the time spent in areas where cooking is done if polluting stoves or fuels are used.*

   Yes·· · 1 HEALTH RISK

No... 2 CAN REDUCE EXPOSURE
Don't know..3

Space-heating and other energy uses

5. What fuel does this household use for heating? For example, do you use a space heater(s) or your cookstove for warmth? *Please circle all space-heating devices used. If any of them are associated with a health risk, explain that these devices produce high levels of pollution that is harmful to health.*

No space heating in house ························· 0
Central heating····························· ························ 1 CLEAN
FOR HEALTH Heat pump·· 2
CLEAN FOR HEALTH Manufactured space
heater························ 3 POSSIBLY CLEAN FOR HEALTH
Traditional space heater or cookstove·············· 4 HEALTH RISK
Open fire·· 5
HEALTH RISK
Moveable heating pan···································· 6 HEALTH RISK
Three-stone stove or open fire······································· 7 HEALTH RISK

6. Does your household burn wood, coal, charcoal, dung, kerosene or agricultural residues for cooking, heating, lighting or other purposes in or near the home? For example, do you use kerosene lamps, biomass to cook food for animals or burn crop residues to keep flies away from your animals?

If yes: explain that burning these fuels around the home releases high concentrations of air pollution that can be harmful to the health of children.

Box 17. Examples of clinical questions for determining risk of ambient air pollution *(2,4–8)*

1. Do you identify or perceive sources of smoke, fog or dust close to your household? Examples include fires from burning garbage or other residues, smoke, smog or dust from surrounding industrial or agricultural activities.

.... usually see, smell, perceive smoke, dust or mist around the house....................... Health risk
.. ..burning areas from dumps and landfills... Health risk
.........industrial or agricultural area .... Can reduce exposure
... ... Do not perceive smells, mist, smoke or dust around the house............................. Clean for health

If any identified ambient air pollution is associated with a health risk, advocate for local monitoring and control and suggest that parents minimize the time their children spend outside while pollution is present.

2. Does your child/your children live or spend time in an area with heavy traffic or a traffic-congested area, such as a road with frequent blocked traffic, slower speeds and long queues?

.... rural or urban area with light traffic........... Clean for health
.. urban with heavy traffic and common traffic congestion.... **Health risk**

If traffic represents a health risk, advocate for local monitoring and control, and suggest that parents keep the windows closed and minimize the time their children spend outside while traffic is congested.

3. How often do lorries pass through the street where you live, on weekdays?

Never……………….
Seldom………….
Frequently……….
Almost the entire day…….
Any other response……….

4. What is the distance (in meters) from your house to the nearest busy road with frequent traffic?

5. For how many hours a day does your child play outdoors?

6.3 Conduct research and publish and disseminate knowledge.

Environmental health literacy is increasing rapidly. Health professionals have a wealth of knowledge available to them and are themselves trusted sources of synthesized knowledge. With growing interest in air pollution and its health effects, health professionals are in a unique position to identify causative risk factors, educate patients on prevention and advocate for protective interventions. As noted throughout this publication, many gaps in research gaps remain. It is well established, however, that children are the most vulnerable to environmental exposure because they have a lifetime ahead of them for development of the associated illnesses. In order to better protect children from the consequences of air pollution, better understanding is needed of the different sources of pollution, how they enter the body and their biological effects. Health professionals must build collaborations, work closely with affected communities and identify and evaluate potential interventions. The health sector is well positioned to take the lead in narrowing the knowledge gaps.

Health professionals play a critical role in advancing research on the effects of air pollution on children's health, as they observe the effects in their daily work. Both independently and in collaboration with researchers, health professionals can conduct and publish investigations of the causes, mechanisms and effects of environmental exposure that affects children, as well as potential treatment, prevention and management options. By publishing articles and submitting reports of unique cases, they can help other practitioners to identify signs of air pollution-related health outcomes and raise awareness of potential exposure pathways. Health professionals can also play a valuable role in recruiting patients for large studies, because of their relationships with patients. They also contribute to identification of public health concerns by reporting sentinel cases and clusters of air pollution-related diseases to government authorities and can assist in monitoring and identifying sources of pollution. Health professionals are encouraged to consider interventions that may improve the lives of children exposed to air pollution and design pilot studies to determine their effectiveness and efficiency in use of resources. It is also important that they use this evidence to inform social and behaviour change communication strategies for public health promotion and prevention of exposure of children to air pollution. Box 18 lists the priorities for research on air pollution and effects on health.

Box 18. Research priorities

- Research on the effect of HAP on children's health is limited. Few sources have been investigated, and the available evidence does not provide a detailed assessment of health outcomes. The types of pollutants and their effects both prenatally and during childhood periods should be evaluated.
- Not only epidemiological studies but also large intervention studies and implementation research are required to assess the efficacy of interventions and their potential deployment on a larger scale.
- Although many studies have evaluated the effects of chemical mixtures in air pollution on children, investigations of associations between chemical components and health effects will clarify which pollutants are most dangerous and how they should be regulated.
- Long-term studies of the effects of air pollution on children over time are necessary to determine the lasting effects of exposure. Children are vulnerable to environmental exposures partly because they have a lifetime to develop illness. More research on health status in adulthood after childhood exposure to air pollutants will indicate whether there is a link with chronic illness.
- There are few studies of interventions. As more becomes known about the effects of air pollution on children's health, studies of protective policies and patient treatments and interventions will be critical.
- Studies of the efficacy of personal protective devices (e.g. facemasks) have shown mixed results. Further studies are required.
- There is increasing recognition that exposure to air pollution in early life can cause epigenetic changes. More research is needed on the long-term consequences of such changes and their role in the biological mechanisms for a wide range of health outcomes.

6.4 Prescribe solutions and educate families and communities.

Health professionals can "prescribe" solutions to problems related to air pollution, such as switching to clean household fuels and devices to reduce exposure (Boxes 19 and 20). When it is difficult to change to clean household energy, health care professionals can recommend "transitional" solutions that offer some health benefit. Information could be collected on the availability, accessibility and affordability of clean household energy alternatives and on the obstacles and also on resources and information available in government and other programmes to help reduce exposure. Education and individual protective measures, such as using clean stoves for cooking and clean-burning space heaters, could mitigate HAP, often improving the health of the whole family. Reducing AAP, however, requires action throughout the community: individual protective measures at family and household level are important but often not enough. As entire communities are affected by AAP – which in turn is determined by regional sources and meteorological patterns – policy interventions are necessary. (See Boxes 20 and 21 for examples.)

Box 19. Advice that clinicians could give to patients.

Note: These are not official guidelines but suggested actions that patients can take to improve the quality of the air and health and safety in their home environments.

- Use only clean household energy for cooking, heating and lighting.
- Use the cleanest possible solutions. As the transition to truly clean energy sources can take time, technologies and fuels that reduce exposure the most should be used (e.g. low-emission biomass cookstoves).
- To reduce the exposure of children to hazardous HAP, minimize the time children spend around smoky fires and kerosene lamps.
- Increasing ventilation by opening windows or doors or installing a chimney with regular maintenance can reduce exposure in the indoor environment.
- To reduce the risk of burns and scalds, ensure that technologies and fuels are used in such a way that it is unlikely that they can be pushed over, dropped, handled or touched by children.
- To minimize the risk of poisoning, do not store liquid fuels in water bottles or similar beverage containers, and keep them out of the reach of children.
- Ensure that stove and fuel combinations have appropriate safety controls and mechanisms (e.g. safety valves) and are regularly maintained.
- Avoid tobacco smoking indoors.
- To reduce exposure during acute episodes of AAP, minimize children's outdoor physical exertion and the time they spend outdoors, especially in areas with heavy traffic. During these events, families should seek advice from a medical doctor before letting their children participate in outdoor sports and other physical activity.

Box 20. Messages for families and communities.

Ambient air pollution

AAP is a risk factor for respiratory diseases in children, including reduced lung function, exacerbated respiratory symptoms and increased severity or frequency of asthma attacks.

For families:

- Respect advisories on local air pollution. In some cities, air pollution can be so severe that people may be advised to limit their activities and mobility, and schools might close. In many countries and regions, advisories are becoming more interactive, with display boards in some locations that show the current level of air pollution or indicate local air quality. Increasingly, mobile phones apps are used to forecast local air quality.

- Be aware of the environment. Families can identify signs and symptoms in their child that may be associated with local air pollutants, bring them to the attention of their health provider and promote investigation.

- Work with the community. Families are encouraged to collaborate with other community members, health providers and the government to identify air pollution in their area, take action to protect children from exposure and contribute to policy-making.

For communities:

- Be aware of the effects that local activities and natural events have on air quality and the potential impact on children's health. Rural areas are affected by outdoor air pollution primarily from burning debris on agricultural land and forest fires. With increasing desertification, dust storms may contribute substantially to outdoor air pollution. Air pollution is influenced by regional wind and weather conditions and may be transported over long distances.

- Take action to improve air quality whenever possible. Reduced exposure decreases the risk of health effects. Communities should reduce health risks by identifying and reducing emissions from local sources of pollution. For example, in urban areas, a significant proportion of air pollution is generated by old vehicles, poor vehicle maintenance and low fuel quality. Communities may advocate to phase out these vehicles.
- Become aware of new measures to reduce air pollution. Cost-effective strategies to reduce pollution include better integration of transport and land use (e.g. high-capacity, dedicated busways and pedestrian

- and cycle networks), use of cleaner (lead-free, low-sulfur) fuels, cleaner vehicle standards and technologies, monitoring of air quality and warnings.
- Actions to reduce air pollution will benefit child health, not only by avoiding direct effects but also by reducing emissions of certain greenhouse gases and thus mitigating climate change and its effects on health *(5)*.

Household air pollution from use of polluting fuels

Use of polluting fuels for cooking and heating poses a serious threat to children's health. HAP is associated with adverse birth outcomes, increased infant mortality, deficits in childhood lung function, asthma and increased risks for lung infection.

For families:

- Switching from wood, dung, coal, charcoal or kerosene to more efficient, less polluting fuels like electricity, solar energy, LPG, biogas and ethanol will reduce exposure to harmful pollutants.
- Kerosene is not a clean fuel. Avoiding use of kerosene for cooking will also prevent burns and poisoning.
- Proper ventilation during cooking and heating may be a partial remedy. Installing eaves spaces and extraction through smoke hoods and opening windows and doors can also reduce indoor air pollution.
- Changing behaviour plays an important role. Newborns and infants are often carried on their mothers' backs while they are cooking or kept close to a warm hearth. Consequently, they spend many hours breathing polluted air during their first years of life when their developing airways and their immature immune systems make them particularly vulnerable *(9)*. Pregnant women should also keep a distance from such sources.
- Quit tobacco smoking or at least avoid smoking in the house *(10)*.

For communities:

- Resources and information on relevant government and other programmes to reduce exposure in the home should be easily accessible. Such programmes are often inexpensive and highly effective.
- Ensure that advice and support to family members to stop tobacco smoking are available to families.

Box 21. Children's environmental health units – a resource for health professionals, communities and families.

"Children's environmental health units" are now established around the world to ensure the care and protection of children exposed to environmental factors that may adversely affect their health. In view of the particular vulnerability of children, the units are accumulating information on the dangers of air pollution and other hazards, responding to public concern, training health professionals and educating communities, governments and other sectors. They are dedicated to the protection of children from environmental threats, management of children with known or suspected exposure to environmental hazards and diagnosis, management and treatment of children with illnesses due to such exposure.

These units, also referred to as "paediatric environmental health units" have been set up in many countries since they were initiated by WHO *(11)*. For example, a unit has been working in Uruguay for more than a decade, and a network of paediatric environmental health specialty units (https://www.pehsu.net/) are located in Canada and the USA to promote awareness of environmental health issues, provide advice and guidance to reduce exposure, help families to seek care and aid in the training of health professionals. There are also paediatricians who run activities on children's environmental health in medical centres, although there are still no national policies to support such centres.

If you suspect that your child has symptoms related to environmental exposure or you are concerned about a potential exposure and would like to discuss it with a professional, find a children's environmental health unit near you and talk to your health care provider about possible treatment. If no such unit exists, advocate for one to be created. Units exist in many places, and their creation does not require extensive resources.

6.5 Educate colleagues and students.

By training others in health and education, health professionals can increase the reach of their messages on the health risks of air pollution and on strategies to reduce exposure. Health professionals can:

- educate and engage their colleagues in the workplace, in local health care centres, at conferences and in health professional associations;

- advocate for the inclusion of children's environmental health and the environmental determinants of health in curricula in post-secondary institutions and particularly in medical, nursing and midwifery schools;
- engage student associations in the health and care professions (e.g. medicine and nursing); and
- promote reduction of air pollution in schools and environmental health education for teachers and students.

Exposure to air pollution and the interventions to counteract it depend on the country of residence, urban or rural location, socioeconomic situation and other factors. WHO training materials are available that can be adapted to the location, situation and audience (see Box 22).

Box 22. Training materials for health professionals

To enable health professionals who care for children's and adolescents' health to recognize, assess and then manage and prevent diseases linked to environmental factors, WHO and experienced professionals have prepared a training package on children's environmental health, including "train the trainer" materials and tools *(12)*. WHO promotes its wide use for training.

6.6 Advocate to policy- and decision-makers.

Health professionals around the world recognize that air pollution is a threat to the healthy development of children. They should share their knowledge with decision-makers, including local governments, school boards and community leaders. Health professionals can accurately convey the health burden of air pollution to decision-makers, conduct health assessments, support improved standards and policies to reduce harmful exposures, advocate for monitoring and emphasize the importance of protecting children at risk. The health sector is promoting this message, coordinating with other groups and aligning their work with government, academia and community to ensure that children are protected. Resources available to support outreach and coordination include the WHO training manual on health-in-all policies *(13)* and the BreatheLife campaign (http://breathelife2030.org/). Health professionals can also advocate; however, by engaging more comprehensively with the broader health sector, they can extend and increase their influence. Promoting interventions and policies to decrease exposure to air pollution during a child's early years will contribute to lifelong health and future well-being.

> *Health professionals around the world recognize that air pollution is a threat to the healthy development of children.*

The heightened risks of children should lead health professionals to consider the "precautionary principle": when there is a likelihood of serious or irreversible damage to health, a lack of full scientific certainty should not preclude the pursuit of effective preventive measures *(14,15)*. The American Public Health Association *(15)* and WHO *(16)* have proposed approaches for using the precautionary principle to protect children from environmental risks such as air pollution. For some of the health outcomes discussed above, there is strong evidence of the effects of AAP on child health effects, but few studies of HAP. As AAP and HAP share many of the same types of combustion sources, minimizing children's exposure to both forms of pollution, especially during the most sensitive developmental stages of early life, should take precedence over establishing near-certainty about the full extent of the risk and the mechanisms involved *(17)*.

6.7 Benefits of cleaner air for health and the climate

HAP and AAP contribute significantly to global climate change. Household energy is a source of both CO_2 and short-lived climate pollutants such as methane, black carbon and volatile organic compounds. Short-lived climate pollutants are also emitted by diesel-fuelled vehicles and generators, open burning of agriculture waste and livestock production *(18)*. Some of the products of incomplete combustion of biomass or fossil fuels contribute to the formation of O_3, another potent climate pollutant.

Black carbon and O_3 damage children's health in both the short term, by direct exposure, and the longer term, by increasing food insecurity, extreme weather, water scarcity and infectious disease incidence brought on by global climate change *(19, 20)*. As atmospheric temperatures increase, so will vector-borne disease, diarrhoeal diseases and undernutrition – some of the major killers of young children. Concentrations of ground-level O_3, pollen, mould and other pollutants will increase as well, exacerbating respiratory illness in children, such as asthma and allergies *(21)*.

The relation between air pollution and climate change is complex: AAP contributes to climate change, and climate change affects air quality. Rising temperatures can result in more frequent, more severe smog and higher annual mean concentrations of $PM_{2.5}$ in certain parts of the world.

The interconnected effects of HAP, AAP and climate change strengthen the benefits of emissions reduction for health and the environment. Changing household energy use to clean options and reducing AAP are critical to both improving children's health and mitigating global climate change. Box 23 gives examples of policy measures for which health professionals could advocate, Box 24 gives an example of a policy that was successful in reducing AAP, and Box 25 describes ways in which households were convinced to change to cleaner fuels.

Box 23. Examples of policy measures for which health professionals could advocate *(20)*

Each of these measures can be promoted by stressing the health effects of air pollutants in children to policy-makers.

- Accelerate access to clean and efficient household energy for cooking, heating and lighting. Programmes to improve access to cleaner fuels and improved stoves can result in large gains in health and productivity and are highly cost-beneficial. Health professionals can promote national campaigns for improved fuels and technologies that adhere to the WHO guidelines for indoor air quality associated with household fuel combustion *(22)*.
- Reduce the emissions of harmful ambient air pollutants from major sources such as heavy vehicles, through grants and low-cost loan programmes. For example, the Diesel Emissions Reduction Act in the USA provides funds to retrofit or replace diesel buses and other vehicles that emit high levels of NO_x, PM and other pollutants.
- Encourage land-use planning for energy-efficient, compact cities that shorten distances, encourage urban street life and create opportunities for children to play and interact with their community.
- Support investments in "green" and "blue" spaces, such as parks, forests and lakes, so that children can benefit from green areas and clean waters. These can also provide urban ecosystem services, including a cooling effect and a refuge from air and noise pollution.
- Transfer subsidies from polluting fuels such as kerosene to clean household options (e.g. solar, biogas, LPG).
- Design a labelling system for stoves and space heaters that includes rating of emissions (linked to health impacts) and efficiency, perhaps using the ISO standards for voluntary performance targets for clean cookstoves and clean cooking solutions *(23)*.
- Encourage further installation of low-emission and renewable power generation to reduce AAP.
- Support public investment in rapid urban transit with dedicated rights of way and pedestrian and cycle networks. Support use of public transport, bicycles, walking and programmes such as safe routes to school and children's free access to public transport in order to increase children's independent mobility.
- Support the planning and building of energy-efficient housing, clustered in neighbourhoods with schools, shops and services nearby. Upgrade slums by introducing cleaner, safer street networks, larger green spaces and better infrastructure to improve children's physical living conditions and quality of life.
- Discourage urban planning that results in low-density urban sprawl and expanding roads, gated communities and large expanses of concrete, which absorb heat and block sunlight, all of which discourage children's involvement in urban street life.
- Advocate for better waste management practices to reduce incineration and burning of agricultural waste and for phasing out use of agro-chemicals in or near urban areas.
- Promote better land-use management in rural areas to stop deforestation, limit agricultural burning practices and charcoal production and improve control of wildfires.
- Create an emergency alert system that provides information on air pollution resulting from natural disasters such as thunderstorms and wildfires, and advocate for protective measures in such situations.

Box 24. A success story in improving air quality

This case study demonstrates what can be achieved with a coordinated, effective policy. Southern California used to be one of the most polluted regions in the USA. A persistent brown haze was a fact of life for residents of Los Angeles in the 1960s. Over the past few decades, however, California has cleaned up its outdoor air dramatically. The state treated its AAP problem as a public health crisis that demanded strong action. It introduced strict emission controls on almost every source of AAP, with low-emission vehicle programmes, emissions standards for heavy-duty vehicles and diesel vehicles, requirements for emissions reduction by power plants and refineries and programmes to improve the energy efficiency of and reduce emissions from consumer products and appliances. Through the Clean Air Act and its amendments, the Federal Government also imposed more stringent air pollution standards and effective, concurrent policies to reduce emissions from vehicles and energy-related industries. California's ambitious efforts, however, went beyond the standards set by national legislation and had huge benefits for Californians, as the concentrations of several air pollutants were reduced by 15–65% *(24)*. Children in California now breathe more easily, as the reduction in pollutant levels has resulted in significant improvements in the lung function *(25)*. California lawmakers took action partly in response to strong evidence of the effects of air pollution on health, highlighting the important role of health professionals in fostering change.

Box 25. Smart subsidies: success in transitioning millions of households to clean fuels

The aim of "Cooking for life", a project of the World LPG Association and the United Nations, is to convince households to change from polluting fuels for cooking primarily to LPG, a fuel that is much cleaner for health. Such a change requires access to affordable fuels and technologies and the financial means to obtain them, and these factors can be influenced by public policy *(26)*.

Indonesia's successful programme for increasing LPG use offers good lessons. In 2006, 48 of 52 million households in Indonesia were using kerosene, a polluting fuel that is also a major risk of poisoning in children, as their main energy source. The Government subsidized the purchase of kerosene, at major expense to the State coffers. In 2007, the Government launched a national programme to switch more than 50 million people from kerosene to LPG. After an extended assessment involving authorities at all levels, conversion packages were distributed, accompanied by communication and education campaigns to increase awareness. Within the first 6 years, LPG packages had been distributed to 54 million households. A large proportion of households have since switched to this cleaner energy source, reducing the cost to the Government of petroleum-related subsidies by more than US$ 6 billion. The programme resulted in a reduction in CO_2 emissions by 8.4 million tonnes per year and also reduced emissions of other air pollutants, such as PM, methane, CO and hydrocarbons. A survey after implementation of the policy showed that 99.8% of households preferred using LPG to kerosene, citing greater efficiency, speed of cooking and cleanliness *(27)*.

Children's health improved dramatically: the infant mortality rate fell by 30% in the regions that received the intervention, half of the decrease being seen among infants in the early neonatal period. This carefully coordinated nationwide intervention is a compelling example for other countries that wish to accelerate the transition from household use of polluting fuels to benefit the health of their children *(27–29)*.

Further evidence of the importance of targeted subsidies in promoting a transition to clean fuels was found in Latin America and the Caribbean. Use of LPG varies widely across the region, and over 80 million people still rely on polluting fuels as their primary source of household energy. Achieving SDG 7 ("ensure access to affordable, reliable, sustainable and modern energy for all") would have huge benefits for health in the region, as it would avert an estimated 82 361 premature deaths and 2 327 146 DALYs annually *(30)*. In Latin America and the Caribbean, access and price were identified as the main limitations to substitution of solid fuels by clean fuels. Subsidies for LPG consumption helped Bolivia to lower the proportion of the population that used polluting cooking fuels from 36% in 2005 to 23% in 2013. Other countries, such as Brazil, used cash transfer programmes, which accelerated the transition, from 16% to < 5% in a decade. It has been estimated that subsidies for natural and LPG gas allowed 39% of the rural population and almost the entire urban population to switch from polluting fuels to LPG. Targeted subsidies should therefore be considered a policy option for achieving the SDG7 on clean energy.

Effective programmes to promote adoption of clean fuels can result in meaningful health gains for children. Health professionals can play a role, by justifying the health benefits of such interventions to policy- and decision-makers, drawing on these success stories.

Box 26. Moving to cleaner fuels in India – The Pradhan Mantri Ujjawala Yojana (PMUY) scheme

In a country where, according to the 2011 Census, nearly 121 million households used traditional biomass cooking stoves or *chullha*, the PMUY scheme (http://www.pmujjwalayojana.com) announced by the Indian Prime Minister Narendra Modi in May 2016 is an innovative approach for accelerating the move to cleaner fuels for household cooking purposes.

The scheme prioritises households which are “below the poverty line” with the aim of improving access to Liquid Petroleum Gas (LPG) through providing free LPG connections. Twenty-eight months after its launch PMUY has already achieved the initial target of providing 50 million LPG connections. Increased efforts to reach an additional 30 million households underway alongside work to evaluate the health benefits of the scheme.

6.8 A perspective on children’s health and air pollution: improving equity and access to protect the most vulnerable

While providing information to families and communities is important, it may not remove other barriers to access. The poorest communities often face the greatest environmental risks to their health, and their children are especially vulnerable. Poverty often underlies these disproportionate risks, as those living in poor communities may be unable to afford cleaner household fuels, access care or move to an area with cleaner air. They may also be members of marginalized groups that face systemic barriers to reducing exposure to air pollution. Polluting industries, waste disposal sites, bus depots and trucking routes are often situated in low-income communities, where residents lack the political power to limit or remove these harmful sources of exposure.

In households that rely on polluting fuels for cooking and heating, women and their children often travel long distances to collect fuel and spend much time gathering, processing and cooking with these fuels. Removing or reducing the primary sources of pollution is often the best way to protect children from the damage it can cause. Therefore, low-cost solutions and approaches are likely to result in the most progress in affected communities.

Low-income families are often constrained in their options to improve air quality in their own homes. Because of market and other forces beyond their control, clean fuels and technologies may not be affordable, available or accessible. Beyond the household, individuals and families have even less control over the air they breathe. To reduce and prevent exposure to both HAP and AAP, public policy is essential. Evidence-based air quality standards, monitoring pollutant levels over time and proper enforcement mechanisms can reduce exposure and save lives.

Air pollutants have no political borders; they travel where the wind and prevailing weather patterns take them. Therefore, regional and international cooperation are also necessary to reduce children’s exposure. Like the pollutants, actions to protect children should transcend sectoral, geographical and political boundaries. What is needed are approaches to preventing exposure that are complementary and mutually reinforcing, at every scale: in the home, the clinic, the health care institution, the municipality, the national government and the global community. Collectively, health care professionals can push for strong action from decision-makers to protect their most vulnerable and voiceless citizens: children who have little or no control over the quality of the air that surrounds them. Exposure to air pollution can alter children’s trajectory through life, pushing them onto a path with suffering, illness and challenge. In some cases, the damage is irreversible – but it is also preventable. The sources of risk and the health effects are diverse and complex, but the solution is clear: we must reduce children’s exposure. By working together, we can protect millions of vulnerable young lives from the health effects of air pollution. The benefits would be immeasurable.

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Annex 1. Global initiatives and organizations working on children’s health and air pollution

Sixty-eighth World Health Assembly (2016)
A 4-year plan for responding to the adverse health effects of air pollution that includes four areas of action:

1. Expand the knowledge base, by building and disseminating global evidence and knowledge on the effects of air pollution on health and the effectiveness of interventions and policies to address it.
2. Enhance systems to monitor and report on health trends and progress towards the air pollution-related targets of the Sustainable Development Goals.
3. Leverage health sector leadership and coordinated action at all levels – local, national, regional and global – to raise awareness of air pollution.
4. Enhance the health sector’s capacity to address the adverse health effects of air pollution by training, guidelines and national action plans. http://www.who.int/mediacentre/news/releases/2016/wha69-27-may-2016/en/ http://www.who.int/sustainable-development/news-events/wha69-roadmap-ap/en/

Sustainable Development Goals (2015)

Health and air pollution are addressed throughout the SDGs. The third SDG, “ensure healthy lives and promote well-being for all at all ages”, emphasizes children’s environmental health. Household energy is explicitly addressed in SDG 7: “ensure access to affordable, reliable, sustainable and modern energy for all”. The SDG targets reflect understanding that household energy is a critically important consideration in many facets of human development, from health (SDG 3) to sustainable urban environments (SDG 11) to gender equality (SDG 5) and climate action (SDG 13). SDG 3 includes targets to end preventable deaths of newborns and children under 5 years by 2030, which form the basis of the Global Strategy for Women’s, Children’s and Adolescent’s Health. http://www.un.org/sustainabledevelopment/sustainable-development-goals/

WHO’s Global Strategy for Women’s, Children’s and Adolescents’ Health (2015)

The strategy has been updated by collaboration among stakeholders, led by WHO. It places women, children and adolescents at the heart of the Sustainable Development Goals. Its aims include reducing premature mortality from noncommunicable diseases in women, children and adolescents by one third by 2030. The Strategy includes targets for extending access to clean household energy and reducing HAP. http://www.who.int/life-course/partners/global-strategy/en/

WHO Nurturing Care Framework for Early Childhood Development (2018)

The Framework, launched at the Seventy-first World Health Assembly in May 2018, outlines a whole-of-society approach to ensure effective policies and interventions for a stable, supportive environment and protection from threats to health and well-being. Environmental risks are identified as clear threats to early childhood development, and tools are proposed to translate scientific results into action. The Framework represents the next step in a global movement to prioritize and invest in early childhood development. It provides an opportunity for more action to address air pollution and other environmental risks as part of broader child health programmes and policies. http://www.who.int/maternal_child_adolescent/child/nurturing-care-framework/en/

Every Newborn Action Plan (2014)

The Plan presents evidence-based means to prevent newborn deaths and stillbirths and a plan up to 2020 with global and national milestones and strategic actions that build on commitments made to end preventable newborn deaths and stillbirths.
http://www.who.int/maternal_child_adolescent/newborns/every-newborn/en/

BreatheLife (2016)

A joint campaign led by the WHO, UN Environment and the Climate and Clean Air Coalition to mobilize cities and individuals to protect our health and the planet from the effects of air pollution.

http://breathelife2030.org/

The Climate and Clean Air Coalition (2012)

The aim of an initiative comprising over 50 governments and 51 civil society and international organizations is to reduce emissions of short-lived climate pollutants. The Coalition catalyses action for rapid introduction of proven technologies and policies to reduce emissions of these pollutants in all sectors.
http://www.ccacoalition.org/en

The Global Alliance for Clean Cookstoves (2011)

An initiative launched by the United Nations Foundation to deliver clean cooking solutions to 100 million households by 2020.
http://cleancookstoves.org

Sustainable Energy for All (2011)

A partnership co-chaired by the Secretary-General of the United Nations and The World Bank for achieving universal access to modern energy sources for cooking, heating, lighting and other uses. Its "global tracking framework" is an approach for monitoring various tiers of access to energy, "diagnose" situations and form the basis of interventions to move up those tiers towards cleaner, healthier, more reliable energy sources. The WHO global household energy database is used to measure progress toward achieving SDG 7.
https://www.seforall.org

UN-Energy (2004)

The mechanism used for inter-agency collaboration in the field of energy to ensure coherence in the multidisciplinary response of the United Nations system to the outcomes of the World Summit on Sustainable Development and to support countries in their transition to sustainable energy.
http://www.un-energy.org

Energising Development (EnDev)

A partnership to promote access to energy, which is currently financed by six donor countries: Germany, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom. EnDev promotes sustainable access to modern energy sources that meet the needs of the poor in 25 countries in Africa, Asia and Latin America.
http://www.who.int/airpollution/household/policy-governance/collaborations/en/

Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea (2013)

A plan prepared by WHO and UNICEF that proposes a cohesive approach to end, by 2025, preventable childhood deaths due to pneumonia and diarrhoea by bringing together critical services and interventions to promote good health practices, appropriate treatment and universal vaccination coverage.
http://www.who.int/maternal_child_adolescent/documents/global_action_plan_pneumonia_diarrhoea/en/

Unmask My City

This global campaign involves local health partners and their communities in promoting practical solutions and creating tangible policy changes for a clear downward trend in urban air pollution by 2030. It is an initiative of the Global Climate and Health Alliance and its partners Health Care Without Harm, the Health and Environment Alliance, the US Climate and Health Alliance and the United Kingdom Health Alliance for Climate Change.
http://unmaskmycity.org/about/

The World Health Assembly resolution on climate change and health (WHA61.19) (2008) and the Paris Agreement of the United Nations Framework Convention on Climate Change (2015)

These global agreements provide a framework to protect health from risks associated with climate change and to ensure that actions to mitigate climate change also protect and improve people's health. The Paris Agreement explicitly states that action to address climate change should include, respect and promote the right to health.
http://www.who.int/globalchange/A61_R19_en.pdf
https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
https://unfccc.int/news/climate-change-agreement-is-public-health-agreement

Annex 2. Additional tables and figures

Table 4. Exposure of children to ambient $PM_{2.5}$ and burden of disease, by country, 2016

Country	Sex	$PM_{2.5}$_exposure_total (µg/m³)	$PM_{2.5}$_exposure_rural (µg/m³)	$PM_{2.5}$_exposure_urban (µg/m³)	No. of DALYs (< 5 years)	DALYs rate per 100 000 (<5 years)	No. of DALYs (5–14 years)	DALYs rate per 100 000 (5–14 years)	No. of deaths (<5 years)	Death rate per 100 000 (<5 years)	No. of deaths (5–14 years)	Death rate per 100 000 (5–14 years)
Afghanistan	Both	53.2	48.7	59.9	386 056.4	7 377.6	27 973.4	280.7	4 245.8	81.1	332.4	3.3
	F				201 830.5	7 933.1	16 339.0	336.4	2 221.6	87.3	194.4	4.0
	M				184 225.9	6 851.9	11 634.3	227.6	2 024.2	75.3	138.0	2.7
Albania	Both	17.9	16.9	18.2	726.6	409.6	119.2	34.9	7.8	4.4	1.4	0.4
	F				344.5	402.0	84.7	51.8	3.7	4.3	1.0	0.6
	M				382.0	416.7	34.5	19.4	4.1	4.5	0.4	0.2
Algeria	Both	35.2	37.6	34.5	77 126.5	1 641.3	3 469.9	49.0	844.5	18.0	40.2	0.6
	F				45 400.9	1 974.4	1 810.1	52.2	497.4	21.6	21.0	0.6
	M				31 725.6	1 322.1	1 659.8	46.0	347.1	14.5	19.2	0.5
Andorra	Both	9.9	9.1	11.5	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA
Angola	Both	27.9	27.7	28.4	353 080.3	6 690.8	17 186.6	208.2	3 884.9	73.6	205.0	2.5
	F				185 045.9	7 043.5	8 587.9	206.1	2 037.8	77.6	102.3	2.5
	M				168 034.3	6 341.2	8 598.7	210.4	1 847.1	69.7	102.6	2.5
Antigua and Barbuda	Both	17.9	14.9	18.0	4.8	59.5	3.0	18.2	0.1	0.6	0.0	0.2
	F				1.9	46.3	0.1	1.2	0.0	0.5	0.0	0.0
	M				2.9	72.5	2.9	35.1	0.0	0.8	0.0	0.4

Argentina	Both	11.8	12.3	11.7	5 940.4	159.0	619.3	8.5	64.6	1.7	7.2	0.1
	F				2 702.2	147.3	321.3	9.0	29.4	1.6	3.8	0.1
	M				3 238.2	170.4	298.0	8.1	35.2	1.9	3.4	0.1
Armenia	Both	30.5	23.7	32.9	1 191.6	589.3	155.0	40.8	13.0	6.4	1.8	0.5
	F				551.1	581.7	70.9	40.0	6.0	6.3	0.8	0.5
	M				640.5	596.0	84.2	41.4	7.0	6.5	1.0	0.5
Australia	Both	7.2	6.1	7.3	228.6	14.7	47.2	1.6	2.4	0.2	0.5	0.0
	F				100.6	13.3	33.4	2.3	1.1	0.1	0.4	0.0
	M				128.0	16.1	13.7	0.9	1.3	0.2	0.1	0.0
Austria	Both	12.4	10.9	13.1	15.4	3.8	36.0	4.4	0.2	0.0	0.4	0.1
	F				7.4	3.7	35.3	8.9	0.1	0.0	0.4	0.1
	M				8.1	3.8	0.7	0.2	0.1	0.0	0.0	0.0
Azerbaijan	Both	18.2	17.8	18.5	9 954.8	1 117.9	911.8	66.9	108.5	12.2	10.7	0.8
	F				5 118.5	1 235.5	410.6	65.0	55.8	13.5	4.8	0.8
	M				4 836.3	1 015.6	501.2	68.6	52.7	11.1	5.8	0.8
Bahamas	Both	17.6	15.6	19.0	124.4	451.8	7.3	13.8	1.4	4.9	0.1	0.2
	F				59.8	446.5	3.1	11.9	0.6	4.8	0.0	0.1
	M				64.6	456.9	4.2	15.6	0.7	5.0	0.0	0.2
Bahrain	Both	69.0	70.7	69.0	110.7	103.6	79.8	43.7	1.2	1.1	0.9	0.5
	F				56.2	108.2	44.2	49.3	0.6	1.1	0.5	0.6
	M				54.5	99.4	35.6	38.3	0.6	1.0	0.4	0.4
Bangladesh	Both	58.3	52.9	58.6	533 035.9	3 498.6	22 646.5	71.1	5 832.3	38.3	266.6	0.8
	F				239 240.0	3 210.1	13 376.9	85.8	2 618.1	35.1	158.3	1.0
	M				293 795.9	3 775.0	9 269.6	57.0	3 214.2	41.3	108.3	0.7
Barbados	Both	22.2	20.3	22.4	18.9	109.0	9.9	26.5	0.2	1.1	0.1	0.3
	F				9.0	105.0	1.6	8.9	0.1	1.1	0.0	0.1
	M				9.9	113.0	8.3	43.1	0.1	1.2	0.1	0.5
Belarus	Both	18.1	16.4	19.3	417.4	72.0	70.9	7.2	4.4	0.8	0.6	0.1

	F				184.2	65.5	34.0	7.1	1.9	0.7	0.3	0.1
	M				233.2	78.2	36.9	7.3	2.5	0.8	0.3	0.1
Belgium	Both	12.9	9.4	13.0	147.6	23.0	22.0	1.7	1.6	0.2	0.2	0.0
	F				62.8	20.0	13.3	2.1	0.7	0.2	0.1	0.0
	M				84.8	25.7	8.6	1.3	0.9	0.3	0.1	0.0
Belize	Both	21.2	21.2	20.9	145.7	361.7	17.7	23.0	1.6	3.9	0.2	0.3
	F				71.8	360.2	7.1	18.8	0.8	3.9	0.1	0.2
	M				73.9	363.1	10.6	27.1	0.8	3.9	0.1	0.3
Benin	Both	33.1	41.3	30.4	138 222.6	7 785.2	14 098.4	488.7	1 520.1	85.6	168.6	5.8
	F				72 869.8	8 336.8	7 239.4	509.0	801.8	91.7	86.5	6.1
	M				65 352.8	7 250.3	6 859.1	468.9	718.2	79.7	82.1	5.6
Bhutan	Both	35.3	35.3	35.4	1 704.3	2 441.1	169.0	116.5	18.6	26.7	2.0	1.4
	F				766.9	2 234.3	92.6	129.7	8.4	24.4	1.1	1.6
	M				937.4	2 641.1	76.4	103.7	10.2	28.9	0.9	1.2
Bolivia (Plurinational State of)	Both	20.2	18.4	23.3	20 868.2	1 755.8	2 703.8	117.6	228.6	19.2	32.4	1.4
	F				9 788.9	1 681.8	1 287.7	114.0	107.2	18.4	15.5	1.4
	M				11 079.3	1 826.9	1 416.1	121.1	121.3	20.0	17.0	1.5
Bosnia and Herzegovina	Both	27.3	24.3	29.7	204.5	130.5	21.9	6.4	2.2	1.4	0.2	0.1
	F				95.5	125.7	8.9	5.4	1.0	1.3	0.1	0.0
	M				109.0	135.0	12.9	7.3	1.1	1.4	0.1	0.1
Botswana	Both	21.2	21.3	20.9	3 767.7	1 453.5	389.3	86.0	41.3	15.9	4.6	1.0
	F				1 818.0	1 417.1	177.2	78.9	19.9	15.5	2.1	0.9
	M				1 949.7	1 489.2	212.1	93.1	21.4	16.3	2.5	1.1
Brazil	Both	11.5	9.5	11.8	40 961.5	274.6	3 745.2	12.1	445.3	3.0	43.0	0.1
	F				18 929.2	259.8	1 786.6	11.7	205.7	2.8	20.4	0.1
	M				22 032.3	288.7	1 958.6	12.4	239.7	3.1	22.6	0.1

Brunei Darussalam	Both	5.8	5.8	5.8	6.8	19.7	3.8	5.9	0.1	0.2	0.0	0.1
	F				3.1	18.4	2.5	8.1	0.0	0.2	0.0	0.1
	M				3.7	20.9	1.3	3.8	0.0	0.2	0.0	0.0
Bulgaria	Both	18.8	17.7	20.8	1 139.7	351.5	218.6	32.1	12.4	3.8	2.5	0.4
	F				509.6	323.6	101.2	30.6	5.5	3.5	1.2	0.4
	M				630.1	377.9	117.4	33.6	6.8	4.1	1.4	0.4
Burkina Faso	Both	36.8	37.2	36.3	184 238.3	5 720.5	23 174.6	442.1	2 025.8	62.9	277.4	5.3
	F				87 392.1	5 524.4	12 790.2	496.9	961.5	60.8	153.0	5.9
	M				96 846.2	5 909.9	10 384.3	389.2	1 064.3	65.0	124.4	4.7
Burundi	Both	35.6	35.2	35.6	113 273.1	5 957.5	19 974.4	708.0	1 244.4	65.4	239.8	8.5
	F				54 101.3	5 728.0	10 650.6	752.5	594.6	62.9	127.8	9.0
	M				59 171.8	6 184.1	9 323.8	663.2	649.8	67.9	112.0	8.0
Cabo Verde	Both	32.0	33.6	31.6	687.7	1 258.9	32.9	29.7	7.5	13.8	0.4	0.4
	F				310.7	1 151.3	15.8	28.7	3.4	12.6	0.2	0.3
	M				377.0	1 363.9	17.2	30.7	4.1	14.9	0.2	0.4
Cambodia	Both	24.0	21.5	24.9	35 159.4	1 996.2	3 230.5	101.4	383.9	21.8	38.0	1.2
	F				15 942.8	1 839.9	1 399.9	89.5	174.2	20.1	16.4	1.1
	M				19 216.6	2 147.7	1 830.6	112.8	209.7	23.4	21.6	1.3
Cameroon	Both	65.3	65.1	65.4	344 937.9	9 067.2	64 364.4	1 029.5	3 790.9	99.7	770.3	12.3
	F				156 001.3	8 284.3	30 891.9	995.8	1 715.1	91.1	369.7	11.9
	M				188 936.6	9 834.5	33 472.5	1 062.6	2 075.8	108.0	400.6	12.7
Canada	Both	6.5	5.3	6.7	157.4	8.2	28.9	0.7	1.7	0.1	0.3	0.0
	F				72.7	7.7	16.9	0.9	0.8	0.1	0.2	0.0
	M				84.7	8.6	12.1	0.6	0.9	0.1	0.1	0.0
Central African Republic	Both	49.5	49.0	51.2	94 519.2	12 939.8	4 449.3	350.8	1 037.9	142.1	53.2	4.2
	F				48 299.8	13 244.6	2 338.6	366.3	530.8	145.5	27.9	4.4

	M				46 219.4	12 635.9	2 110.7	335.1	507.1	138.6	25.2	4.0
Chad	Both	53.0	53.6	50.8	547 683.0	20 540.3	28 618.3	684.4	6 039.4	226.5	343.8	8.2
	F				263 619.5	19 947.5	15 518.3	748.0	2 908.3	220.1	186.5	9.0
	M				284 063.5	21 122.8	13 100.0	621.7	3 131.1	232.8	157.3	7.5
Chile	Both	21.0	17.8	23.1	1 071.5	90.5	83.5	3.3	11.6	1.0	0.9	0.0
	F				480.8	82.8	40.7	3.3	5.2	0.9	0.4	0.0
	M				590.8	97.9	42.8	3.4	6.4	1.1	0.4	0.0
China	Both	49.2	35.7	51.0	611 083.6	709.1	46 469.9	28.5	6 645.8	7.7	515.0	0.3
	F				270 327.0	675.7	26 131.2	34.6	2 930.2	7.3	279.1	0.4
	M				340 756.6	738.0	20 338.7	23.2	3 715.6	8.0	235.9	0.3
Colombia	Both	15.2	13.4	17.2	15 240.6	410.6	1 558.1	19.7	166.5	4.5	18.6	0.2
	F				7 085.8	390.2	674.2	17.4	77.4	4.3	8.0	0.2
	M				8 154.8	430.1	884.0	21.9	89.1	4.7	10.6	0.3
Comoros	Both	18.6	18.4	18.6	5 320.3	4 465.4	294.4	148.0	58.4	49.0	3.5	1.8
	F				2 609.0	4 464.0	142.8	146.1	28.7	49.1	1.7	1.7
	M				2 711.3	4 466.7	151.6	149.8	29.8	49.0	1.8	1.8
Congo	Both	38.7	41.4	36.4	33 752.7	4 094.9	2 446.2	181.4	370.5	45.0	29.4	2.2
	F				16 543.0	4 052.4	1 384.0	206.4	181.8	44.5	16.6	2.5
	M				17 209.8	4 136.6	1 062.2	156.7	188.7	45.4	12.7	1.9
Cook Islands	Both	12.0	12.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA
Costa Rica	Both	15.9	12.6	16.7	403.1	116.6	51.7	7.2	4.3	1.3	0.5	0.1
	F				188.1	111.5	28.1	8.0	2.0	1.2	0.3	0.1
	M				215.0	121.5	23.6	6.4	2.3	1.3	0.3	0.1
Côte d'Ivoire	Both	23.7	23.5	23.9	248 406.3	6 434.4	36 550.7	586.9	2 728.3	70.7	439.2	7.1
	F				110 022.3	5 738.8	20 246.4	651.2	1 208.9	63.1	243.3	7.8
	M				138 384.0	7 120.6	16 304.3	522.8	1 519.4	78.2	195.9	6.3

Croatia	Both	17.0	15.8	17.6	106.9	54.5	15.1	3.6	1.1	0.6	0.2	0.0
	F				44.0	46.1	1.0	0.5	0.5	0.5	0.0	0.0
	M				63.0	62.4	14.1	6.5	0.7	0.7	0.2	0.1
Cuba	Both	18.4	15.8	21.6	1 241.4	195.1	93.1	7.6	13.5	2.1	1.0	0.1
	F				571.2	184.5	58.2	9.8	6.2	2.0	0.7	0.1
	M				670.2	205.1	34.9	5.6	7.3	2.2	0.3	0.1
Cyprus	Both	16.8	15.9	17.1	5.7	8.7	0.2	0.1	0.1	0.1	0.0	0.0
	F				2.7	8.6	0.1	0.1	0.0	0.1	0.0	0.0
	M				3.0	8.8	0.1	0.1	0.0	0.1	0.0	0.0
Czechia	Both	15.1	13.6	15.6	296.9	55.6	89.1	8.2	3.2	0.6	1.0	0.1
	F				122.2	47.1	32.9	6.2	1.3	0.5	0.3	0.1
	M				174.7	63.7	56.2	10.1	1.9	0.7	0.6	0.1
Democratic People's Republic of Korea	Both	30.4	29.0	31.0	23 721.3	1 374.0	1 592.9	44.6	258.9	15.0	18.3	0.5
	F				10 458.3	1 240.5	882.3	50.5	114.0	13.5	10.1	0.6
	M				13 263.0	1 501.5	710.6	39.0	144.9	16.4	8.2	0.5
Democratic Republic of the Congo	Both	37.6	37.8	37.4	1 175 790.2	8 112.2	90 407.6	411.0	12 890.7	88.9	1 088.9	5.0
	F				585 953.1	8 166.0	49 954.8	457.5	6 426.4	89.6	601.4	5.5
	M				589 837.2	8 059.6	40 452.8	365.2	6 464.4	88.3	487.5	4.4
Denmark	Both	10.1	9.5	10.3	35.6	12.5	3.9	0.6	0.4	0.1	0.0	0.0
	F				16.7	12.0	3.3	1.0	0.2	0.1	0.0	0.0
	M				19.0	13.0	0.6	0.2	0.2	0.1	0.0	0.0
Djibouti	Both	40.4	40.1	41.0	4 942.5	4 832.2	1 142.5	585.3	54.1	52.9	13.8	7.1
	F				2 281.4	4 524.2	556.6	577.3	25.0	49.5	6.7	7.0
	M				2 661.1	5 131.7	585.9	593.1	29.1	56.1	7.1	7.2

Dominica	Both	18.2	16.9	18.8	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA
Dominican Republic	Both	12.9	11.3	13.3	8 736.8	824.6	466.1	22.2	95.7	9.0	5.4	0.3
	F				3 481.5	671.0	221.4	21.5	38.1	7.3	2.6	0.2
	M				5 255.4	972.0	244.7	23.0	57.6	10.7	2.8	0.3
Ecuador	Both	14.9	14.1	15.5	10 798.2	670.2	866.4	28.0	118.1	7.3	10.3	0.3
	F				4 993.3	634.5	408.9	27.0	54.7	6.9	4.9	0.3
	M				5 804.9	704.3	457.5	29.0	63.5	7.7	5.5	0.3
Egypt	Both	79.3	69.4	79.6	222 583.9	1 728.7	56 687.9	296.3	2 431.9	18.9	675.5	3.5
	F				97 331.7	1 560.2	25 258.7	272.1	1 063.8	17.1	300.1	3.2
	M				125 252.2	1 887.0	31 429.2	319.0	1 368.1	20.6	375.4	3.8
El Salvador	Both	23.4	20.7	23.8	3 664.6	635.7	516.9	43.6	40.0	6.9	6.3	0.5
	F				1 427.1	506.9	186.3	32.1	15.5	5.5	2.2	0.4
	M				2 237.5	758.5	330.6	54.6	24.4	8.3	4.1	0.7
Equatorial Guinea	Both	45.9	45.5	49.1	15 735.2	8 662.9	1 469.4	535.1	172.6	95.0	17.6	6.4
	F				6 747.9	7 527.1	811.9	599.2	74.0	82.6	9.7	7.2
	M				8 987.3	9 769.8	657.5	472.6	98.5	107.1	7.9	5.7
Eritrea	Both	42.4	42.9	41.1	38 460.1	5 171.2	4 830.2	360.5	422.3	56.8	57.6	4.3
	F				17 784.4	4 884.5	2 226.2	338.9	195.3	53.6	26.5	4.0
	M				20 675.7	5 446.1	2 604.0	381.2	227.0	59.8	31.1	4.6
Estonia	Both	6.7	6.2	7.0	9.5	14.0	5.9	4.1	0.1	0.1	0.1	0.0
	F				4.5	13.5	2.3	3.3	0.0	0.1	0.0	0.0
	M				5.0	14.6	3.6	4.9	0.1	0.1	0.0	0.0
eSwatini	Both	16.3	16.4	16.2	5 927.3	3 300.2	582.3	180.5	64.9	36.1	6.9	2.2
	F				2 764.4	3 098.5	302.6	188.2	30.3	33.9	3.6	2.2
	M				3 162.9	3 499.1	279.7	172.8	34.6	38.3	3.3	2.1

Ethiopia	Both	34.4	34.9	34.0	703 519.9	4 635.4	100 742.9	374.4	7 733.5	51.0	1 209.0	4.5
	F				313 661.3	4 195.2	47 635.0	357.8	3 447.9	46.1	571.2	4.3
	M				389 858.5	5 062.7	53 107.9	390.5	4 285.6	55.7	637.7	4.7
Fiji	Both	10.2	9.7	10.5	440.5	508.7	57.6	33.8	4.8	5.5	0.7	0.4
	F				213.3	506.5	29.5	35.8	2.3	5.5	0.3	0.4
	M				227.2	510.8	28.1	31.9	2.5	5.6	0.3	0.4
Finland	Both	5.9	5.5	6.5	11.4	3.9	0.4	0.1	0.1	0.0	0.0	0.0
	F				5.4	3.7	0.2	0.1	0.1	0.0	0.0	0.0
	M				6.0	4.0	0.3	0.1	0.1	0.0	0.0	0.0
France	Both	11.6	9.9	12.4	354.4	9.2	95.0	1.2	3.6	0.1	0.7	0.0
	F				169.4	9.0	44.1	1.1	1.7	0.1	0.3	0.0
	M				185.0	9.4	50.8	1.3	1.9	0.1	0.4	0.0
Gabon	Both	38.5	38.8	37.8	9 337.7	3 412.7	1 320.2	302.5	102.4	37.4	16.2	3.7
	F				4 241.4	3 134.8	635.5	293.9	46.6	34.4	7.8	3.6
	M				5 096.3	3 684.6	684.7	311.1	55.9	40.4	8.4	3.8
Gambia	Both	32.2	31.7	32.3	16 104.3	4 467.4	1 452.4	255.8	177.3	49.2	17.3	3.1
	F				7 641.2	4 282.0	840.0	298.5	84.2	47.2	10.0	3.6
	M				8 463.0	4 649.3	612.4	213.9	93.1	51.2	7.3	2.6
Georgia	Both	21.2	17.9	24.0	662.8	244.4	235.7	49.9	7.2	2.7	2.8	0.6
	F				330.1	252.8	86.9	38.9	3.6	2.7	1.0	0.5
	M				332.7	236.6	148.7	59.6	3.6	2.6	1.8	0.7
Germany	Both	11.7	10.5	11.9	487.6	13.7	137.5	1.9	5.2	0.1	1.5	0.0
	F				221.7	12.8	51.1	1.5	2.4	0.1	0.5	0.0
	M				265.9	14.6	86.4	2.4	2.8	0.2	1.0	0.0
Ghana	Both	31.9	34.0	31.1	132 424.2	3 241.5	13 607.8	199.4	1 454.6	35.6	163.1	2.4
	F				58 899.7	2 944.6	6 977.2	209.1	646.9	32.3	83.6	2.5
	M				73 524.5	3 526.3	6 630.6	190.1	807.7	38.7	79.5	2.3
Greece	Both	15.7	13.5	16.4	209.0	44.1	32.2	2.9	2.3	0.5	0.4	0.0

	F				95.2	41.5	14.6	2.7	1.0	0.5	0.2	0.0
	M				113.8	46.6	17.6	3.0	1.2	0.5	0.2	0.0
Grenada	Both	21.6	20.4	21.8	64.8	656.6	2.1	11.6	0.7	7.1	0.0	0.1
	F				30.5	633.5	0.1	1.7	0.3	6.9	0.0	0.0
	M				34.3	678.5	2.0	21.1	0.4	7.4	0.0	0.2
Guatemala	Both	23.6	21.0	24.2	33 930.6	1 677.5	2 561.5	65.8	371.2	18.4	30.6	0.8
	F				15 724.5	1 589.9	1 272.7	66.8	172.0	17.4	15.2	0.8
	M				18 206.1	1 761.4	1 288.8	64.9	199.2	19.3	15.4	0.8
Guinea	Both	22.4	22.6	22.2	114 271.7	5 762.9	12 485.4	380.5	1 255.6	63.3	149.5	4.6
	F				54 110.4	5 492.7	7 599.1	466.5	594.8	60.4	90.9	5.6
	M				60 161.3	6 029.7	4 886.2	295.8	660.8	66.2	58.6	3.5
Guinea-Bissau	Both	27.1	27.6	26.5	20 053.3	6 895.0	1 125.1	242.1	221.1	76.0	13.5	2.9
	F				9 528.5	6 581.2	587.9	253.1	105.1	72.6	7.0	3.0
	M				10 524.9	7 206.1	537.3	231.1	116.1	79.5	6.4	2.8
Guyana	Both	20.5	17.4	21.6	702.5	919.3	122.6	81.2	7.7	10.0	1.5	1.0
	F				325.6	874.3	53.1	72.2	3.6	9.6	0.6	0.9
	M				376.9	962.0	69.5	89.6	4.1	10.5	0.8	1.1
Haiti	Both	14.6	13.3	14.7	49 247.9	3 992.8	3 714.0	155.8	540.6	43.8	44.4	1.9
	F				22 195.9	3 670.9	1 570.6	133.9	243.7	40.3	18.8	1.6
	M				27 052.0	4 302.3	2 143.4	177.1	296.9	47.2	25.6	2.1
Honduras	Both	20.1	18.9	21.5	6 832.2	718.2	276.6	13.9	74.7	7.8	3.2	0.2
	F				3 055.7	655.5	78.0	8.0	33.4	7.2	0.9	0.1
	M				3 776.4	778.5	198.6	19.6	41.3	8.5	2.4	0.2
Hungary	Both	15.6	14.4	16.3	303.6	69.6	12.8	1.3	3.2	0.7	0.0	0.0
	F				127.2	60.2	6.1	1.3	1.3	0.6	0.0	0.0
	M				176.4	78.6	6.7	1.4	1.9	0.8	0.0	0.0
Iceland	Both	5.9	6.0	5.9	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0
	F				0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0

	M				0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0
India	Both	65.2	55.9	68.0	5 560 430.5	4 633.8	368 945.7	145.6	60 987.2	50.8	4 360.5	1.7
	F				2 996 229.5	5 270.4	205 376.5	171.5	32 889.5	57.9	2 441.7	2.0
	M				2 564 201.0	4 060.6	163 569.2	122.4	28 097.7	44.5	1 918.9	1.4
Indonesia	Both	15.6	13.2	16.4	265 856.9	1 071.1	16 089.2	34.0	2 902.5	11.7	187.5	0.4
	F				130 505.2	1 076.1	7 446.9	32.2	1 425.5	11.8	86.4	0.4
	M				135 351.7	1 066.2	8 642.3	35.6	1 477.0	11.6	101.1	0.4
Iran (Islamic Republic of)	Both	35.1	35.6	34.4	64 015.8	938.3	2 711.3	22.3	698.5	10.2	29.9	0.2
	F				33 860.4	1 014.1	1 344.0	22.5	370.0	11.1	14.8	0.2
	M				30 155.4	865.6	1 367.3	22.0	328.5	9.4	15.1	0.2
Iraq	Both	57.7	54.8	60.1	181 782.9	3 168.3	3 681.5	39.4	1 988.9	34.7	41.6	0.4
	F				59 381.7	2 129.3	1 993.5	43.9	650.6	23.3	22.7	0.5
	M				122 401.2	4 150.9	1 688.0	35.1	1 338.3	45.4	18.9	0.4
Ireland	Both	8.3	7.6	8.7	31.3	9.1	3.4	0.5	0.3	0.1	0.0	0.0
	F				13.5	8.1	2.7	0.8	0.1	0.1	0.0	0.0
	M				17.8	10.1	0.7	0.2	0.2	0.1	0.0	0.0
Israel	Both	19.5	21.1	19.4	148.5	17.7	58.7	4.1	1.6	0.2	0.7	0.0
	F				72.5	17.7	25.5	3.6	0.8	0.2	0.3	0.0
	M				76.0	17.6	33.3	4.5	0.8	0.2	0.4	0.1
Italy	Both	15.3	11.1	15.7	279.8	11.3	63.8	1.1	3.0	0.1	0.7	0.0
	F				125.5	10.4	43.0	1.6	1.3	0.1	0.5	0.0
	M				154.2	12.1	20.8	0.7	1.6	0.1	0.2	0.0
Jamaica	Both	13.3	12.5	13.6	316.6	154.4	48.6	10.6	3.4	1.7	0.5	0.1
	F				144.1	144.9	24.0	10.7	1.5	1.6	0.3	0.1
	M				172.6	163.4	24.6	10.6	1.9	1.8	0.3	0.1

Japan	Both	11.4	9.3	11.8	1 882.6	35.2	527.3	4.7	20.2	0.4	5.4	0.0
	F				885.3	34.1	216.7	4.0	9.5	0.4	2.2	0.0
	M				997.2	36.3	310.6	5.4	10.7	0.4	3.2	0.1
Jordan	Both	32.1	38.0	31.7	8 581.1	699.3	672.2	31.2	93.5	7.6	7.8	0.4
	F				4 112.6	684.8	388.5	36.5	44.8	7.5	4.5	0.4
	M				4 468.5	713.2	283.7	26.0	48.6	7.8	3.2	0.3
Kazakhstan	Both	11.3	10.4	14.5	5 701.0	285.5	390.6	13.3	62.1	3.1	4.4	0.2
	F				2 567.9	264.5	187.5	13.1	28.0	2.9	2.1	0.1
	M				3 133.1	305.3	203.1	13.5	34.1	3.3	2.3	0.2
Kenya	Both	25.9	26.1	25.8	215 951.5	3 074.8	13 977.7	109.3	2 370.7	33.8	167.5	1.3
	F				104 676.1	3 011.9	5 498.3	86.6	1 149.5	33.1	65.7	1.0
	M				111 275.4	3 136.3	8 479.4	131.6	1 221.2	34.4	101.8	1.6
Kiribati	Both	10.5	10.4	10.9	283.7	1 958.7	16.6	65.7	3.1	21.5	0.2	0.8
	F				136.5	1 932.1	4.8	38.6	1.5	21.2	0.1	0.4
	M				147.2	1 984.1	11.9	91.7	1.6	21.8	0.1	1.1
Kuwait	Both	57.2	52.5	58.9	1 046.9	331.2	219.3	41.1	11.4	3.6	2.5	0.5
	F				517.5	334.8	99.8	39.0	5.6	3.6	1.1	0.4
	M				529.4	327.7	119.5	43.0	5.7	3.6	1.4	0.5
Kyrgyzstan	Both	18.1	18.7	17.4	10 768.6	1 416.0	448.8	40.2	117.7	15.5	5.2	0.5
	F				4 973.2	1 344.2	196.4	35.9	54.3	14.7	2.2	0.4
	M				5 795.4	1 484.0	252.4	44.3	63.3	16.2	2.9	0.5
Lao People's Democratic Republic	Both	24.5	23.7	25.5	33 457.6	4 370.1	2 398.2	161.7	366.7	47.9	28.4	1.9
	F				16 173.4	4 314.4	1 085.7	149.4	177.4	47.3	12.8	1.8
	M				17 284.2	4 423.4	1 312.5	173.6	189.3	48.4	15.5	2.1
Latvia	Both	12.7	10.8	14.4	66.6	68.8	3.6	1.8	0.7	0.7	0.0	0.0
	F				31.8	67.7	1.7	1.7	0.3	0.7	0.0	0.0
	M				34.8	69.8	1.9	1.8	0.4	0.7	0.0	0.0

Lebanon	Both	30.7	29.7	30.7	937.8	194.1	69.3	7.4	10.1	2.1	0.6	0.1
	F				516.4	217.0	37.1	7.9	5.6	2.3	0.3	0.1
	M				421.4	171.8	32.1	7.0	4.5	1.9	0.3	0.1
Lesotho	Both	27.8	27.3	28.1	17 410.3	6 089.3	1 225.1	246.4	190.7	66.7	14.6	2.9
	F				8 789.9	6 191.7	681.4	275.5	96.3	67.8	8.2	3.3
	M				8 620.5	5 988.2	543.7	217.7	94.4	65.6	6.5	2.6
Liberia	Both	17.2	17.4	17.0	24 483.1	3 421.9	1 996.1	162.6	268.2	37.5	24.0	2.0
	F				12 191.9	3 482.8	1 088.0	181.1	133.6	38.2	13.1	2.2
	M				12 291.1	3 363.5	908.1	144.9	134.6	36.8	10.9	1.7
Libya	Both	44.2	44.9	41.7	4 146.2	661.8	735.2	63.3	45.3	7.2	8.4	0.7
	F				2 155.4	705.9	354.6	62.6	23.5	7.7	4.0	0.7
	M				1 990.8	619.8	380.6	64.0	21.7	6.8	4.4	0.7
Lithuania	Both	11.5	10.9	12.3	66.7	43.9	3.9	1.4	0.7	0.5	0.0	0.0
	F				34.1	46.0	1.9	1.4	0.4	0.5	0.0	0.0
	M				32.6	41.8	2.0	1.4	0.3	0.4	0.0	0.0
Luxembourg	Both	10.2	8.8	10.4	1.0	3.1	0.1	0.1	0.0	0.0	0.0	0.0
	F				0.4	2.8	0.0	0.1	0.0	0.0	0.0	0.0
	M				0.5	3.3	0.0	0.1	0.0	0.0	0.0	0.0
Madagascar	Both	21.4	20.7	22.5	111 123.1	2 948.7	14 298.0	219.6	1 218.9	32.3	171.2	2.6
	F				54 845.3	2 946.9	6 740.7	208.3	601.8	32.3	80.5	2.5
	M				56 277.8	2 950.4	7 557.3	230.8	617.0	32.3	90.6	2.8
Malawi	Both	22.1	23.3	21.9	78 573.0	2 701.7	4 617.6	90.5	861.8	29.6	55.1	1.1
	F				36 320.7	2 526.5	2 056.0	81.1	398.3	27.7	24.4	1.0
	M				42 252.3	2 873.0	2 561.5	99.9	463.4	31.5	30.7	1.2
Malaysia	Both	16.0	11.6	17.3	3 312.3	126.8	1,170.5	23.1	35.8	1.4	13.8	0.3
	F				1 425.4	113.1	509.3	20.7	15.4	1.2	6.0	0.2
	M				1 886.9	139.6	661.2	25.4	20.4	1.5	7.9	0.3
Maldives	Both	7.6	7.6	7.7	28.2	72.3	4.2	6.8	0.3	0.8	0.0	0.1

	F				15.2	81.3	2.2	7.5	0.2	0.9	0.0	0.1
	M				13.0	64.0	1.9	6.2	0.1	0.7	0.0	0.1
Mali	Both	31.2	32.7	29.0	248 818.1	7 467.3	16 723.2	317.0	2 737.2	82.1	199.4	3.8
	F				126 586.9	7 736.3	9 540.6	367.5	1 393.1	85.1	113.8	4.4
	M				122 231.3	7 207.7	7 182.6	268.0	1 344.2	79.3	85.6	3.2
Malta	Both	14.0	10.1	14.0	9.1	42.2	0.1	0.1	0.1	0.5	0.0	0.0
	F				4.6	43.9	0.0	0.1	0.1	0.5	0.0	0.0
	M				4.5	40.5	0.0	0.1	0.0	0.4	0.0	0.0
Marshall Islands	Both	9.4	9.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA
Mauritania	Both	40.8	40.0	41.7	46 817.5	7 146.5	2 088.2	195.2	515.1	78.6	24.8	2.3
	F				19 235.3	5 982.5	1 172.9	222.6	211.7	65.8	13.9	2.6
	M				27 582.2	8 268.4	915.3	168.6	303.5	91.0	10.9	2.0
Mauritius	Both	13.5	14.9	13.5	155.6	228.4	28.0	16.4	1.7	2.5	0.3	0.2
	F				65.9	197.4	16.1	19.2	0.7	2.1	0.2	0.2
	M				89.7	258.2	11.9	13.7	1.0	2.8	0.1	0.2
Mexico	Both	20.1	14.4	20.9	57 023.4	492.4	2 449.4	10.7	623.2	5.4	29.0	0.1
	F				26 372.7	466.0	1 107.7	9.9	288.2	5.1	13.0	0.1
	M				30 650.7	517.6	1 341.7	11.4	334.9	5.7	16.0	0.1
Micronesia (Federated States of)	Both	10.2	10.1	10.5	116.4	999.6	10.7	45.4	1.3	10.9	0.1	0.5
	F				53.4	948.9	4.5	39.3	0.6	10.4	0.1	0.5
	M				63.0	1 047.0	6.2	51.1	0.7	11.5	0.1	0.6
Monaco	Both	12.2	NA	12.2	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA

Mongolia	Both	40.4	36.9	49.5	4 467.1	1 215.3	413.2	79.5	48.7	13.2	4.8	0.9
	F				1 608.8	886.9	170.3	66.3	17.5	9.7	2.0	0.8
	M				2 858.3	1 535.2	242.9	92.5	31.2	16.7	2.8	1.1
Montenegro	Both	20.2	20.6	19.3	19.6	54.1	9.4	11.9	0.2	0.5	0.1	0.1
	F				8.6	49.1	4.8	12.8	0.1	0.5	0.0	0.1
	M				11.0	58.8	4.5	11.1	0.1	0.6	0.0	0.1
Morocco	Both	31.0	30.4	31.1	48 582.1	1 384.7	2 072.4	33.3	531.5	15.1	23.9	0.4
	F				22 119.4	1 296.0	1 070.0	35.3	242.3	14.2	12.4	0.4
	M				26 462.6	1 468.8	1 002.4	31.5	289.2	16.1	11.5	0.4
Mozambique	Both	19.4	20.1	18.4	174 278.2	3 520.8	15 233.8	189.7	1 908.5	38.6	183.5	2.3
	F				85 623.6	3 486.0	7 451.6	186.2	937.8	38.2	89.7	2.2
	M				88 654.6	3 555.1	7 782.2	193.3	970.7	38.9	93.8	2.3
Myanmar	Both	34.7	34.8	34.6	205 998.5	4 539.6	15 630.7	157.3	2 258.5	49.8	185.8	1.9
	F				92 061.5	4 085.8	5 573.1	112.8	1 010.9	44.9	66.1	1.3
	M				113 936.9	4 987.1	10 057.6	201.2	1 247.6	54.6	119.7	2.4
Namibia	Both	22.6	24.0	21.0	9 710.1	2 821.7	884.3	154.9	106.6	31.0	10.6	1.9
	F				4 613.1	2 699.0	395.9	139.0	50.6	29.6	4.7	1.7
	M				5 096.9	2 942.8	488.4	170.9	56.0	32.3	5.9	2.1
Nauru	Both	12.5	10.0	12.5	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA
Nepal	Both	94.3	68.3	99.5	115 948.0	4 206.8	7 958.3	123.9	1 268.4	46.0	93.7	1.5
	F				51 581.9	3 863.0	4 026.1	128.5	564.3	42.3	47.5	1.5
	M				64 366.1	4 530.0	3 932.2	119.4	704.1	49.6	46.2	1.4
Netherlands	Both	12.1	11.0	12.1	106.7	11.9	72.5	3.8	1.2	0.1	0.8	0.0
	F				46.4	10.7	50.6	5.4	0.5	0.1	0.6	0.1
	M				60.3	13.1	21.9	2.2	0.7	0.1	0.2	0.0
New Zealand	Both	5.7	5.2	5.8	82.5	27.1	7.6	1.2	0.9	0.3	0.1	0.0

	F				39.2	26.4	3.5	1.2	0.4	0.3	0.0	0.0
	M				43.3	27.8	4.1	1.3	0.5	0.3	0.0	0.0
Nicaragua	Both	16.9	14.6	19.0	6 290.0	1 053.1	452.9	37.2	68.8	11.5	5.5	0.4
	F				2 417.2	827.6	214.0	36.2	26.4	9.0	2.6	0.4
	M				3 872.8	1 268.9	238.8	38.1	42.4	13.9	2.9	0.5
Niger	Both	70.8	69.7	73.0	545 182.9	12 925.6	77 215.2	1 252.2	6 014.2	142.6	929.3	15.1
	F				277 404.3	13 442.9	40 120.8	1 327.8	3 062.3	148.4	482.8	16.0
	M				267 778.6	12 430.0	37 094.4	1 179.5	2 951.9	137.0	446.5	14.2
Nigeria	Both	48.7	56.5	46.3	4 330 967.5	13 618.7	486 606.3	969.4	47 674.7	149.9	5 810.7	11.6
	F				1 996 787.6	12 877.7	278 996.4	1 135.2	21 994.6	141.8	3 330.2	13.6
	M				2 334 180.0	14 323.9	207 609.9	810.4	25 680.1	157.6	2 480.5	9.7
Niue	Both	11.5	11.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA
Norway	Both	7.0	6.4	7.8	15.5	5.1	2.6	0.4	0.2	0.1	0.0	0.0
	F				6.4	4.3	0.5	0.2	0.1	0.0	0.0	0.0
	M				9.1	5.8	2.1	0.7	0.1	0.1	0.0	0.0
Oman	Both	38.2	40.0	36.2	1 380.0	344.9	132.8	23.2	15.0	3.7	1.4	0.2
	F				794.5	408.8	68.1	24.0	8.6	4.4	0.7	0.3
	M				585.6	284.5	64.7	22.3	6.3	3.1	0.7	0.2
Pakistan	Both	55.2	52.0	56.2	1 928 216.0	7 724.4	93 060.9	219.2	21 136.9	84.7	1 110.8	2.6
	F				975 687.2	8 129.1	35 489.6	173.8	10 699.8	89.1	422.3	2.1
	M				952 528.8	7 349.6	57 571.3	261.4	10 437.1	80.5	688.5	3.1
Palau	Both	12.2	12.0	12.4	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA

Panama	Both	11.2	9.4	12.0	1 642.7	423.0	148.3	20.4	17.9	4.6	1.8	0.2
	F				713.3	375.3	65.1	18.3	7.8	4.1	0.8	0.2
	M				929.3	468.7	83.2	22.4	10.1	5.1	1.0	0.3
Papua New Guinea	Both	10.9	10.8	11.5	18 250.9	1 767.3	1 273.6	67.0	199.6	19.3	15.0	0.8
	F				7 956.8	1 595.6	443.8	48.3	87.0	17.4	5.2	0.6
	M				10 294.1	1 927.7	829.9	84.6	112.6	21.1	9.8	1.0
Paraguay	Both	11.2	10.2	11.7	2 865.3	426.6	300.0	22.6	31.2	4.6	3.3	0.3
	F				1 286.8	390.9	144.0	22.1	14.0	4.3	1.6	0.2
	M				1 578.5	460.9	156.0	23.1	17.2	5.0	1.8	0.3
Peru	Both	24.3	18.4	29.0	17 394.2	573.6	5 134.5	89.2	189.7	6.3	61.1	1.1
	F				7 802.9	525.6	2 295.6	81.5	85.1	5.7	27.3	1.0
	M				9 591.3	619.6	2 838.9	96.7	104.6	6.8	33.8	1.2
Philippines	Both	18.4	14.0	18.7	173 752.3	1 506.9	25 630.5	119.2	1 904.2	16.5	308.8	1.4
	F				80 151.2	1 431.7	11 809.2	112.9	878.8	15.7	141.9	1.4
	M				93 601.1	1 577.9	13 821.4	125.2	1 025.5	17.3	166.9	1.5
Poland	Both	20.5	18.0	21.5	1 403.7	77.2	595.6	15.5	15.1	0.8	6.9	0.2
	F				625.5	70.7	281.8	15.1	6.7	0.8	3.3	0.2
	M				778.2	83.3	313.8	15.9	8.4	0.9	3.6	0.2
Portugal	Both	7.9	7.1	8.1	95.0	22.0	9.7	1.0	1.0	0.2	0.1	0.0
	F				43.7	21.0	3.5	0.7	0.5	0.2	0.0	0.0
	M				51.3	23.0	6.3	1.2	0.6	0.3	0.1	0.0
Qatar	Both	90.3	81.3	91.7	385.3	296.5	62.4	27.5	4.2	3.2	0.7	0.3
	F				150.5	236.1	24.9	22.6	1.6	2.5	0.3	0.2
	M				234.8	354.6	37.5	32.3	2.5	3.8	0.4	0.4
Republic of Korea	Both	24.6	23.7	24.7	645.2	29.0	163.6	3.5	6.6	0.3	1.2	0.0
	F				319.2	29.8	72.6	3.2	3.3	0.3	0.5	0.0
	M				326.0	28.3	90.9	3.7	3.3	0.3	0.7	0.0

Republic of Moldova	Both	16.0	15.2	16.5	1 656.5	760.4	109.3	26.0	18.0	8.3	1.2	0.3
	F				709.3	675.2	48.9	24.0	7.7	7.4	0.5	0.3
	M				947.2	839.8	60.3	27.9	10.3	9.1	0.7	0.3
Romania	Both	14.3	12.7	15.4	6 136.0	649.9	623.5	29.9	66.9	7.1	7.2	0.3
	F				2 759.5	600.6	323.4	31.9	30.1	6.5	3.8	0.4
	M				3 376.5	696.6	300.0	28.0	36.8	7.6	3.5	0.3
Russian Federation	Both	13.7	12.2	14.7	11 757.3	123.0	2 015.2	13.1	126.3	1.3	21.4	0.1
	F				5 386.8	115.9	1 006.5	13.5	57.8	1.2	10.8	0.1
	M				6 370.5	129.6	1 008.7	12.8	68.4	1.4	10.6	0.1
Rwanda	Both	40.7	44.0	40.7	44 833.3	2 577.0	8 471.6	274.8	491.3	28.2	101.7	3.3
	F				20 259.5	2 338.0	3 931.9	254.3	222.0	25.6	47.2	3.0
	M				24 573.8	2 814.2	4 539.8	295.4	269.3	30.8	54.5	3.5
Saint Kitts and Nevis	Both	12.3	12.3	12.3	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA
Saint Lucia	Both	21.2	19.0	21.2	37.3	340.6	1.4	5.8	0.4	3.7	0.0	0.0
	F				18.1	334.8	1.1	9.7	0.2	3.6	0.0	0.1
	M				19.2	346.3	0.2	2.0	0.2	3.8	0.0	0.0
Saint Vincent and the Grenadines	Both	21.2	19.7	21.4	56.7	683.0	4.3	24.0	0.6	7.4	0.1	0.3
	F				27.5	669.5	2.2	24.4	0.3	7.3	0.0	0.3
	M				29.3	696.2	2.2	23.6	0.3	7.6	0.0	0.3
Samoa	Both	10.6	10.2	10.9	71.7	305.2	10.2	21.1	0.8	3.3	0.1	0.2
	F				29.1	256.7	4.0	17.3	0.3	2.8	0.0	0.2
	M				42.6	350.5	6.2	24.7	0.5	3.8	0.1	0.3

San Marino	Both	13.4	NA	13.4	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA
Sao Tome and Principe	Both	25.7	26.3	25.2	544.1	1 736.7	122.3	222.4	6.0	19.0	1.4	2.6
	F				225.2	1 450.3	58.9	215.8	2.5	15.9	0.7	2.6
	M				318.9	2 018.1	63.4	228.9	3.5	22.1	0.8	2.7
Saudi Arabia	Both	78.4	75.1	86.7	16 146.4	544.4	1 854.7	35.2	176.7	6.0	20.7	0.4
	F				7 905.3	541.1	1 028.9	39.6	86.5	5.9	11.5	0.4
	M				8 241.1	547.7	825.8	30.8	90.2	6.0	9.1	0.3
Senegal	Both	37.5	35.2	39.7	93 893.9	3 690.3	11 931.3	292.3	1 030.6	40.5	143.3	3.5
	F				42 660.2	3 399.8	6 145.4	304.7	468.6	37.3	73.7	3.7
	M				51 233.7	3 973.0	5 785.9	280.2	562.0	43.6	69.7	3.4
Serbia	Both	24.3	23.0	24.7	388.2	82.8	51.5	5.2	4.1	0.9	0.5	0.1
	F				173.2	75.6	21.6	4.5	1.8	0.8	0.2	-
	M				215.0	89.6	29.8	5.9	2.3	1.0	0.3	0.1
Seychelles	Both	18.7	19.0	18.6	21.4	272.7	10.5	81.6	0.2	3.0	0.1	1.0
	F				8.6	224.8	4.8	74.2	0.1	2.4	0.1	0.9
	M				12.7	318.7	5.8	89.0	0.1	3.5	0.1	1.1
Sierra Leone	Both	20.6	20.7	20.6	63 466.9	5 563.1	7 217.0	361.5	695.0	60.9	86.0	4.3
	F				30 738.8	5 405.9	3 832.8	383.0	336.6	59.2	45.6	4.6
	M				32 728.1	5 719.3	3 384.3	340.0	358.4	62.6	40.3	4.1
Singapore	Both	18.3	12.7	18.3	213.1	80.3	17.9	3.0	2.3	0.9	0.2	0.0
	F				89.0	69.7	10.4	3.6	1.0	0.8	0.1	0.0
	M				124.1	90.1	7.5	2.5	1.3	1.0	0.1	0.0
Slovakia	Both	17.5	16.4	18.0	503.7	179.1	99.6	18.1	5.5	1.9	1.2	0.2
	F				228.7	166.4	54.2	20.1	2.5	1.8	0.6	0.2
	M				275.0	191.1	45.5	16.1	3.0	2.1	0.5	0.2
Slovenia	Both	15.8	14.7	16.4	10.8	10.1	6.0	3.0	0.1	0.1	0.1	0.0

	F				5.4	10.4	0.8	0.9	0.1	0.1	0.0	0.0
	M				5.4	9.8	5.2	5.0	0.0	0.1	0.1	0.0
Solomon Islands	Both	10.7	10.6	11.5	745.1	900.4	39.5	26.0	8.1	9.8	0.5	0.3
	F				365.1	910.9	16.3	22.1	4.0	9.9	0.2	0.3
	M				380.0	890.6	23.2	29.6	4.2	9.7	0.3	0.3
Somalia	Both	29.5	29.9	28.0	385 089.7	14 714.7	22 838.9	564.4	4 241.5	162.1	272.4	6.7
	F				185 858.5	14 323.6	11 821.5	587.0	2 047.4	157.8	140.9	7.0
	M				199 231.2	15 099.3	11 017.3	542.0	2 194.1	166.3	131.5	6.5
South Africa	Both	23.6	20.9	24.3	159 530.4	2 796.4	10 686.9	100.4	1 743.2	30.6	127.7	1.2
	F				74 588.8	2 642.3	4 634.3	87.8	815.1	28.9	55.1	1.0
	M				84 941.6	2 947.3	6 052.6	113.0	928.2	32.2	72.6	1.4
South Sudan	Both	41.1	41.1	40.9	205 630.5	10 681.8	9 267.5	289.9	2 265.4	117.7	110.6	3.5
	F				99 177.9	10 458.9	4 687.2	296.8	1 092.9	115.3	55.9	3.5
	M				106 452.6	10 898.3	4 580.3	283.1	1 172.6	120.0	54.7	3.4
Spain	Both	9.5	8.3	9.8	235.3	11.4	37.1	0.8	2.5	0.1	0.4	0.0
	F				111.5	11.1	24.8	1.1	1.2	0.1	0.3	0.0
	M				123.8	11.6	12.2	0.5	1.3	0.1	0.1	0.0
Sri Lanka	Both	15.2	17.3	15.1	1 913.9	119.5	617.8	17.9	20.7	1.3	7.1	0.2
	F				792.1	100.6	315.9	18.4	8.6	1.1	3.7	0.2
	M				1 121.8	137.8	301.9	17.4	12.1	1.5	3.5	0.2
Sudan	Both	47.9	48.3	46.8	346 987.7	5 841.2	15 068.4	145.6	3 829.3	64.5	178.4	1.7
	F				197 254.8	6 755.9	7 456.8	146.3	2 177.0	74.6	88.4	1.7
	M				149 732.9	4 957.1	7 611.6	144.8	1 652.2	54.7	90.0	1.7
Suriname	Both	23.6	19.4	25.8	250.4	497.6	26.0	26.4	2.7	5.4	0.3	0.3
	F				107.4	442.2	11.9	25.0	1.2	4.8	0.1	0.3
	M				143.0	549.4	14.1	27.6	1.6	6.0	0.2	0.3
Sweden	Both	5.9	5.4	6.1	42.0	7.2	16.6	1.5	0.5	0.1	0.2	0.0
	F				16.8	5.9	4.8	0.9	0.2	0.1	0.1	0.0

	M				25.2	8.4	11.8	2.0	0.3	0.1	0.1	0.0
Switzerland	Both	10.2	8.6	10.4	43.3	10.0	8.4	1.0	0.5	0.1	0.1	0.0
	F				19.4	9.2	6.7	1.7	0.2	0.1	0.1	0.0
	M				23.9	10.7	1.7	0.4	0.3	0.1	0.0	0.0
Syrian Arab Republic	Both	39.4	49.2	37.4	18 592.1	885.5	4 051.8	84.6	203.6	9.7	47.8	1.0
	F				8 281.0	809.8	2 258.2	96.7	90.7	8.9	26.7	1.1
	M				10 311.1	957.4	1 793.6	73.1	112.9	10.5	21.0	0.9
Tajikistan	Both	40.0	37.8	42.8	49 135.8	4 153.5	3 787.6	200.5	536.9	45.4	44.1	2.3
	F				23 175.8	4 024.1	1 867.1	203.1	253.3	44.0	21.8	2.4
	M				25 959.9	4 276.3	1 920.5	198.1	283.6	46.7	22.4	2.3
Thailand	Both	26.2	25.2	26.6	13 971.7	370.8	2 541.5	30.3	152.1	4.0	29.8	0.4
	F				5 898.3	321.9	828.5	20.3	64.3	3.5	9.5	0.2
	M				8 073.4	417.1	1 713.1	39.7	87.9	4.5	20.3	0.5
The former Yugoslav Republic of Macedonia	Both	28.3	24.6	33.0	405.1	343.4	26.1	11.3	4.4	3.7	0.2	0.1
	F				194.7	339.1	2.9	2.5	2.1	3.7	0.0	0.0
	M				210.4	347.4	23.3	19.6	2.3	3.7	0.2	0.2
Timor-Leste	Both	17.9	17.2	18.2	7 316.2	3 549.9	295.4	84.7	80.1	38.8	3.5	1.0
	F				3 747.9	3 710.8	161.7	94.6	41.0	40.6	1.9	1.1
	M				3 568.3	3 395.4	133.7	75.1	39.0	37.1	1.6	0.9
Togo	Both	32.7	35.1	31.2	65 377.8	5 560.0	9 176.9	457.6	718.5	61.1	110.3	5.5
	F				28 670.6	4 891.1	5 227.8	522.8	315.2	53.8	62.8	6.3
	M				36 707.2	6 224.8	3 949.1	392.7	403.3	68.4	47.5	4.7
Tonga	Both	10.1	9.9	10.2	41.9	330.0	5.6	21.4	0.5	3.6	0.1	0.2
	F				23.9	386.3	2.2	17.3	0.3	4.2	0.0	0.2
	M				18.0	276.5	3.4	25.3	0.2	3.0	0.0	0.3

Trinidad and Tobago	Both	22.0	20.9	22.4	464.1	490.8	27.0	14.3	5.0	5.3	0.3	0.2
	F				213.9	459.9	7.0	7.5	2.3	5.0	0.1	0.1
	M				250.2	520.7	20.0	21.0	2.7	5.7	0.2	0.2
Tunisia	Both	35.7	35.5	35.7	5 505.9	523.6	694.4	41.5	60.0	5.7	7.9	0.5
	F				2 825.9	550.1	414.5	50.6	30.8	6.0	4.8	0.6
	M				2 680.0	498.4	280.0	32.7	29.2	5.4	3.1	0.4
Turkey	Both	42.0	43.2	41.2	17 035.1	251.5	2 769.7	20.8	184.7	2.7	31.2	0.2
	F				8 288.6	250.6	1 223.3	18.7	89.9	2.7	13.6	0.2
	M				8 746.5	252.2	1 546.4	22.7	94.7	2.7	17.5	0.3
Turkmenistan	Both	19.0	18.0	24.2	19 238.8	2 712.4	641.9	61.9	210.6	29.7	7.6	0.7
	F				8 186.1	2 343.3	273.3	53.4	89.6	25.7	3.2	0.6
	M				11 052.7	3 070.5	368.7	70.3	121.0	33.6	4.4	0.8
Tuvalu	Both	11.4	11.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
	F				NA	NA	NA	NA	NA	NA	NA	NA
	M				NA	NA	NA	NA	NA	NA	NA	NA
Uganda	Both	48.4	47.1	48.7	405 794.7	5 270.8	54 975.3	450.3	4 456.2	57.9	659.9	5.4
	F				187 496.0	4 917.1	26 635.4	439.5	2 057.7	54.0	319.6	5.3
	M				218 298.8	5 618.0	28 339.8	460.9	2 398.5	61.7	340.3	5.5
Ukraine	Both	18.3	16.7	19.4	5 379.3	230.5	494.5	11.2	58.1	2.5	4.8	0.1
	F				2 864.5	253.2	251.9	11.7	31.0	2.7	2.5	0.1
	M				2 514.7	209.1	242.7	10.6	27.1	2.3	2.3	0.1
United Arab Emirates	Both	39.4	40.2	37.2	826.1	178.1	63.3	7.7	8.8	1.9	0.6	0.1
	F				464.4	204.5	21.0	5.2	5.0	2.2	0.2	0.0
	M				361.7	152.7	42.3	10.1	3.8	1.6	0.4	0.1
United Kingdom	Both	10.5	8.4	10.6	1,201.2	30.0	218.7	2.9	13.1	0.3	2.5	0.0
	F				551.8	28.3	98.1	2.6	6.0	0.3	1.1	0.0

	M				649.4	31.7	120.7	3.1	7.1	0.3	1.4	0.0
United Republic of Tanzania	Both	25.6	26.4	25.1	349 813.8	3 623.0	38 743.3	251.6	3 841.4	39.8	461.5	3.0
	F				170 825.3	3 572.0	19 573.9	255.0	1 875.9	39.2	233.0	3.0
	M				178 988.5	3 673.0	19 169.4	248.2	1 965.5	40.3	228.5	3.0
United States of America	Both	7.4	6.7	7.6	4 106.7	20.9	780.7	1.9	44.0	0.2	7.9	0.0
	F				1 880.0	19.6	359.9	1.8	20.2	0.2	3.6	0.0
	M				2 226.8	22.2	420.8	2.0	23.8	0.2	4.3	0.0
Uruguay	Both	8.6	8.0	8.7	132.5	55.3	10.8	2.2	1.4	0.6	0.1	0.0
	F				57.9	49.3	3.0	1.3	0.6	0.5	0.0	0.0
	M				74.7	61.1	7.8	3.1	0.8	0.7	0.1	0.0
Uzbekistan	Both	25.3	22.3	28.9	42 403.4	1 331.7	6 865.0	122.3	462.4	14.5	81.3	1.4
	F				19 002.0	1 238.2	3 183.6	116.4	207.2	13.5	37.7	1.4
	M				23 401.4	1 418.6	3 681.4	127.9	255.2	15.5	43.6	1.5
Vanuatu	Both	10.3	10.1	11.0	244.9	711.6	18.5	29.2	2.7	7.8	0.2	0.3
	F				115.3	693.7	6.7	22.0	1.3	7.6	0.1	0.3
	M				129.6	728.3	11.8	35.7	1.4	7.9	0.1	0.4
Venezuela (Bolivarian Republic of)	Both	15.8	14.6	16.8	13 427.7	451.5	945.7	16.2	146.6	4.9	11.2	0.2
	F				5 822.2	400.5	399.7	14.0	63.6	4.4	4.7	0.2
	M				7 605.5	500.2	546.0	18.3	83.1	5.5	6.5	0.2
Viet Nam	Both	29.7	26.6	30.1	89 655.6	1 155.2	2 679.9	19.1	979.7	12.6	30.0	0.2
	F				35 201.1	958.1	875.3	13.0	384.5	10.5	9.4	0.1
	M				54 454.5	1 332.5	1 804.7	24.7	595.2	14.6	20.7	0.3
Yemen	Both	45.0	46.5	44.3	221 360.4	5 431.9	6 609.1	94.0	2 427.7	59.6	77.4	1.1
	F				126 048.6	6 323.9	3 465.8	100.6	1 382.6	69.4	40.7	1.2

	M				95 311.9	4 578.0	3 143.4	87.7	1 045.1	50.2	36.7	1.0
Zambia	Both	24.7	25.2	23.8	103 337.7	3 664.3	9 846.4	211.2	1 134.4	40.2	117.7	2.5
	F				49 165.1	3 519.4	4 660.9	201.2	539.9	38.6	55.7	2.4
	M				54 172.6	3 806.6	5 185.5	221.2	594.5	41.8	62.0	2.6
Zimbabwe	Both	19.4	19.5	19.1	69 229.9	2 726.2	9 044.7	218.3	760.2	29.9	108.5	2.6
	F				34 940.5	2 765.4	4 816.1	233.0	383.8	30.4	57.8	2.8
	M				34 289.5	2 687.4	4 228.6	203.6	376.4	29.5	50.7	2.4

NA, not available

F, females; M, males

Table 5. Exposure of children to household $PM_{2.5}$ and burden of disease, by country, 2016

Country	Sex	Households that rely primarily on clean cooking fuels (%)	Households that rely primarily on polluting fuels (%)	No. of DALYs (<5 years)	DALYs rate per 100 000 (< 5 year)	No. of DALYs (5 - 14 years)	DALYs rate per 100 000 (5 - 14 years)	No. of deaths (<5 years)	Death rate per 100 000 (< 5 years)	No. of deaths (5 - 14 years)	Death rate per 100 000 (5 - 14 years)
Afghanistan	Both	<5	68	536 072.8	10 244.4	38 386.5	385.1	5 895.7	112.7	456.2	4.6
	F			280 259.1	11 015.8	23 334.5	480.5	3 084.9	121.3	277.7	5.7

	M			255 813.7	9 514.4	15 052.0	294.5	2 810.8	104.5	178.5	3.5
Albania	Both	77	<5	961.1	541.9	157.8	46.2	10.4	5.8	1.8	0.5
	F			455.8	531.8	116.4	71.2	4.9	5.7	1.4	0.8
	M			505.4	551.3	41.4	23.3	5.4	5.9	0.4	0.3
Algeria	Both	93	7	20 107.2	427.9	885.4	12.5	220.2	4.7	10.3	0.1
	F			11 836.2	514.7	493.3	14.2	129.7	5.6	5.7	0.2
	M			8 271.0	344.7	392.1	10.9	90.5	3.8	4.5	0.1
Andorra	Both	>95	<5	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Angola	Both	<5	52	611 101.3	11 580.2	29 091.3	352.5	6 723.9	127.4	346.9	4.2
	F			320 272.3	12 190.6	15 335.7	368.1	3 526.9	134.2	182.8	4.4
	M			290 829.1	10 975.1	13 755.6	336.6	3 197.0	120.6	164.2	4.0
Antigua and Barbuda	Both	>95	<5	0.5	5.8	0.3	1.6	0.0	0.1	0.0	0.0
	F			0.2	4.6	0.0	0.1	0.0	0.0	0.0	0.0
	M			0.3	7.1	0.2	3.0	0.0	0.1	0.0	0.0
Argentina	Both	>95	<5	979.7	26.2	99.4	1.4	10.7	0.3	1.2	0.0
	F			445.7	24.3	55.8	1.6	4.8	0.3	0.7	0.0
	M			534.1	28.1	43.5	1.2	5.8	0.3	0.5	0.0
Armenia	Both	>95	<5	169.1	83.6	21.2	5.6	1.8	0.9	0.2	0.1
	F			78.2	82.6	10.6	6.0	0.9	0.9	0.1	0.1
	M			90.9	84.6	10.6	5.2	1.0	0.9	0.1	0.1
Australia	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Austria	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Azerbaijan	Both	>95	<5	3 262.8	366.4	286.8	21.0	35.6	4.0	3.4	0.2
	F			1 677.6	404.9	140.6	22.3	18.3	4.4	1.6	0.3
	M			1 585.1	332.9	146.2	20.0	17.3	3.6	1.7	0.2
Bahamas	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bahrain	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bangladesh	Both	<5	82	791 065.4	5 192.2	33 263.4	104.4	8 655.5	56.8	391.7	1.2
	F			355 050.2	4 764.0	20 364.5	130.7	3 885.5	52.1	241.0	1.5
	M			436 015.2	5 602.4	12 898.9	79.3	4 770.0	61.3	150.8	0.9
Barbados	Both	>95	<5	0.7	4.0	0.3	0.9	0.0	0.0	0.0	0.0
	F			0.3	3.9	0.1	0.3	0.0	0.0	0.0	0.0
	M			0.4	4.2	0.3	1.4	0.0	0.0	0.0	0.0
Belarus	Both	>95	<5	52.1	9.0	8.6	0.9	0.5	0.1	0.1	0.0
	F			23.0	8.2	4.5	0.9	0.2	0.1	0.0	0.0
	M			29.1	9.8	4.1	0.8	0.3	0.1	0.0	0.0
Belgium	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Belize	Both	85	<5	124.2	308.1	14.4	18.8	1.3	3.3	0.2	0.2
	F			61.2	306.9	6.3	16.7	0.7	3.3	0.1	0.2
	M			63.0	309.3	8.1	20.7	0.7	3.4	0.1	0.2
Benin	Both	6	94	285 483.2	16 079.5	28 648.8	993.0	3 139.6	176.8	342.7	11.9
	F			150 504.4	17 218.8	15 313.6	1 076.7	1 656.1	189.5	183.0	12.9
	M			134 978.8	14 974.7	13 335.2	911.7	1 483.5	164.6	159.7	10.9
Bhutan	Both	52	<5	2 332.0	3 340.2	227.3	156.7	25.5	36.5	2.7	1.9

	F			1 049.3	3 057.2	130.9	183.3	11.5	33.4	1.6	2.2
	M			1 282.7	3 613.9	96.5	130.9	14.0	39.5	1.2	1.6
Bolivia (Plurinational State of)	Both	80	<5	23 378.9	1 967.1	2 935.6	127.7	256.1	21.5	35.2	1.5
	F			10 966.6	1 884.1	1 503.4	133.1	120.1	20.6	18.0	1.6
	M			12 412.3	2 046.7	1 432.2	122.5	135.9	22.4	17.2	1.5
Bosnia and Herzegovina	Both	63	<5	291.9	186.3	30.1	8.8	3.1	2.0	0.2	0.1
	F			136.3	179.4	13.2	7.9	1.4	1.9	0.1	0.1
	M			155.6	192.7	16.9	9.6	1.6	2.0	0.1	0.1
Botswana	Both	64	<5	5 980.2	2 307.0	599.3	132.5	65.6	25.3	7.2	1.6
	F			2 885.6	2 249.3	291.2	129.7	31.6	24.7	3.5	1.5
	M			3 094.6	2 363.6	308.1	135.2	34.0	25.9	3.7	1.6
Brazil	Both	>95	<5	19 393.6	130.0	1 711.1	5.5	210.8	1.4	19.6	0.1
	F			8 962.2	123.0	888.5	5.8	97.4	1.3	10.1	0.1
	M			10 431.4	136.7	822.6	5.2	113.5	1.5	9.5	0.1
Brunei Darussalam	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bulgaria	Both	89	<5	400.5	123.5	74.2	10.9	4.3	1.3	0.9	0.1
	F			179.1	113.7	37.1	11.2	1.9	1.2	0.4	0.1
	M			221.4	132.8	37.1	10.6	2.4	1.4	0.4	0.1
Burkina Faso	Both	9	91	365 511.5	11 349.0	45 373.5	865.5	4 019.0	124.8	543.0	10.4
	F			173 377.7	10 959.8	25 996.9	1 009.9	1 907.4	120.6	311.0	12.1
	M			192 133.8	11 724.7	19 376.6	726.2	2 111.6	128.9	232.0	8.7
Burundi	Both	<5	>95	253 667.5	13 341.5	44 100.4	1 563.2	2 786.7	146.6	529.3	18.8
	F			121 156.3	12 827.4	24 410.2	1 724.6	1 331.5	141.0	292.9	20.7

	M			132 511.3	13 848.9	19 690.1	1 400.6	1 455.2	152.1	236.4	16.8
Cabo Verde	Both	71	<5	749.1	1,371.2	34.9	31.5	8.2	15.0	0.4	0.4
	F			338.5	1,254.0	17.9	32.5	3.7	13.7	0.2	0.4
	M			410.6	1,485.6	17.0	30.5	4.5	16.2	0.2	0.4
Cambodia	Both	<5	82	85 859.8	4 874.9	7 697.8	241.6	937.4	53.2	90.6	2.8
	F			38 932.6	4 493.1	3 506.9	224.3	425.3	49.1	41.2	2.6
	M			46 927.2	5 244.6	4 190.9	258.2	512.1	57.2	49.4	3.0
Cameroon	Both	<5	77	467 990.2	12 301.8	85 522.5	1 367.9	5 143.3	135.2	1 023.5	16.4
	F			211 652.8	11 239.6	43 030.6	1 387.1	2 327.0	123.6	515.0	16.6
	M			256 337.4	13 342.8	42 491.9	1 348.9	2 816.3	146.6	508.5	16.1
Canada	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Central African Republic	Both	<5	>95	172 005.1	23 547.7	7 977.6	629.0	1 888.8	258.6	95.3	7.5
	F			87 895.5	24 102.4	4 355.6	682.3	965.9	264.9	52.0	8.1
	M			84 109.6	22 994.7	3 622.0	575.0	922.9	252.3	43.3	6.9
Chad	Both	<5	>95	932 652.8	34 978.1	48 074.9	1 149.6	10 284.5	385.7	577.5	13.8
	F			448 919.3	33 968.7	27 053.5	1 303.9	4 952.6	374.7	325.1	15.7
	M			483 733.4	35 970.1	21 021.3	997.7	5 332.0	396.5	252.4	12.0
Chile	Both	92	8	520.2	43.9	39.3	1.6	5.6	0.5	0.4	0.0
	F			233.4	40.2	20.7	1.7	2.5	0.4	0.2	0.0
	M			286.8	47.5	18.6	1.5	3.1	0.5	0.2	0.0
China	Both	59	<5	641 169.7	744.0	47 970.3	29.4	6 973.0	8.1	530.3	0.3
	F			283 636.2	709.0	28 360.7	37.6	3 074.5	7.7	302.9	0.4
	M			357 533.4	774.3	19 609.5	22.4	3 898.6	8.4	227.4	0.3
Colombia	Both	92	8	9 831.5	264.9	964.0	12.2	107.4	2.9	11.5	0.1
	F			4 571.0	251.7	455.5	11.8	49.9	2.7	5.4	0.1
	M			5 260.6	277.5	508.6	12.6	57.5	3.0	6.1	0.2

Comoros	Both	9	91	16 620.7	13 950.0	902.5	453.7	182.6	153.2	10.8	5.4
	F			8 150.6	13 945.8	457.2	467.8	89.6	153.2	5.4	5.6
	M			8 470.1	13 954.1	445.4	440.2	93.0	153.2	5.3	5.3
Congo	Both	<5	76	59 422.8	7 209.3	4 250.9	315.3	652.3	79.1	51.0	3.8
	F			29 124.4	7 134.4	2 502.1	373.1	320.0	78.4	30.0	4.5
	M			30 298.3	7 282.7	1 748.8	258.1	332.3	79.9	21.0	3.1
Cook Islands	Both	84	<5	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Costa Rica	Both	93	7	216.4	62.6	27.1	3.8	2.3	0.7	0.3	0.0
	F			101.0	59.8	15.8	4.5	1.1	0.6	0.2	0.0
	M			115.4	65.3	11.3	3.1	1.2	0.7	0.1	0.0
Côte d'Ivoire	Both	<5	82	615 560.0	15 944.6	89 345.5	1 434.5	6 760.8	175.1	1 073.6	17.2
	F			272 639.3	14 220.9	51 471.6	1 655.4	2 995.7	156.3	618.4	19.9
	M			342 920.7	17 645.1	37 873.9	1 214.4	3 765.2	193.7	455.2	14.6
Croatia	Both	93	7	53.0	27.0	6.7	1.6	0.6	0.3	0.1	0.0
	F			21.8	22.8	0.5	0.3	0.2	0.2	0.0	0.0
	M			31.2	30.9	6.2	2.9	0.3	0.3	0.1	0.0
Cuba	Both	79	<5	1 300.7	204.4	96.7	7.9	14.1	2.2	1.0	0.1
	F			598.4	193.3	63.2	10.7	6.5	2.1	0.7	0.1
	M			702.2	214.9	33.4	5.3	7.6	2.3	0.3	0.1
Cyprus	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Czechia	Both	>95	<5	57.0	10.7	16.1	1.5	0.6	0.1	0.2	0.0
	F			23.5	9.0	6.6	1.3	0.3	0.1	0.1	0.0
	M			33.5	12.2	9.5	1.7	0.4	0.1	0.1	0.0
Democratic People's Republic	Both	<5	89	51 126.5	2 961.4	3 388.3	95.0	558.0	32.3	39.0	1.1

of Korea											
	F			22 540.8	2 673.5	1 948.9	111.6	245.6	29.1	22.4	1.3
	M			28 585.7	3 236.2	1 439.5	79.0	312.4	35.4	16.6	0.9
Democratic Republic of the Congo	Both	<5	>95	2 447 746.5	16 888.0	185 810.5	844.7	26 835.8	185.2	2 237.9	10.2
	F			1 219 830.4	16 999.8	106 474.9	975.1	13 378.4	186.4	1 281.9	11.7
	M			1 227 916.2	16 778.3	79 335.6	716.2	13 457.4	183.9	956.0	8.6
Denmark	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Djibouti	Both	<5	88	9 180.7	8 975.9	2 082.3	1 066.8	100.4	98.2	25.1	12.9
	F			4 237.7	8 403.8	1 059.7	1 099.0	46.4	91.9	12.8	13.2
	M			4 943.0	9 532.2	1 022.6	1 035.2	54.1	104.3	12.3	12.5
Dominica	Both	91	9	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Dominican Republic	Both	90	<5	7 409.4	699.3	381.7	18.2	81.2	7.7	4.4	0.2
	F			2 952.5	569.0	196.5	19.1	32.3	6.2	2.3	0.2
	M			4 456.9	824.3	185.2	17.4	48.8	9.0	2.1	0.2
Ecuador	Both	>95	<5	4 218.9	261.9	325.8	10.5	46.2	2.9	3.9	0.1
	F			1 950.9	247.9	167.4	11.1	21.4	2.7	2.0	0.1
	M			2 268.0	275.2	158.4	10.0	24.8	3.0	1.9	0.1
Egypt	Both	>95	<5	15 687.4	121.8	3 820.6	20.0	171.4	1.3	45.5	0.2
	F			6 859.8	110.0	1 853.4	20.0	75.0	1.2	22.0	0.2
	M			8 827.6	133.0	1 967.2	20.0	96.4	1.5	23.5	0.2

El Salvador	Both	86	<5	2 740.1	475.3	367.4	31.0	29.9	5.2	4.5	0.4
	F			1 067.1	379.0	145.4	25.0	11.6	4.1	1.8	0.3
	M			1 673.0	567.2	222.0	36.7	18.3	6.2	2.7	0.5
Equatorial Guinea	Both	<5	66	22 068.8	12,149.8	2,029.8	739.2	242.0	133.2	24.3	8.8
	F			9 464.0	10 556.8	1 171.0	864.3	103.9	115.8	14.0	10.3
	M			12 604.9	13 702.3	858.9	617.4	138.2	150.2	10.3	7.4
Eritrea	Both	<5	84	67 043.0	9 014.3	8 238.4	614.8	736.1	99.0	98.2	7.3
	F			31 001.5	8 514.6	3 980.0	605.8	340.4	93.5	47.4	7.2
	M			36 041.5	9 493.6	4 258.3	623.5	395.7	104.2	50.9	7.4
Estonia	Both	93	7	13.1	19.4	7.8	5.4	0.1	0.2	0.1	0.1
	F			6.1	18.6	3.3	4.7	0.1	0.2	0.0	0.0
	M			7.0	20.1	4.5	6.0	0.1	0.2	0.0	0.1
eSwatini	Both	50	50	14 882.5	8 286.2	1 432.7	444.1	163.0	90.8	17.1	5.3
	F			6 941.0	7 780.0	784.2	487.8	76.0	85.2	9.4	5.8
	M			7 941.5	8 785.8	648.4	400.6	87.0	96.2	7.7	4.8
Ethiopia	Both	<5	>95	1 532 998.5	10 100.7	215 306.3	800.1	16 851.7	111.0	2 583.7	9.6
	F			683 480.8	9 141.6	106 266.4	798.3	7 513.1	100.5	1 274.3	9.6
	M			849 517.7	11 031.9	109 039.9	801.8	9 338.6	121.3	1 309.4	9.6
Fiji	Both	<5	60	1 801.2	2 080.3	230.9	135.5	19.6	22.7	2.7	1.6
	F			872.1	2 071.4	124.3	150.9	9.5	22.6	1.5	1.8
	M			929.1	2 088.8	106.5	121.1	10.1	22.8	1.3	1.4
Finland	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
France	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gabon	Both	79	<5	6 915.9	2 527.6	949.1	217.5	75.9	27.7	11.6	2.7
	F			3 141.4	2 321.8	489.8	226.5	34.5	25.5	6.0	2.8
	M			3 774.5	2 729.0	459.4	208.7	41.4	29.9	5.6	2.6
Gambia	Both	<5	>95	36 698.0	10 180.3	3 274.6	576.8	404.1	112.1	39.1	6.9
	F			17 412.6	9 757.6	1 959.7	696.3	191.9	107.5	23.4	8.3
	M			19 285.3	10 594.6	1 315.0	459.4	212.2	116.6	15.7	5.5
Georgia	Both	78	<5	766.2	282.5	260.6	55.1	8.3	3.1	3.1	0.7
	F			381.7	292.2	104.7	46.9	4.1	3.2	1.2	0.5
	M			384.6	273.5	156.0	62.5	4.2	3.0	1.9	0.7
Germany	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ghana	Both	<5	78	272 401.1	6 667.9	27 499.1	403.0	2 992.1	73.2	329.5	4.8
	F			121 158.7	6 057.1	14 732.9	441.5	1 330.6	66.5	176.5	5.3
	M			151 242.3	7 253.8	12 766.2	366.1	1 661.5	79.7	153.0	4.4
Greece	Both	94	6	85.5	18.0	12.8	1.1	0.9	0.2	0.1	0.0
	F			39.0	17.0	6.3	1.1	0.4	0.2	0.1	0.0
	M			46.6	19.0	6.5	1.1	0.5	0.2	0.1	0.0
Grenada	Both	>95	<5	13.7	138.9	0.4	2.2	0.1	1.5	0.0	0.0
	F			6.4	134.0	0.0	0.4	0.1	1.5	0.0	0.0
	M			7.3	143.5	0.4	4.0	0.1	1.6	0.0	0.0
Guatemala	Both	<5	55	71 014.1	3 510.9	5 243.6	134.8	776.9	38.4	62.6	1.6
	F			32 910.2	3 327.5	2 746.5	144.2	360.1	36.4	32.7	1.7
	M			38 103.9	3 686.4	2 497.2	125.7	416.9	40.3	29.9	1.5
Guinea	Both	<5	>95	339 682.9	17 130.7	36 814.8	1 122.0	3 732.4	188.2	440.8	13.4
	F			160 848.1	16 327.5	23 119.8	1 419.1	1 768.1	179.5	276.6	17.0
	M			178 834.9	17 923.7	13 695.0	829.0	1 964.3	196.9	164.2	9.9

Guinea-Bissau	Both	<5	>95	51 497.1	17 706.4	2 846.0	612.3	567.9	195.3	34.1	7.3
	F			24 469.1	16 900.6	1 545.1	665.2	269.8	186.3	18.5	8.0
	M			27 028.0	18 505.3	1 300.8	559.5	298.1	204.1	15.6	6.7
Guyana	Both	74	<5	931.1	1 218.4	156.8	103.8	10.2	13.3	1.9	1.2
	F			431.6	1 158.8	73.2	99.6	4.7	12.7	0.9	1.2
	M			499.5	1 275.0	83.6	107.8	5.5	13.9	1.0	1.3
Haiti	Both	<5	>95	189 093.2	15 330.7	13 926.5	584.4	2 075.7	168.3	166.6	7.0
	F			85 223.7	14 094.7	6 174.6	526.4	935.6	154.7	73.9	6.3
	M			103 869.6	16 519.2	7 751.9	640.5	1 140.1	181.3	92.7	7.7
Honduras	Both	53	<5	14 417.5	1 515.7	556.3	27.9	157.5	16.6	6.4	0.3
	F			6 448.3	1 383.4	169.9	17.4	70.4	15.1	1.9	0.2
	M			7 969.2	1 642.8	386.4	38.1	87.1	18.0	4.6	0.5
Hungary	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iceland	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
India	Both	<5	59	6 098 660.0	5 082.3	398 523.0	157.3	66 890.5	55.7	4 711.7	1.9
	F			3 286 253.8	5 780.6	232 061.8	193.8	36 073.1	63.5	2 758.9	2.3
	M			2 812 406.5	4 453.7	166 461.2	124.6	30 817.4	48.8	1 952.8	1.5
Indonesia	Both	58	<5	628 573.7	2 532.3	36 982.9	78.1	6 862.4	27.6	430.8	0.9
	F			308 557.5	2 544.4	18 211.6	78.7	3 370.4	27.8	211.2	0.9
	M			320 016.2	2 520.8	18 771.4	77.4	3 492.0	27.5	219.6	0.9
Iran (Islamic Republic of)	Both	>95	<5	4 347.9	63.7	178.3	1.5	47.4	0.7	2.0	0.0

	F			2 299.8	68.9	95.8	1.6	25.1	0.8	1.1	0.0
	M			2 048.1	58.8	82.5	1.3	22.3	0.6	0.9	0.0
Iraq	Both	>95	<5	14 770.1	257.4	292.2	3.1	161.6	2.8	3.3	0.0
	F			4 824.8	173.0	170.5	3.8	52.9	1.9	1.9	0.0
	M			9 945.3	337.3	121.7	2.5	108.7	3.7	1.4	0.0
Ireland	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Israel	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Italy	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jamaica	Both	90	<5	267.6	130.5	39.8	8.7	2.9	1.4	0.4	0.1
	F			121.7	122.4	21.3	9.5	1.3	1.3	0.2	0.1
	M			145.8	138.1	18.6	8.0	1.6	1.5	0.2	0.1
Japan	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jordan	Both	>95	<5	392.0	31.9	30.0	1.4	4.3	0.3	0.3	0.0
	F			187.9	31.3	18.6	1.7	2.0	0.3	0.2	0.0
	M			204.1	32.6	11.4	1.0	2.2	0.4	0.1	0.0
Kazakhstan	Both	95	5	2 738.7	137.1	181.1	6.2	29.8	1.5	2.1	0.1
	F			1 233.6	127.1	94.1	6.6	13.4	1.4	1.1	0.1
	M			1 505.1	146.7	87.0	5.8	16.4	1.6	1.0	0.1
Kenya	Both	<5	87	504 366.5	7 181.3	31 760.7	248.3	5 536.8	78.8	380.6	3.0
	F			244 476.8	7 034.4	13 165.4	207.5	2 684.7	77.2	157.4	2.5

	M			259 889.7	7 325.1	18 595.3	288.5	2 852.1	80.4	223.2	3.5
Kiribati	Both	6	94	1 420.1	9 803.2	80.4	317.4	15.6	107.4	0.9	3.7
	F			683.2	9 670.0	24.5	197.6	7.5	105.9	0.3	2.3
	M			736.9	9 929.9	55.9	431.9	8.1	108.9	0.7	5.1
Kuwait	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kyrgyzstan	Both	81	<5	11 263.5	1 481.1	453.0	40.6	123.1	16.2	5.2	0.5
	F			5 201.8	1 406.0	214.0	39.2	56.8	15.4	2.4	0.4
	M			6 061.8	1 552.2	238.9	41.9	66.2	17.0	2.8	0.5
Lao People's Democratic Republic	Both	6	94	90 213.0	11 783.1	6 330.0	426.9	988.7	129.1	74.9	5.1
	F			43 609.0	11 633.1	2 997.9	412.5	478.2	127.6	35.5	4.9
	M			46 604.0	11 927.1	3 332.1	440.7	510.4	130.6	39.5	5.2
Latvia	Both	95	5	30.7	31.7	1.6	0.8	0.3	0.3	0.0	0.0
	F			14.6	31.2	0.8	0.8	0.2	0.3	0.0	0.0
	M			16.0	32.1	0.8	0.7	0.2	0.3	0.0	0.0
Lebanon	Both	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Lesotho	Both	<5	64	34 605.3	12 103.2	2 399.1	482.6	379.0	132.5	28.7	5.8
	F			17 471.0	12 306.8	1 393.5	563.4	191.3	134.8	16.7	6.7
	M			17 134.3	11 902.4	1 005.5	402.6	187.6	130.3	12.0	4.8
Liberia	Both	<5	>95	89 766.3	12 546.2	7 222.4	588.4	983.2	137.4	87.0	7.1
	F			44 701.3	12 769.7	4 082.6	679.5	489.7	139.9	49.1	8.2
	M			45 065.0	12 332.1	3 139.7	501.0	493.6	135.1	37.8	6.0
Libya	Both	NA		NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA

	M			NA	NA	NA	NA	NA	NA	NA	NA
Lithuania	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Luxembourg	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Madagascar	Both	<5	>95	335 527.3	8 903.3	42 347.8	650.4	3 680.3	97.7	506.9	7.8
	F			165 601.0	8 898.1	20 830.2	643.6	1 817.2	97.6	248.8	7.7
	M			169 926.2	8 908.3	21 517.6	657.1	1 863.1	97.7	258.1	7.9
Malawi	Both	<5	>95	230 369.8	7 921.2	13 249.1	259.7	2 526.6	86.9	158.2	3.1
	F			106 489.4	7 407.4	6 170.7	243.3	1 167.9	81.2	73.3	2.9
	M			123 880.4	8 423.4	7 078.4	276.0	1 358.7	92.4	84.8	3.3
Malaysia	Both	>95	<5	993.0	38.0	337.5	6.7	10.7	0.4	4.0	0.1
	F			427.3	33.9	160.0	6.5	4.6	0.4	1.9	0.1
	M			565.7	41.8	177.5	6.8	6.1	0.5	2.1	0.1
Maldives	Both	94	6	29.5	75.6	4.2	6.9	0.3	0.8	0.0	0.1
	F			15.9	85.0	2.4	8.2	0.2	0.9	0.0	0.1
	M			13.6	66.9	1.8	5.8	0.1	0.7	0.0	0.1
Mali	Both	<5	>95	554 968.1	16 655.1	36 885.2	699.1	6 105.1	183.2	439.8	8.3
	F			282 341.5	17 255.2	21 778.6	838.9	3 107.1	189.9	259.7	10.0
	M			272 626.7	16 076.1	15 106.6	563.7	2 998.0	176.8	180.1	6.7
Malta	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marshall Islands	Both	65	<5	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA

Mauritania	Both	<5	53	67 277.8	10 269.7	2 955.2	276.2	740.3	113.0	35.1	3.3
	F			27 641.6	8 597.0	1 738.2	329.9	304.2	94.6	20.6	3.9
	M			39 636.2	11 881.8	1 217.0	224.1	436.1	130.7	14.4	2.7
Mauritius	Both	93	7	86.9	127.6	15.3	9.0	0.9	1.4	0.2	0.1
	F			36.8	110.3	9.4	11.2	0.4	1.2	0.1	0.1
	M			50.1	144.2	6.0	6.9	0.5	1.6	0.1	0.1
Mexico	Both	85	<5	49 786.2	429.9	2 060.9	9.0	544.1	4.7	24.4	0.1
	F			23 025.6	406.9	1 010.1	9.0	251.7	4.4	11.9	0.1
	M			26 760.7	451.9	1 050.8	9.0	292.4	4.9	12.5	0.1
Micronesia (Federated States of)	Both	<5	88	587.9	5 048.6	52.7	223.7	6.4	55.3	0.6	2.6
	F			269.8	4 792.5	23.1	203.7	3.0	52.5	0.3	2.4
	M			318.1	5 288.2	29.6	242.4	3.5	57.9	0.3	2.9
Monaco	Both	>95	<5	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Mongolia	Both	<5	57	6 965.2	1 894.9	624.9	120.3	75.9	20.6	7.2	1.4
	F			2 508.5	1 382.8	273.6	106.5	27.3	15.1	3.2	1.2
	M			4 456.7	2 393.8	351.2	133.7	48.6	26.1	4.1	1.6
Montenegro	Both	69	<5	29.7	81.8	13.8	17.6	0.3	0.8	0.1	0.2
	F			13.1	74.2	7.5	20.0	0.1	0.7	0.1	0.2
	M			16.6	88.9	6.3	15.4	0.2	0.9	0.1	0.1
Morocco	Both	>95	<5	7 844.1	223.6	325.9	5.2	85.8	2.4	3.8	0.1
	F			3 571.4	209.2	181.6	6.0	39.1	2.3	2.1	0.1
	M			4 272.7	237.1	144.3	4.5	46.7	2.6	1.7	0.1
Mozambique	Both	<5	>95	541 134.6	10 932.0	46 454.2	578.6	5 925.9	119.7	559.7	7.0
	F			265 861.7	10 823.9	23 688.1	591.9	2 912.0	118.6	285.2	7.1
	M			275 272.9	11 038.5	22 766.1	565.4	3,013.9	120.9	274.4	6.8

Myanmar	Both	<5	82	404 645.6	8 917.2	29 751.4	299.4	4 436.5	97.8	353.5	3.6
	F			180 837.7	8 025.9	11 230.6	227.3	1 985.8	88.1	133.2	2.7
	M			223 807.9	9 796.3	18 520.8	370.5	2 450.7	107.3	220.4	4.4
Namibia	Both	<5	58	21 020.8	6 108.6	1 863.9	326.6	230.8	67.1	22.4	3.9
	F			9 986.7	5 842.9	882.9	309.9	109.6	64.1	10.6	3.7
	M			11 034.0	6 370.7	981.0	343.2	121.2	70.0	11.8	4.1
Nauru	Both	91	9	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Nepal	Both	<5	72	130 634.5	4 739.7	8 797.7	136.9	1 429.0	51.8	103.5	1.6
	F			58 115.5	4 352.2	4 660.9	148.8	635.7	47.6	55.0	1.8
	M			72 519.0	5 103.8	4 136.8	125.6	793.3	55.8	48.6	1.5
Netherlands	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nicaragua	Both	52	<5	15 219.7	2 548.2	1 067.6	87.7	166.5	27.9	12.9	1.1
	F			5 848.9	2 002.6	534.8	90.5	64.0	21.9	6.4	1.1
	M			9 370.8	3 070.4	532.9	85.0	102.5	33.6	6.4	1.0
Niger	Both	<5	>95	823 082.0	19 514.2	114 793.9	1 861.6	9 079.8	215.3	1 381.6	22.4
	F			418 807.2	20 295.2	61 999.4	2 051.9	4 623.2	224.0	746.1	24.7
	M			404 274.8	18 766.0	52 794.6	1 678.8	4 456.6	206.9	635.5	20.2
Nigeria	Both	5	95	6 950 066.0	21 854.5	772 212.4	1 538.4	76 505.4	240.6	9 221.0	18.4
	F			3 204 320.0	20 665.3	458 454.4	1 865.4	35 295.5	227.6	5 472.3	22.3
	M			3 745	22 986.1	313	1 224.7	41 209.8	252.9	3 748.7	14.6

				746.0		757.9					
Niue	Both	93	7	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Norway	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oman	Both	95	5	250.4	62.6	23.5	4.1	2.7	0.7	0.3	0.0
	F			144.2	74.2	12.9	4.5	1.6	0.8	0.1	0.0
	M			106.3	51.6	10.6	3.7	1.1	0.6	0.1	0.0
Pakistan	Both	<5	57	2 365 748.2	9 477.2	110 327.6	259.9	25 933.0	103.9	1 316.7	3.1
	F			1 197 080.8	9 973.7	44 879.4	219.7	13 127.7	109.4	534.1	2.6
	M			1 168 667.5	9 017.3	65 448.2	297.2	12 805.3	98.8	782.7	3.6
Palau	Both	87	<5	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Panama	Both	89	<5	1 907.1	491.1	165.4	22.8	20.8	5.4	2.0	0.3
	F			828.2	435.7	79.0	22.2	9.0	4.8	0.9	0.3
	M			1 079.0	544.1	86.4	23.3	11.8	5.9	1.0	0.3
Papua New Guinea	Both	<5	87	89 471.3	8 663.9	6 050.7	318.5	978.4	94.7	71.1	3.7
	F			39 006.5	7 821.9	2 230.1	242.5	426.4	85.5	26.1	2.8
	M			50 464.8	9 450.2	3 820.6	389.7	552.0	103.4	45.1	4.6
Paraguay	Both	66	<5	7 976.4	1 187.6	812.4	61.2	86.9	12.9	9.1	0.7
	F			3 582.2	1 088.3	415.6	63.8	38.9	11.8	4.6	0.7
	M			4 394.2	1 283.0	396.9	58.7	47.9	14.0	4.5	0.7

Peru	Both	75	<5	20 398.0	672.6	5,818.1	101.1	222.4	7.3	69.2	1.2
	F			9 150.4	616.4	2 798.7	99.3	99.8	6.7	33.3	1.2
	M			11 247.6	726.6	3 019.4	102.8	122.7	7.9	36.0	1.2
Philippines	Both	<5	57	455 244.2	3 948.2	65 457.6	304.5	4 989.2	43.3	788.6	3.7
	F			210 002.3	3 751.0	31 886.4	304.9	2 302.4	41.1	383.2	3.7
	M			245 242.0	4 134.3	33 571.1	304.1	2 686.8	45.3	405.4	3.7
Poland	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Portugal	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Qatar	Both	>95	<5	16.9	13.0	2.6	1.2	0.2	0.1	0.0	0.0
	F			6.6	10.4	1.2	1.0	0.1	0.1	0.0	0.0
	M			10.3	15.6	1.5	1.3	0.1	0.2	0.0	0.0
Republic of Korea	Both	>95	<5	119.3	5.4	29.0	0.6	1.2	0.1	0.2	0.0
	F			59.0	5.5	14.0	0.6	0.6	0.1	0.1	0.0
	M			60.3	5.2	15.0	0.6	0.6	0.1	0.1	0.0
Republic of Moldova	Both	92	8	957.3	439.4	60.7	14.4	10.4	4.8	0.7	0.2
	F			409.9	390.2	29.5	14.5	4.5	4.2	0.3	0.2
	M			547.4	485.3	31.2	14.4	6.0	5.3	0.4	0.2
Romania	Both	86	<5	6 372.2	674.9	630.6	30.3	69.4	7.4	7.3	0.4
	F			2 865.7	623.7	350.1	34.5	31.2	6.8	4.1	0.4
	M			3 506.5	723.4	280.6	26.2	38.2	7.9	3.3	0.3
Russian Federation	Both	>95	<5	2 056.0	21.5	340.2	2.2	22.1	0.2	3.6	0.0
	F			942.0	20.3	184.9	2.5	10.1	0.2	2.0	0.0
	M			1 114.0	22.7	155.4	2.0	12.0	0.2	1.6	0.0

Rwanda	Both	<5	>95	93 389.2	5 367.9	17 300.2	561.1	1 023.4	58.8	207.6	6.7
	F			42 201.2	4 870.1	8 381.9	542.1	462.3	53.4	100.5	6.5
	M			51 188.0	5 862.0	8 918.3	580.2	561.0	64.2	107.1	7.0
Saint Kitts and Nevis	Both	>95	<5	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Saint Lucia	Both	>95	<5	6.9	63.1	0.3	1.1	0.1	0.7	0.0	0.0
	F			3.4	62.0	0.2	1.9	0.0	0.7	0.0	0.0
	M			3.6	64.2	0.0	0.3	0.0	0.7	0.0	0.0
Saint Vincent and the Grenadines	Both	>95	<5	14.3	172.7	1.1	5.9	0.2	1.9	0.0	0.1
	F			6.9	169.3	0.6	6.5	0.1	1.8	0.0	0.1
	M			7.4	176.1	0.5	5.3	0.1	1.9	0.0	0.1
Samoa	Both	<5	68	311.1	1 324.6	43.0	88.9	3.4	14.4	0.5	1.0
	F			126.2	1 113.8	18.0	77.1	1.4	12.1	0.2	0.9
	M			184.9	1 521.0	25.0	99.8	2.0	16.5	0.3	1.2
San Marino	Both	>95	<5	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Sao Tome and Principe	Both	<5	83	1 362.7	4 349.7	300.2	545.9	14.9	47.6	3.6	6.5
	F			564.0	3 632.4	151.3	554.3	6.2	39.7	1.8	6.6
	M			798.7	5 054.6	148.9	537.7	8.7	55.3	1.8	6.4
Saudi Arabia	Both	>95	<5	1 917.2	64.6	216.4	4.1	21.0	0.7	2.4	0.0
	F			938.7	64.2	127.9	4.9	10.3	0.7	1.4	0.1
	M			978.6	65.0	88.4	3.3	10.7	0.7	1.0	0.0
Senegal	Both	<5	68	161 812.9	6 359.8	20 185.9	494.5	1 776.0	69.8	242.4	5.9
	F			73 518.8	5 859.1	10 889.6	539.8	807.5	64.4	130.5	6.5

	M			88 294.1	6 846.9	9 296.2	450.2	968.6	75.1	111.9	5.4
Serbia	Both	76	<5	417.4	89.0	53.2	5.4	4.4	0.9	0.5	0.1
	F			186.2	81.3	24.1	5.0	2.0	0.9	0.2	0.0
	M			231.1	96.3	29.1	5.7	2.5	1.0	0.3	0.1
Seychelles	Both	90	<5	11.3	143.7	5.4	41.8	0.1	1.6	0.1	0.5
	F			4.5	118.5	2.6	40.8	0.0	1.3	0.0	0.5
	M			6.7	167.9	2.8	42.8	0.1	1.8	0.0	0.5
Sierra Leone	Both	<5	>95	203 840.7	17 867.4	22 848.1	1 144.6	2 232.3	195.7	272.1	13.6
	F			98 725.7	17 362.6	12 599.0	1 258.9	1 081.2	190.1	150.0	15.0
	M			105 115.1	18 369.1	10 249.0	1 029.6	1 151.0	201.1	122.2	12.3
Singapore	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Slovakia	Both	>95	<5	84.8	30.1	16.3	3.0	0.9	0.3	0.2	0.0
	F			38.5	28.0	9.5	3.5	0.4	0.3	0.1	0.0
	M			46.3	32.2	6.8	2.4	0.5	0.3	0.1	0.0
Slovenia	Both	>95	<5	3.9	3.6	2.0	1.0	0.0	0.0	0.0	0.0
	F			1.9	3.7	0.3	0.3	0.0	0.0	0.0	0.0
	M			1.9	3.5	1.7	1.6	0.0	0.0	0.0	0.0
Solomon Islands	Both	8	92	3 880.4	4 689.4	200.8	131.9	42.4	51.2	2.3	1.5
	F			1 901.6	4 743.8	87.0	118.1	20.8	51.8	1.0	1.4
	M			1 978.8	4 638.4	113.7	144.8	21.6	50.7	1.3	1.7
Somalia	Both	<5	>95	895 779.6	34 228.7	52 304.9	1 292.6	9 866.4	377.0	623.9	15.4
	F			432 336.2	33 319.0	28 148.6	1 397.7	4 762.6	367.0	335.6	16.7
	M			463 443.4	35 123.4	24 156.4	1 188.5	5 103.7	386.8	288.4	14.2
South Africa	Both	85	<5	126 567.7	2 218.6	8 149.6	76.6	1 383.1	24.2	97.4	0.9
	F			59 177.1	2 096.4	3 836.4	72.7	646.7	22.9	45.6	0.9
	M			67 390.7	2 338.3	4 313.1	80.5	736.4	25.6	51.7	1.0

South Sudan	Both	<5	>95	403 214.0	20 945.7	17 876.2	559.1	4 442.2	230.8	213.3	6.7
	F			194 474.8	20 508.5	9 406.2	595.5	2 143.0	226.0	112.2	7.1
	M			208 739.3	21 370.0	8 470.0	523.6	2 299.3	235.4	101.1	6.3
Spain	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sri Lanka	Both	<5	74	7 689.0	480.1	2 436.8	70.6	83.0	5.2	28.1	0.8
	F			3 182.3	404.0	1 303.7	75.9	34.4	4.4	15.1	0.9
	M			4 506.7	553.7	1 133.1	65.5	48.6	6.0	13.0	0.7
Sudan	Both	<5	59	476 142.0	8 015.4	20 232.5	195.4	5 254.6	88.5	239.5	2.3
	F			270 676.2	9 270.5	10 540.7	206.8	2 987.3	102.3	124.9	2.5
	M			205 465.8	6 802.2	9 691.8	184.4	2 267.2	75.1	114.6	2.2
Suriname	Both	90	<5	146.9	291.9	14.7	14.9	1.6	3.2	0.2	0.2
	F			63.0	259.4	7.3	15.4	0.7	2.8	0.1	0.2
	M			83.9	322.3	7.4	14.5	0.9	3.5	0.1	0.2
Sweden	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switzerland	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syrian Arab Republic	Both	>95	<5	733.6	34.9	155.3	3.2	8.0	0.4	1.8	0.0
	F			326.8	32.0	92.9	4.0	3.6	0.4	1.1	0.0
	M			406.9	37.8	62.4	2.5	4.5	0.4	0.7	0.0
Tajikistan	Both	80	<5	34 122.4	2 884.4	2 555.6	135.3	372.8	31.5	29.8	1.6
	F			16 094.5	2 794.5	1 350.2	146.9	175.9	30.5	15.7	1.7
	M			18 027.9	2 969.7	1 205.4	124.3	196.9	32.4	14.0	1.4
Thailand	Both	74	<5	15 863.0	421.0	2 744.5	32.7	172.7	4.6	32.1	0.4

	F			6 696.7	365.5	977.7	24.0	73.0	4.0	11.2	0.3
	M			9 166.3	473.6	1 766.8	41.0	99.8	5.2	21.0	0.5
The former Yugoslav Republic of Macedonia	Both	66	<5	534.5	453.0	32.0	13.8	5.8	4.9	0.3	0.1
	F			256.9	447.3	3.9	3.5	2.8	4.8	0.0	0.0
	M			277.6	458.3	28.1	23.7	3.0	4.9	0.3	0.2
Timor-Leste	Both	7	93	23 025.5	11 172.3	917.4	262.9	251.9	122.2	10.9	3.1
	F			11 795.4	11 678.5	521.4	305.0	129.1	127.8	6.2	3.6
	M			11 230.1	10 685.8	395.9	222.5	122.8	116.9	4.7	2.6
Togo	Both	7	93	142 733.2	12 138.6	19 804.5	987.5	1 568.6	133.4	238.1	11.9
	F			62 593.9	10 678.3	11 690.4	1 169.1	688.1	117.4	140.4	14.0
	M			80 139.3	13 590.1	8 114.1	806.9	880.4	149.3	97.6	9.7
Tonga	Both	59	<5	136.4	1 072.9	17.6	67.2	1.5	11.6	0.2	0.8
	F			77.8	1 255.9	7.3	58.1	0.8	13.6	0.1	0.7
	M			58.6	898.9	10.3	75.6	0.6	9.8	0.1	0.9
Trinidad and Tobago	Both	>95	<5	22.9	24.2	1.2	0.7	0.2	0.3	0.0	0.0
	F			10.6	22.7	0.4	0.4	0.1	0.2	0.0	0.0
	M			12.4	25.7	0.9	0.9	0.1	0.3	0.0	0.0
Tunisia	Both	>95	<5	243.2	23.1	30.2	1.8	2.7	0.3	0.3	0.0
	F			124.8	24.3	19.2	2.3	1.4	0.3	0.2	0.0
	M			118.4	22.0	11.0	1.3	1.3	0.2	0.1	0.0
Turkey	Both	NA		NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Turkmenistan	Both	>95	<5	1 003.4	141.5	31.8	3.1	11.0	1.5	0.4	0.0
	F			427.0	122.2	14.9	2.9	4.7	1.3	0.2	0.0

	M			576.5	160.1	16.9	3.2	6.3	1.8	0.2	0.0
Tuvalu	Both	50	50	NA	NA	NA	NA	NA	NA	NA	NA
	F			NA	NA	NA	NA	NA	NA	NA	NA
	M			NA	NA	NA	NA	NA	NA	NA	NA
Uganda	Both	<5	>95	735 637.6	9 555.1	97 865.2	801.5	8 078.3	104.9	1 174.7	9.6
	F			339 898.6	8 913.8	49 416.8	815.4	3 730.2	97.8	593.0	9.8
	M			395 738.9	10 184.4	48 448.4	787.9	4 348.1	111.9	581.7	9.5
Ukraine	Both	>95	<5	1 408.3	60.3	125.4	2.8	15.2	0.7	1.2	0.0
	F			750.0	66.3	69.0	3.2	8.1	0.7	0.7	0.0
	M			658.4	54.7	56.4	2.5	7.1	0.6	0.5	0.0
United Arab Emirates	Both	>95	<5	53.1	11.4	3.8	0.5	0.6	0.1	0.0	0.0
	F			29.8	13.1	1.4	0.3	0.3	0.1	0.0	0.0
	M			23.2	9.8	2.4	0.6	0.2	0.1	0.0	0.0
United Kingdom	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
United Republic of Tanzania	Both	<5	>95	885 108.1	9 166.9	96 415.9	626.2	9 719.6	100.7	1 148.4	7.5
	F			432 226.7	9 038.0	50 695.0	660.5	4 746.4	99.2	603.5	7.9
	M			452 881.4	9 293.4	45 720.9	592.1	4 973.2	102.1	544.9	7.1
United States of America	Both	>95	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	F			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uruguay	Both	>95	<5	41.5	17.3	3.2	0.6	0.4	0.2	0.0	0.0
	F			18.1	15.4	1.0	0.4	0.2	0.2	0.0	0.0
	M			23.4	19.1	2.2	0.9	0.3	0.2	0.0	0.0
Uzbekistan	Both	92	8	16 830.9	528.6	2 626.3	46.8	183.6	5.8	31.1	0.6

	F			7 542.3	491.5	1 324.3	48.4	82.3	5.4	15.7	0.6
	M			9 288.6	563.1	1 302.1	45.2	101.3	6.1	15.4	0.5
Vanuatu	Both	<5	87	1 297.3	3 768.9	94.8	149.9	14.1	41.1	1.1	1.7
	F			610.8	3 674.3	36.1	119.6	6.7	40.1	0.4	1.4
	M			686.5	3 857.3	58.7	177.6	7.5	42.1	0.7	2.1
Venezuela (Bolivarian Republic of)	Both	>95	<5	2 899.1	97.5	195.5	3.4	31.7	1.1	2.3	0.0
	F			1 257.1	86.5	91.0	3.2	13.7	0.9	1.1	0.0
	M			1 642.1	108.0	104.5	3.5	17.9	1.2	1.3	0.0
Viet Nam	Both	67	<5	113 253.8	1 459.3	3 228.0	23.0	1 237.5	15.9	36.1	0.3
	F			44 466.4	1 210.3	1 146.8	17.0	485.7	13.2	12.3	0.2
	M			68 787.5	1 683.2	2 081.2	28.4	751.8	18.4	23.9	0.3
Yemen	Both	65	<5	224 534.9	5 509.8	6 560.1	93.3	2 462.5	60.4	76.8	1.1
	F			127 856.2	6 414.6	3 643.3	105.8	1 402.5	70.4	42.8	1.2
	M			96 678.7	4 643.6	2 916.8	81.3	1 060.1	50.9	34.0	0.9
Zambia	Both	<5	84	258 792.2	9 176.6	24 151.9	518.1	2 840.8	100.7	288.7	6.2
	F			123 126.0	8 813.7	11 972.1	516.8	1 352.0	96.8	143.0	6.2
	M			135 666.2	9 532.9	12 179.8	519.5	1 488.8	104.6	145.7	6.2
Zimbabwe	Both	<5	71	188 041.6	7 404.9	24 163.5	583.2	2 064.8	81.3	289.8	7.0
	F			94 904.9	7 511.4	13 445.1	650.6	1 042.4	82.5	161.3	7.8
	M			93 136.7	7 299.5	10 718.4	516.1	1 022.4	80.1	128.5	6.2

B, both sexes; F, females; M, males

Table 6. Joint effects of exposure of children to ambient and household $PM_{2.5}$ and burden of disease, by country, 2016

Country	Sex	No. of DALYs (< 5 years)	DALYs rate per 100 000 (< 5 years)	No. of DALYs (5-14 years)	DALYs rate per 100 000 (5-14 years)	No. of deaths (<5 years)	Death rate per 100 000 (<5 years)	No. of deaths (5-14 years)	Death rate per 100 000 (5 -14 years)
Afghanistan	Both	743 587.6	14 210.0	53 573.7	537.5	8 177.9	156.3	636.7	6.4
	F	388 748.0	15 280.0	31 906.4	657.0	4 279.1	168.2	379.7	7.8
	M	354 839.6	13 197.5	21 667.3	424.0	3 898.8	145.0	257.0	5.0
Albania	Both	1 532.4	863.9	251.5	73.7	16.5	9.3	2.9	0.8
	F	726.6	847.8	182.3	111.5	7.8	9.1	2.1	1.3
	M	805.7	878.9	69.1	38.9	8.7	9.5	0.7	0.4
Algeria	Both	91 680.0	1 951.0	4 110.7	58.1	1 003.8	21.4	47.6	0.7
	F	53 967.9	2 346.9	2 167.2	62.5	591.2	25.7	25.1	0.7
	M	37 712.1	1 571.6	1 943.5	53.8	412.6	17.2	22.5	0.6
Andorra	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Angola	Both	824 454.4	15 623.2	39 623.8	480.1	9 071.4	171.9	472.5	5.7
	F	432 088.5	16 446.7	20 416.8	490.0	4 758.3	181.1	243.3	5.8
	M	392 365.8	14 806.8	19 206.9	469.9	4 313.2	162.8	229.2	5.6
Antigua and Barbuda	Both	5.2	64.4	3.2	19.5	0.1	0.7	0.0	0.2
	F	2.0	50.1	0.1	1.3	0.0	0.5	0.0	0.0

	M	3.2	78.5	3.1	37.6	0.0	0.8	0.0	0.4
Argentina	Both	6 806.6	182.2	707.2	9.8	74.0	2.0	8.2	0.1
	F	3 096.2	168.7	370.7	10.4	33.7	1.8	4.3	0.1
	M	3 710.4	195.2	336.5	9.1	40.4	2.1	3.9	0.1
Armenia	Both	1 319.8	652.7	171.1	45.0	14.3	7.1	1.9	0.5
	F	610.4	644.3	78.9	44.6	6.6	7.0	0.9	0.5
	M	709.4	660.1	92.2	45.3	7.7	7.2	1.1	0.5
Australia	Both	228.6	14.7	47.2	1.6	2.4	0.2	0.5	0.0
	F	100.6	13.3	33.4	2.3	1.1	0.1	0.4	0.0
	M	128.0	16.1	13.7	0.9	1.3	0.2	0.1	0.0
Austria	Both	15.4	3.8	36.0	4.4	0.2	0.0	0.4	0.1
	F	7.4	3.7	35.3	8.9	0.1	0.0	0.4	0.1
	M	8.1	3.8	0.7	0.2	0.1	0.0	0.0	0.0
Azerbaijan	Both	12 697.7	1 425.9	1 152.9	84.6	138.4	15.5	13.5	1.0
	F	6 528.9	1 575.9	528.8	83.7	71.2	17.2	6.2	1.0
	M	6 168.9	1 295.4	624.1	85.4	67.3	14.1	7.3	1.0
Bahamas	Both	124.4	451.8	7.3	13.8	1.4	4.9	0.1	0.2
	F	59.8	446.5	3.1	11.9	0.6	4.8	0.0	0.1
	M	64.6	456.9	4.2	15.6	0.7	5.0	0.0	0.2
Bahrain	Both	110.7	103.6	79.8	43.7	1.2	1.1	0.9	0.5
	F	56.2	108.2	44.2	49.3	0.6	1.1	0.5	0.6
	M	54.5	99.4	35.6	38.3	0.6	1.0	0.4	0.4
Bangladesh	Both	1 049 873.4	6 890.9	44 378.0	139.3	11 487.3	75.4	522.6	1.6
	F	471 209.8	6 322.6	26 686.1	171.2	5 156.7	69.2	315.8	2.0
	M	578 663.6	7 435.2	17 691.9	108.7	6 330.6	81.3	206.8	1.3
Barbados	Both	19.4	112.3	10.2	27.2	0.2	1.2	0.1	0.3
	F	9.2	108.1	1.7	9.2	0.1	1.1	0.0	0.1
	M	10.2	116.4	8.5	44.3	0.1	1.2	0.1	0.5

Belarus	Both	461.0	79.6	78.1	8.0	4.8	0.8	0.6	0.1
	F	203.5	72.4	37.8	7.9	2.1	0.8	0.3	0.1
	M	257.6	86.3	40.3	8.0	2.7	0.9	0.3	0.1
Belgium	Both	147.6	23.0	22.0	1.7	1.6	0.2	0.2	0.0
	F	62.8	20.0	13.3	2.1	0.7	0.2	0.1	0.0
	M	84.8	25.7	8.6	1.3	0.9	0.3	0.1	0.0
Belize	Both	247.4	614.0	29.5	38.4	2.7	6.7	0.3	0.4
	F	122.0	611.5	12.3	32.5	1.3	6.6	0.1	0.4
	M	125.5	616.4	17.2	44.1	1.4	6.7	0.2	0.5
Benin	Both	348 671.9	19 638.6	35 215.4	1 220.6	3 834.5	216.0	421.2	14.6
	F	183 817.0	21 030.0	18 528.9	1 302.7	2 022.7	231.4	221.5	15.6
	M	164 855.0	18 289.2	16 686.5	1 140.8	1 811.8	201.0	199.8	13.7
Bhutan	Both	3 407.2	4 880.4	335.0	230.9	37.2	53.3	4.0	2.8
	F	1 533.1	4 466.9	188.2	263.5	16.7	48.8	2.3	3.2
	M	1 874.1	5 280.3	146.8	199.3	20.5	57.7	1.8	2.4
Bolivia (Plurinational State of)	Both	40 128.4	3 376.4	5 121.9	222.8	439.5	37.0	61.4	2.7
	F	18 823.5	3 234.0	2 526.0	223.6	206.2	35.4	30.3	2.7
	M	21 304.9	3 513.0	2 595.8	221.9	233.3	38.5	31.1	2.7
Bosnia and Herzegovina	Both	432.5	276.1	45.4	13.2	4.6	2.9	0.4	0.1
	F	201.9	265.9	19.2	11.6	2.1	2.8	0.1	0.1
	M	230.6	285.6	26.2	14.8	2.4	3.0	0.2	0.1
Botswana	Both	8 588.3	3 313.2	872.3	192.8	94.2	36.3	10.4	2.3
	F	4 144.1	3 230.3	411.9	183.5	45.4	35.4	4.9	2.2
	M	4 444.2	3 394.5	460.4	202.0	48.8	37.2	5.5	2.4
Brazil	Both	58 241.8	390.4	5 269.7	17.0	633.2	4.2	60.5	0.2
	F	26 914.8	369.4	2 578.1	16.9	292.4	4.0	29.4	0.2

	M	31 327.0	410.5	2 691.6	17.0	340.8	4.5	31.1	0.2
Brunei Darussalam	Both	6.8	19.7	3.8	5.9	0.1	0.2	0.0	0.1
	F	3.1	18.4	2.5	8.1	0.0	0.2	0.0	0.1
	M	3.7	20.9	1.3	3.8	0.0	0.2	0.0	0.0
Bulgaria	Both	1 471.8	454.0	280.1	41.1	16.0	4.9	3.2	0.5
	F	658.1	417.9	132.0	39.9	7.1	4.5	1.5	0.5
	M	813.7	488.0	148.2	42.3	8.8	5.3	1.7	0.5
Burkina Faso	Both	450 882.7	13 999.8	56 272.2	1 073.4	4 957.7	153.9	673.5	12.8
	F	213 872.9	13 519.7	31 756.9	1 233.7	2 353.0	148.7	379.9	14.8
	M	237 009.8	14 463.2	24 515.4	918.7	2 604.7	159.0	293.6	11.0
Burundi	Both	303 901.0	15 983.5	53 112.4	1 882.6	3 338.6	175.6	637.5	22.6
	F	145 148.7	15 367.7	28 995.1	2 048.5	1 595.2	168.9	347.9	24.6
	M	158 752.3	16 591.4	24 117.2	1 715.5	1 743.4	182.2	289.6	20.6
Cabo Verde	Both	1 256.2	2 299.4	59.4	53.6	13.7	25.1	0.7	0.6
	F	567.6	2 103.0	29.3	53.4	6.2	23.0	0.3	0.6
	M	688.6	2 491.3	30.1	53.9	7.5	27.2	0.4	0.6
Cambodia	Both	103 146.9	5 856.4	9 325.3	292.6	1 126.1	63.9	109.7	3.4
	F	46 771.4	5 397.7	4 176.7	267.1	510.9	59.0	49.0	3.1
	M	56 375.6	6 300.6	5 148.7	317.2	615.2	68.8	60.7	3.7
Cameroon	Both	641 356.5	16 858.9	118 525.0	1 895.7	7 048.7	185.3	1,418.4	22.7
	F	290 059.3	15 403.3	58 157.5	1 874.7	3 189.0	169.4	696.0	22.4
	M	351 297.2	18 285.7	60 367.5	1 916.4	3 859.6	200.9	722.4	22.9
Canada	Both	157.4	8.2	28.9	0.7	1.7	0.1	0.3	0.0
	F	72.7	7.7	16.9	0.9	0.8	0.1	0.2	0.0
	M	84.7	8.6	12.1	0.6	0.9	0.1	0.1	0.0
Central African Republic	Both	213 754.1	29 263.2	9 978.9	786.8	2 347.2	321.3	119.2	9.4
	F	109 229.5	29 952.5	5 358.5	839.4	1 200.4	329.2	64.0	10.0

	M	104 524.6	28 576.0	4 620.3	733.5	1 146.9	313.5	55.2	8.8
Chad	Both	1 177 331.0	44 154.5	61 071.6	1 460.4	12 982.7	486.9	733.7	17.5
	F	566 691.8	42 880.3	33 786.8	1 628.5	6 251.9	473.1	406.1	19.6
	M	610 639.2	45 406.7	27 284.8	1 294.9	6 730.8	500.5	327.6	15.5
Chile	Both	1 499.5	126.7	115.9	4.6	16.2	1.4	1.2	0.0
	F	672.8	115.9	57.8	4.7	7.3	1.3	0.6	0.0
	M	826.7	137.1	58.1	4.6	9.0	1.5	0.6	0.0
China	Both	1 046 128.8	1 213.9	79 016.5	48.4	11 377.2	13.2	874.8	0.5
	F	462 779.3	1 156.8	45 380.3	60.2	5 016.3	12.5	484.7	0.6
	M	583 349.5	1 263.4	33 636.2	38.3	6 360.9	13.8	390.1	0.4
Colombia	Both	23 646.1	637.0	2 382.2	30.1	258.3	7.0	28.4	0.4
	F	10 993.8	605.3	1 063.5	27.5	120.1	6.6	12.6	0.3
	M	12 652.3	667.4	1 318.7	32.7	138.2	7.3	15.8	0.4
Comoros	Both	19 120.9	16 048.4	1 043.8	524.7	210.0	176.3	12.4	6.3
	F	9 376.7	16 043.6	522.4	534.5	103.0	176.3	6.2	6.4
	M	9 744.2	16 053.1	521.4	515.3	107.0	176.3	6.2	6.2
Congo	Both	76 625.6	9 296.3	5 512.9	408.9	841.1	102.0	66.2	4.9
	F	37 555.9	9 199.9	3 189.4	475.6	412.7	101.1	38.3	5.7
	M	39 069.7	9 391.0	2 323.5	342.9	428.5	103.0	27.9	4.1
Cook Islands	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Costa Rica	Both	589.1	170.4	75.0	10.4	6.3	1.8	0.8	0.1
	F	274.9	162.9	41.6	11.8	2.9	1.7	0.4	0.1
	M	314.2	177.6	33.3	9.0	3.4	1.9	0.4	0.1
Côte d'Ivoire	Both	738 191.4	19 121.1	107 634.4	1 728.2	8 107.7	210.0	1 293.4	20.8
	F	326 954.3	17 053.9	61 198.6	1 968.2	3 592.5	187.4	735.3	23.6
	M	411 237.1	21 160.3	46 435.8	1488.9	4 515.2	232.3	558.1	17.9

Croatia	Both	151.8	77.3	20.8	4.9	1.6	0.8	0.2	0.0
	F	62.4	65.4	1.5	0.7	0.7	0.7	0.0	0.0
	M	89.4	88.6	19.3	8.9	1.0	0.9	0.2	0.1
Cuba	Both	2 327.2	365.7	173.8	14.2	25.3	4.0	1.9	0.2
	F	1 070.7	345.9	111.0	18.7	11.6	3.8	1.2	0.2
	M	1 256.4	384.4	62.8	10.0	13.7	4.2	0.6	0.1
Cyprus	Both	5.7	8.7	0.2	0.1	0.1	0.1	0.0	0.0
	F	2.7	8.6	0.1	0.1	0.0	0.1	0.0	0.0
	M	3.0	8.8	0.1	0.1	0.0	0.1	0.0	0.0
Czechia	Both	345.7	64.7	102.9	9.5	3.7	0.7	1.1	0.1
	F	142.3	54.8	38.5	7.3	1.5	0.6	0.4	0.1
	M	203.4	74.1	64.4	11.6	2.2	0.8	0.7	0.1
Democratic People's Republic of Korea	Both	62 342.0	3 611.1	4 152.2	116.4	680.4	39.4	47.8	1.3
	F	27 485.5	3 260.0	2 354.5	134.8	299.5	35.5	27.0	1.5
	M	34 856.5	3 946.2	1 797.7	98.7	380.9	43.1	20.8	1.1
Democratic Republic of the Congo	Both	2 977 828.2	20 545.2	227 190.6	1 032.8	32 647.3	225.2	2 736.3	12.4
	F	1 483 995.6	20 681.3	128 347.4	1 175.4	16 275.6	226.8	1 545.2	14.2
	M	1 493 832.5	20 411.8	98 843.2	892.3	16 371.7	223.7	1 191.1	10.8
Denmark	Both	35.6	12.5	3.9	0.6	0.4	0.1	0.0	0.0
	F	16.7	12.0	3.3	1.0	0.2	0.1	0.0	0.0
	M	19.0	13.0	0.6	0.2	0.2	0.1	0.0	0.0
Djibouti	Both	11 510.3	11 253.5	2 632.0	1 348.4	125.9	123.1	31.7	16.2
	F	5 313.0	10 536.2	1 314.8	1 363.6	58.1	115.2	15.8	16.4
	M	6 197.3	11 950.9	1 317.1	1 333.5	67.8	130.8	15.9	16.1

Dominica	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Dominican Republic	Both	15 211.5	1 435.7	799.6	38.1	166.6	15.7	9.2	0.4
	F	6 061.5	1 168.2	393.1	38.2	66.4	12.8	4.5	0.4
	M	9 150.0	1 692.3	406.6	38.1	100.3	18.5	4.7	0.4
Ecuador	Both	14 450.1	896.9	1 148.3	37.1	158.1	9.8	13.7	0.4
	F	6 682.0	849.1	553.7	36.6	73.1	9.3	6.6	0.4
	M	7 768.1	942.5	594.6	37.6	85.0	10.3	7.1	0.4
Egypt	Both	231 920.0	1 801.2	58 961.3	308.2	2,533.9	19.7	702.6	3.7
	F	101 414.2	1 625.7	26 362.2	284.0	1 108.4	17.8	313.2	3.4
	M	130 505.8	1 966.2	32 599.1	330.9	1 425.5	21.5	389.3	4.0
El Salvador	Both	5 853.9	1 015.4	810.5	68.3	63.9	11.1	9.9	0.8
	F	2,279.7	809.8	302.5	52.1	24.8	8.8	3.6	0.6
	M	3,574.2	1,211.7	508.0	83.9	39.0	13.2	6.2	1.0
Equatorial Guinea	Both	30 835.4	16 976.2	2 858.1	1 040.8	338.1	186.2	34.2	12.5
	F	13 223.4	14 750.4	1 613.3	1 190.7	145.1	161.9	19.3	14.2
	M	17 612.0	19 145.3	1 244.8	894.9	193.0	209.8	14.9	10.7
Eritrea	Both	85 692.6	11 521.8	10 633.4	793.5	940.9	126.5	126.8	9.5
	F	39 625.4	10 883.1	5 030.6	765.7	435.1	119.5	59.9	9.1
	M	46 067.3	12 134.4	5 602.8	820.3	505.8	133.2	66.9	9.8
Estonia	Both	21.9	32.4	13.3	9.2	0.2	0.3	0.1	0.1
	F	10.3	31.1	5.4	7.7	0.1	0.3	0.1	0.1
	M	11.6	33.6	7.9	10.6	0.1	0.3	0.1	0.1
eSwatini	Both	18 542.3	10 323.9	1 796.5	556.8	203.1	113.1	21.4	6.6
	F	8 647.9	9 693.2	967.2	601.7	94.7	106.2	11.5	7.2
	M	9 894.4	10 946.4	829.3	512.3	108.4	119.9	9.9	6.1

Ethiopia	Both	1 849 426.1	12 185.6	261 665.8	972.3	20 330.0	134.0	3 140.1	11.7
	F	824 558.8	11 028.5	127 071.8	954.6	9 063.9	121.2	1 523.8	11.4
	M	1 024 867.4	13 309.0	134 594.1	989.7	11 266.1	146.3	1 616.2	11.9
Fiji	Both	2 058.4	2 377.5	264.9	155.5	22.4	25.9	3.1	1.8
	F	996.6	2 367.2	141.2	171.3	10.9	25.8	1.7	2.0
	M	1 061.8	2 387.2	123.8	140.6	11.6	26.0	1.5	1.7
Finland	Both	11.4	3.9	0.4	0.1	0.1	0.0	0.0	0.0
	F	5.4	3.7	0.2	0.1	0.1	0.0	0.0	0.0
	M	6.0	4.0	0.3	0.1	0.1	0.0	0.0	0.0
France	Both	354.4	9.2	95.0	1.2	3.6	0.1	0.7	0.0
	F	169.4	9.0	44.1	1.1	1.7	0.1	0.3	0.0
	M	185.0	9.4	50.8	1.3	1.9	0.1	0.4	0.0
Gabon	Both	14 354.1	5 246.1	2 008.6	460.3	157.5	57.6	24.6	5.6
	F	6 520.0	4 818.9	990.8	458.1	71.6	52.9	12.1	5.6
	M	7 834.1	5 664.1	1 017.7	462.4	85.9	62.1	12.5	5.7
Gambia	Both	43 944.2	12 190.4	3 936.4	693.4	483.8	134.2	47.0	8.3
	F	20 850.8	11 684.3	2 326.7	826.7	229.7	128.7	27.8	9.9
	M	23 093.4	12 686.6	1 609.7	562.4	254.1	139.6	19.2	6.7
Georgia	Both	1 287.8	474.8	448.2	94.8	14.0	5.2	5.3	1.1
	F	641.4	491.1	172.3	77.2	7.0	5.3	2.0	0.9
	M	646.4	459.7	275.9	110.6	7.0	5.0	3.3	1.3
Germany	Both	487.6	13.7	137.5	1.9	5.2	0.1	1.5	0.0
	F	221.7	12.8	51.1	1.5	2.4	0.1	0.5	0.0
	M	265.9	14.6	86.4	2.4	2.8	0.2	1.0	0.0
Ghana	Both	339 033.1	8 298.9	34 463.0	505.0	3 724.0	91.2	413.0	6.1
	F	150 795.4	7 538.8	18 151.8	544.0	1 656.1	82.8	217.5	6.5
	M	188 237.7	9 028.1	16 311.2	467.7	2 067.9	99.2	195.5	5.6
Greece	Both	282.4	59.6	43.2	3.8	3.1	0.6	0.5	0.0

	F	128.6	56.1	20.0	3.6	1.4	0.6	0.2	0.0
	M	153.8	62.9	23.2	4.0	1.7	0.7	0.3	0.0
Grenada	Both	75.9	768.8	2.5	13.4	0.8	8.4	0.0	0.1
	F	35.7	741.8	0.2	2.0	0.4	8.1	0.0	0.0
	M	40.2	794.4	2.3	24.3	0.4	8.7	0.0	0.3
Guatemala	Both	91 132.4	4 505.6	6 784.8	174.4	997.0	49.3	81.0	2.1
	F	42 233.7	4 270.1	3 484.7	183.0	462.1	46.7	41.6	2.2
	M	48 898.7	4 730.8	3 300.0	166.1	535.0	51.8	39.5	2.0
Guinea	Both	390 832.7	19 710.2	42 456.6	1 293.9	4 294.4	216.6	508.3	15.5
	F	185 068.8	18 786.1	26 421.0	1 621.8	2 034.3	206.5	316.1	19.4
	M	205 764.0	20 622.7	16 035.6	970.7	2 260.1	226.5	192.2	11.6
Guinea-Bissau	Both	60 451.1	20 785.1	3 357.5	722.4	666.6	229.2	40.2	8.6
	F	28 723.7	19 839.1	1 799.9	774.9	316.7	218.8	21.5	9.3
	M	31 727.4	21 722.9	1 557.6	670.0	349.9	239.6	18.7	8.0
Guyana	Both	1 465.2	1 917.4	251.1	166.2	16.0	21.0	3.0	2.0
	F	679.2	1 823.7	113.1	153.8	7.4	19.9	1.3	1.8
	M	786.1	2 006.5	138.0	177.9	8.6	21.9	1.7	2.2
Haiti	Both	211 679.7	17 161.9	15 676.2	657.8	2 323.7	188.4	187.6	7.9
	F	95 403.3	15 778.3	6 873.8	586.1	1 047.4	173.2	82.3	7.0
	M	116 276.4	18 492.3	8 802.4	727.3	1 276.3	203.0	105.3	8.7
Honduras	Both	18 714.4	1 967.4	735.0	36.9	204.5	21.5	8.5	0.4
	F	8 370.1	1 795.6	218.0	22.3	91.4	19.6	2.4	0.2
	M	10 344.3	2 132.4	517.0	51.0	113.1	23.3	6.1	0.6
Hungary	Both	303.6	69.6	12.8	1.3	3.2	0.7	0.0	0.0
	F	127.2	60.2	6.1	1.3	1.3	0.6	0.0	0.0
	M	176.4	78.6	6.7	1.4	1.9	0.8	0.0	0.0
Iceland	Both	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0
	F	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0

	M	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0
India	Both	9 280 411.0	7 733.8	612 021.7	241.6	101 788.2	84.8	7 234.4	2.9
	F	5 000 735.5	8 796.4	346 992.9	289.8	54 893.0	96.6	4 125.3	3.4
	M	4 279 675.5	6 777.2	265 028.8	198.3	46 895.2	74.3	3 109.1	2.3
Indonesia	Both	804 671.2	3 241.8	47 788.0	100.9	8 784.9	35.4	556.7	1.2
	F	395 001.1	3 257.2	23 055.2	99.7	4 314.6	35.6	267.4	1.2
	M	409 670.1	3 227.1	24 732.8	102.0	4 470.3	35.2	289.4	1.2
Iran (Islamic Republic of)	Both	67 188.0	984.8	2 841.3	23.3	733.1	10.7	31.3	0.3
	F	35 538.3	1 064.4	1 413.9	23.7	388.3	11.6	15.5	0.3
	M	31 649.7	908.5	1 427.4	23.0	344.8	9.9	15.8	0.3
Iraq	Both	191 318.0	3 334.5	3 870.2	41.4	2 093.2	36.5	43.7	0.5
	F	62 496.4	2 241.0	2 103.6	46.4	684.7	24.6	23.9	0.5
	M	128 821.5	4 368.6	1 766.5	36.8	1 408.5	47.8	19.8	0.4
Ireland	Both	31.3	9.1	3.4	0.5	0.3	0.1	0.0	0.0
	F	13.5	8.1	2.7	0.8	0.1	0.1	0.0	0.0
	M	17.8	10.1	0.7	0.2	0.2	0.1	0.0	0.0
Israel	Both	148.5	17.7	58.7	4.1	1.6	0.2	0.7	0.0
	F	72.5	17.7	25.5	3.6	0.8	0.2	0.3	0.0
	M	76.0	17.6	33.3	4.5	0.8	0.2	0.4	0.1
Italy	Both	279.8	11.3	63.8	1.1	3.0	0.1	0.7	0.0
	F	125.5	10.4	43.0	1.6	1.3	0.1	0.5	0.0
	M	154.2	12.1	20.8	0.7	1.6	0.1	0.2	0.0
Jamaica	Both	551.7	269.0	83.6	18.3	5.9	2.9	0.9	0.2
	F	251.0	252.4	42.7	19.1	2.7	2.7	0.5	0.2
	M	300.7	284.7	40.9	17.6	3.2	3.1	0.5	0.2
Japan	Both	1 882.6	35.2	527.3	4.7	20.2	0.4	5.4	0.0
	F	885.3	34.1	216.7	4.0	9.5	0.4	2.2	0.0
	M	997.2	36.3	310.6	5.4	10.7	0.4	3.2	0.1

Jordan	Both	8 873.6	723.1	694.6	32.2	96.6	7.9	8.0	0.4
	F	4 252.8	708.1	402.3	37.8	46.4	7.7	4.7	0.4
	M	4 620.8	737.5	292.3	26.8	50.3	8.0	3.3	0.3
Kazakhstan	Both	8 157.7	408.5	553.0	18.9	88.8	4.4	6.3	0.2
	F	3 674.5	378.4	271.9	19.1	40.0	4.1	3.1	0.2
	M	4 483.2	436.9	281.2	18.7	48.8	4.8	3.2	0.2
Kenya	Both	607 742.3	8 653.2	38 646.6	302.2	6 671.7	95.0	463.1	3.6
	F	294 585.2	8 476.2	15 724.9	247.8	3 234.9	93.1	188.0	3.0
	M	313 157.1	8 826.5	22 921.6	355.7	3 436.7	96.9	275.1	4.3
Kiribati	Both	1 551.9	10 713.3	88.5	349.1	17.0	117.4	1.0	4.1
	F	746.6	10 567.8	26.6	215.0	8.2	115.8	0.3	2.5
	M	805.3	10 851.9	61.8	477.4	8.8	119.0	0.7	5.6
Kuwait	Both	1 046.9	331.2	219.3	41.1	11.4	3.6	2.5	0.5
	F	517.5	334.8	99.8	39.0	5.6	3.6	1.1	0.4
	M	529.4	327.7	119.5	43.0	5.7	3.6	1.4	0.5
Kyrgyzstan	Both	20 013.1	2 631.6	820.5	73.5	218.7	28.8	9.4	0.8
	F	9 242.5	2 498.2	372.0	68.1	101.0	27.3	4.2	0.8
	M	10 770.6	2 758.0	448.5	78.7	117.7	30.1	5.2	0.9
Lao People's Democratic Republic	Both	105 545.5	13 785.8	7 456.0	502.8	1 156.7	151.1	88.2	6.0
	F	51 020.7	13 610.3	3 481.1	479.0	559.5	149.3	41.2	5.7
	M	54 524.8	13 954.2	3 974.9	525.8	597.2	152.8	47.1	6.2
Latvia	Both	93.5	96.6	5.0	2.4	1.0	1.0	0.0	0.0
	F	44.6	95.0	2.4	2.4	0.5	1.0	0.0	0.0
	M	48.9	98.0	2.6	2.5	0.5	1.0	0.0	0.0
Lebanon	Both	937.8	194.1	69.3	7.4	10.1	2.1	0.6	0.1
	F	516.4	217.0	37.1	7.9	5.6	2.3	0.3	0.1
	M	421.4	171.8	32.1	7.0	4.5	1.9	0.3	0.1

Lesotho	Both	44 220.4	15 466.0	3 083.5	620.3	484.2	169.4	36.8	7.4
	F	22 325.3	15 726.3	1 761.0	711.9	244.5	172.2	21.1	8.5
	M	21 895.0	15 209.4	1 322.6	529.5	239.7	166.5	15.8	6.3
Liberia	Both	100 750.4	14 081.4	8 131.9	662.5	1 103.5	154.2	97.9	8.0
	F	50 171.1	14 332.2	4 556.3	758.4	549.6	157.0	54.8	9.1
	M	50 579.3	13 841.1	3 575.7	570.6	554.0	151.6	43.1	6.9
Libya	Both	4 146.2	661.8	735.2	63.3	45.3	7.2	8.4	0.7
	F	2 155.4	705.9	354.6	62.6	23.5	7.7	4.0	0.7
	M	1 990.8	619.8	380.6	64.0	21.7	6.8	4.4	0.7
Lithuania	Both	66.7	43.9	3.9	1.4	0.7	0.5	0.0	0.0
	F	34.1	46.0	1.9	1.4	0.4	0.5	0.0	0.0
	M	32.6	41.8	2.0	1.4	0.3	0.4	0.0	0.0
Luxembourg	Both	1.0	3.1	0.1	0.1	0.0	0.0	0.0	0.0
	F	0.4	2.8	0.0	0.1	0.0	0.0	0.0	0.0
	M	0.5	3.3	0.0	0.1	0.0	0.0	0.0	0.0
Madagascar	Both	385 194.1	10 221.2	48 886.6	750.8	4 225.0	112.1	585.2	9.0
	F	190 114.3	10 215.2	23 754.0	734.0	2 086.2	112.1	283.8	8.8
	M	195 079.8	10 227.0	25 132.6	767.4	2 138.9	112.1	301.4	9.2
Malawi	Both	265 781.4	9 138.8	15 383.5	301.6	2 915.0	100.2	183.7	3.6
	F	122 858.6	8 546.0	7 070.1	278.8	1 347.4	93.7	84.0	3.3
	M	142 922.9	9 718.2	8 313.4	324.1	1 567.6	106.6	99.6	3.9
Malaysia	Both	4 161.7	159.3	1 459.2	28.8	45.0	1.7	17.2	0.3
	F	1 790.9	142.1	646.2	26.2	19.4	1.5	7.6	0.3
	M	2 370.8	175.4	813.1	31.3	25.7	1.9	9.7	0.4
Maldives	Both	55.9	143.1	8.1	13.3	0.6	1.6	0.1	0.1
	F	30.2	160.9	4.5	15.1	0.3	1.8	0.1	0.2
	M	25.7	126.7	3.6	11.6	0.3	1.4	0.0	0.1
Mali	Both	665 347.8	19 967.7	44 405.1	841.6	7 319.4	219.7	529.5	10.0

	F	338 497.4	20 687.2	25 887.1	997.2	3 725.1	227.7	308.7	11.9
	M	326 850.4	19 273.6	18 518.1	691.0	3 594.3	211.9	220.8	8.2
Malta	Both	9.1	42.2	0.1	0.1	0.1	0.5	0.0	0.0
	F	4.6	43.9	0.0	0.1	0.1	0.5	0.0	0.0
	M	4.5	40.5	0.0	0.1	0.0	0.4	0.0	0.0
Marshall Islands	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Mauritania	Both	95 137.9	14 522.4	4 210.4	393.6	1 046.8	159.8	50.0	4.7
	F	39 088.1	12 157.1	2 421.5	459.6	430.1	133.8	28.8	5.5
	M	56 049.8	16 802.2	1 788.9	329.5	616.7	184.9	21.2	3.9
Mauritius	Both	231.3	339.6	41.4	24.3	2.5	3.7	0.5	0.3
	F	98.0	293.5	24.2	29.0	1.1	3.2	0.3	0.3
	M	133.4	384.0	17.1	19.7	1.5	4.2	0.2	0.2
Mexico	Both	97 907.4	845.4	4 141.5	18.0	1 070.0	9.2	49.1	0.2
	F	45 281.0	800.1	1 937.1	17.3	494.9	8.7	22.8	0.2
	M	52 626.3	888.7	2 204.4	18.8	575.1	9.7	26.3	0.2
Micronesia (Federated States of)	Both	644.3	5,532.5	58.1	246.3	7.1	60.6	0.7	2.9
	F	295.7	5 251.9	25.2	222.2	3.2	57.5	0.3	2.6
	M	348.6	5 795.2	32.8	268.7	3.8	63.4	0.4	3.2
Monaco	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Mongolia	Both	9 546.4	2 597.0	868.8	167.2	104.0	28.3	10.1	1.9
	F	3 438.1	1 895.2	369.9	144.0	37.4	20.6	4.3	1.7
	M	6 108.3	3 280.9	499.0	190.0	66.6	35.8	5.8	2.2
Montenegro	Both	44.0	121.1	20.7	26.3	0.4	1.2	0.2	0.2

	F	19.3	109.9	11.0	29.2	0.2	1.1	0.1	0.3
	M	24.6	131.6	9.7	23.7	0.2	1.3	0.1	0.2
Morocco	Both	54 513.0	1 553.8	2 318.8	37.3	596.4	17.0	26.7	0.4
	F	24 819.8	1 454.2	1 207.4	39.8	271.8	15.9	13.9	0.5
	M	29 693.2	1 648.1	1 111.4	34.9	324.6	18.0	12.8	0.4
Mozambique	Both	620 295.6	12 531.2	53 519.6	666.6	6 792.8	137.2	644.8	8.0
	F	304 753.8	12 407.3	26 973.9	674.0	3 338.0	135.9	324.8	8.1
	M	315 541.8	12 653.3	26 545.7	659.3	3 454.8	138.5	320.0	7.9
Myanmar	Both	505 643.2	11 142.9	37 658.4	378.9	5 543.8	122.2	447.5	4.5
	F	225 973.9	10 029.1	13 890.0	281.2	2 481.4	110.1	164.7	3.3
	M	279 669.2	12 241.3	23 768.4	475.5	3 062.4	134.0	282.8	5.7
Namibia	Both	26 643.4	7 742.5	2 385.5	418.0	292.5	85.0	28.6	5.0
	F	12 658.0	7 405.8	1 107.0	388.6	139.0	81.3	13.3	4.7
	M	13 985.4	8 074.7	1 278.5	447.3	153.6	88.7	15.4	5.4
Nauru	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Nepal	Both	190 700.7	6 919.0	12 992.0	202.2	2,086.1	75.7	152.9	2.4
	F	84 837.2	6 353.4	6 694.8	213.7	928.0	69.5	79.0	2.5
	M	105 863.4	7 450.5	6 297.2	191.3	1,158.0	81.5	73.9	2.2
Netherlands	Both	106.7	11.9	72.5	3.8	1.2	0.1	0.8	0.0
	F	46.4	10.7	50.6	5.4	0.5	0.1	0.6	0.1
	M	60.3	13.1	21.9	2.2	0.7	0.1	0.2	0.0
New Zealand	Both	82.5	27.1	7.6	1.2	0.9	0.3	0.1	0.0
	F	39.2	26.4	3.5	1.2	0.4	0.3	0.0	0.0
	M	43.3	27.8	4.1	1.3	0.5	0.3	0.0	0.0
Nicaragua	Both	19 161.4	3 208.2	1 355.7	111.4	209.6	35.1	16.3	1.3
	F	7 363.6	2 521.3	666.2	112.8	80.5	27.6	8.0	1.4

	M	11,797.8	3,865.5	689.5	110.0	129.1	42.3	8.3	1.3
Niger	Both	1 064 295.9	25 233.0	149 607.5	2 426.2	11 740.8	278.4	1 800.6	29.2
	F	541 543.6	26 242.9	79 237.6	2 622.4	5 978.1	289.7	953.6	31.6
	M	522 752.3	24 265.7	70 369.9	2 237.6	5 762.7	267.5	847.1	26.9
Nigeria	Both	8 902 806.0	27 994.9	994 548.2	1 981.3	98 000.8	308.2	11 876.0	23.7
	F	4 104 628.2	26 471.5	580 661.6	2 362.6	45 212.4	291.6	6 931.0	28.2
	M	4 798,177.0	29 444.5	413 886.6	1 615.5	52 788.4	323.9	4 945.0	19.3
Niue	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Norway	Both	15.5	5.1	2.6	0.4	0.2	0.1	0.0	0.0
	F	6.4	4.3	0.5	0.2	0.1	0.0	0.0	0.0
	M	9.1	5.8	2.1	0.7	0.1	0.1	0.0	0.0
Oman	Both	1 559.4	389.7	149.7	26.1	16.9	4.2	1.6	0.3
	F	897.8	461.9	77.3	27.2	9.8	5.0	0.8	0.3
	M	661.7	321.5	72.3	25.0	7.1	3.5	0.8	0.3
Pakistan	Both	3 489 562.8	13 979.2	165 856.7	390.7	38 252.1	153.2	1 979.6	4.7
	F	1 765 736.8	14 711.6	65 119.0	318.8	19 363.8	161.3	774.9	3.8
	M	1 723 826.1	13 300.8	100 737.8	457.4	18 888.3	145.7	1 204.7	5.5
Palau	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Panama	Both	3 354.1	863.6	296.7	40.8	36.6	9.4	3.5	0.5
	F	1 456.5	766.3	136.0	38.2	15.9	8.4	1.6	0.5
	M	1 897.6	956.9	160.7	43.4	20.7	10.5	1.9	0.5
Papua New Guinea	Both	98 364.8	9 525.1	6 691.4	352.2	1 075.6	104.2	78.7	4.1
	F	42 883.8	8 599.4	2 440.3	265.4	468.8	94.0	28.5	3.1
	M	55 481.0	10 389.6	4 251.1	433.6	606.8	113.6	50.1	5.1

Paraguay	Both	9 998.8	1 488.7	1 026.5	77.3	108.9	16.2	11.4	0.9
	F	4 490.5	1 364.2	515.6	79.2	48.8	14.8	5.7	0.9
	M	5 508.3	1 608.4	510.9	75.6	60.1	17.5	5.7	0.8
Peru	Both	33 641.7	1 109.3	9 768.1	169.7	366.8	12.1	116.3	2.0
	F	15 091.4	1 016.5	4 524.6	160.6	164.5	11.1	53.8	1.9
	M	18 550.3	1 198.3	5 243.5	178.5	202.3	13.1	62.5	2.1
Philippines	Both	557 310.0	4 833.4	80 775.9	375.8	6 107.8	53.0	973.2	4.5
	F	257 084.8	4 592.0	38 670.5	369.8	2 818.7	50.3	464.8	4.4
	M	300 225.2	5 061.2	42 105.3	381.5	3 289.2	55.4	508.4	4.6
Poland	Both	1 403.7	77.2	595.6	15.5	15.1	0.8	6.9	0.2
	F	625.5	70.7	281.8	15.1	6.7	0.8	3.3	0.2
	M	778.2	83.3	313.8	15.9	8.4	0.9	3.6	0.2
Portugal	Both	95.0	22.0	9.7	1.0	1.0	0.2	0.1	0.0
	F	43.7	21.0	3.5	0.7	0.5	0.2	0.0	0.0
	M	51.3	23.0	6.3	1.2	0.6	0.3	0.1	0.0
Qatar	Both	395.1	304.0	64.0	28.2	4.3	3.3	0.7	0.3
	F	154.3	242.1	25.6	23.2	1.7	2.6	0.3	0.2
	M	240.8	363.7	38.4	33.0	2.6	3.9	0.4	0.4
Republic of Korea	Both	739.8	33.2	186.5	4.0	7.6	0.3	1.3	0.0
	F	366.0	34.1	83.7	3.7	3.8	0.4	0.6	0.0
	M	373.8	32.4	102.8	4.2	3.8	0.3	0.7	0.0
Republic of Moldova	Both	2 470.4	1 134.1	160.9	38.3	26.9	12.4	1.8	0.4
	F	1 057.9	1 007.0	74.0	36.3	11.5	11.0	0.8	0.4
	M	1 412.6	1 252.5	86.9	40.2	15.4	13.6	1.0	0.5
Romania	Both	11 648.5	1 233.7	1 169.0	56.1	126.9	13.4	13.6	0.7
	F	5 238.6	1 140.2	626.2	61.7	57.1	12.4	7.3	0.7
	M	6 409.9	1 322.4	542.7	50.7	69.8	14.4	6.3	0.6

Russian Federation	Both	13 546.5	141.7	2 311.2	15.1	145.5	1.5	24.6	0.2
	F	6 206.5	133.6	1 167.3	15.6	66.6	1.4	12.5	0.2
	M	7 340.0	149.3	1 143.9	14.6	78.8	1.6	12.1	0.2
Rwanda	Both	113 210.2	6 507.2	21 136.9	685.5	1 240.6	71.3	253.6	8.2
	F	51 158.0	5 903.7	10 069.3	651.2	560.5	64.7	120.8	7.8
	M	62 052.2	7 106.1	11 067.5	720.1	680.1	77.9	132.9	8.6
Saint Kitts and Nevis	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Saint Lucia	Both	42.9	391.9	1.6	6.7	0.5	4.3	0.0	0.1
	F	20.8	385.2	1.3	11.3	0.2	4.2	0.0	0.1
	M	22.1	398.4	0.3	2.3	0.2	4.3	0.0	0.0
Saint Vincent and the Grenadines	Both	68.3	822.7	5.2	28.7	0.7	9.0	0.1	0.3
	F	33.1	806.4	2.7	29.6	0.4	8.8	0.0	0.4
	M	35.2	838.5	2.6	27.9	0.4	9.1	0.0	0.3
Samoa	Both	350.5	1 492.2	48.8	100.7	3.8	16.2	0.6	1.2
	F	142.1	1 254.7	20.2	86.3	1.5	13.6	0.2	1.0
	M	208.3	1 713.4	28.6	114.2	2.3	18.6	0.3	1.3
San Marino	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Sao Tome and Principe	Both	1 631.9	5 208.9	361.9	658.1	17.9	57.0	4.3	7.8
	F	675.4	4 349.9	179.7	658.2	7.4	47.6	2.1	7.8
	M	956.5	6 053.0	182.2	658.1	10.5	66.2	2.2	7.8

Saudi Arabia	Both	17 303.6	583.4	1 985.3	37.6	189.4	6.4	22.1	0.4
	F	8 471.9	579.8	1 106.2	42.6	92.7	6.3	12.4	0.5
	M	8 831.7	586.9	879.2	32.8	96.7	6.4	9.7	0.4
Senegal	Both	212 158.8	8 338.5	26 683.1	653.7	2 328.6	91.5	320.5	7.9
	F	96 393.2	7 682.1	14 105.1	699.2	1 058.7	84.4	169.1	8.4
	M	115 765.6	8 977.3	12 577.9	609.2	1 269.9	98.5	151.4	7.3
Serbia	Both	719.0	153.3	93.6	9.4	7.6	1.6	0.9	0.1
	F	320.8	140.1	40.7	8.4	3.4	1.5	0.4	0.1
	M	398.2	165.9	52.9	10.4	4.2	1.8	0.5	0.1
Seychelles	Both	30.7	392.2	15.0	116.4	0.3	4.3	0.2	1.4
	F	12.4	323.3	7.0	108.1	0.1	3.5	0.1	1.3
	M	18.3	458.3	8.1	124.5	0.2	5.0	0.1	1.5
Sierra Leone	Both	232 286.8	20 360.9	26 138.2	1 309.4	2 543.8	223.0	311.3	15.6
	F	112 502.9	19 785.5	14 266.1	1 425.4	1 232.1	216.7	169.8	17.0
	M	119 783.9	20 932.5	11 872.1	1 192.7	1 311.7	229.2	141.5	14.2
Singapore	Both	213.1	80.3	17.9	3.0	2.3	0.9	0.2	0.0
	F	89.0	69.7	10.4	3.6	1.0	0.8	0.1	0.0
	M	124.1	90.1	7.5	2.5	1.3	1.0	0.1	0.0
Slovakia	Both	575.4	204.5	113.4	20.6	6.2	2.2	1.3	0.2
	F	261.3	190.1	62.2	23.1	2.8	2.1	0.7	0.3
	M	314.1	218.3	51.2	18.1	3.4	2.4	0.6	0.2
Slovenia	Both	14.1	13.2	7.7	3.8	0.1	0.1	0.1	0.0
	F	7.1	13.6	1.1	1.1	0.1	0.1	0.0	0.0
	M	7.0	12.8	6.6	6.4	0.1	0.1	0.1	0.1
Solomon Islands	Both	4 233.0	5 115.5	220.0	144.5	46.2	55.9	2.5	1.7
	F	2 074.3	5 174.7	94.5	128.3	22.7	56.5	1.1	1.5
	M	2 158.6	5 059.8	125.4	159.7	23.6	55.3	1.5	1.9
Somalia	Both	1 068 103.0	40 813.4	62 716.7	1 549.9	11 764.4	449.5	748.1	18.5

	F	515 505.8	39 728.6	33 284.4	1 652.7	5 678.8	437.7	396.8	19.7
	M	552 597.1	41 880.2	29 432.3	1 448.0	6 085.5	461.2	351.3	17.3
South Africa	Both	260 058.2	4 558.5	17 158.8	161.3	2 841.8	49.8	205.1	1.9
	F	121 590.9	4 307.4	7 681.2	145.5	1 328.7	47.1	91.4	1.7
	M	138 467.4	4 804.5	9 477.6	176.9	1,513.0	52.5	113.7	2.1
South Sudan	Both	494 024.8	25 663.0	22 051.9	689.7	5 442.7	282.7	263.2	8.2
	F	238 273.8	25 127.4	11 415.7	722.7	2 625.6	276.9	136.1	8.6
	M	255 751.0	26 182.9	10 636.2	657.5	2 817.1	288.4	127.0	7.9
Spain	Both	235.3	11.4	37.1	0.8	2.5	0.1	0.4	0.0
	F	111.5	11.1	24.8	1.1	1.2	0.1	0.3	0.0
	M	123.8	11.6	12.2	0.5	1.3	0.1	0.1	0.0
Sri Lanka	Both	8 692.4	542.8	2 765.8	80.2	93.8	5.9	31.9	0.9
	F	3 597.6	456.8	1 465.1	85.3	38.9	4.9	17.0	1.0
	M	5 094.8	626.0	1 300.8	75.1	54.9	6.7	14.9	0.9
Sudan	Both	674 268.1	11 350.7	28 973.5	279.9	7 441.0	125.3	343.0	3.3
	F	383 306.5	13 128.1	14 703.7	288.5	4 230.4	144.9	174.3	3.4
	M	290 961.6	9 632.6	14 269.9	271.5	3 210.7	106.3	168.8	3.2
Suriname	Both	368.5	732.4	37.9	38.4	4.0	8.0	0.4	0.4
	F	158.1	650.8	17.8	37.4	1.7	7.1	0.2	0.4
	M	210.4	808.5	20.1	39.3	2.3	8.8	0.2	0.5
Sweden	Both	42.0	7.2	16.6	1.5	0.5	0.1	0.2	0.0
	F	16.8	5.9	4.8	0.9	0.2	0.1	0.1	0.0
	M	25.2	8.4	11.8	2.0	0.3	0.1	0.1	0.0
Switzerland	Both	43.3	10.0	8.4	1.0	0.5	0.1	0.1	0.0
	F	19.4	9.2	6.7	1.7	0.2	0.1	0.1	0.0
	M	23.9	10.7	1.7	0.4	0.3	0.1	0.0	0.0
Syrian Arab Republic	Both	19 112.1	910.3	4 161.8	86.9	209.3	10.0	49.1	1.0
	F	8 512.6	832.4	2 324.0	99.6	93.3	9.1	27.5	1.2

	M	10 599.5	984.2	1 837.8	74.9	116.0	10.8	21.6	0.9
Tajikistan	Both	73 611.8	6 222.5	5 620.4	297.5	804.3	68.0	65.5	3.5
	F	34 720.4	6 028.6	2 835.7	308.5	379.4	65.9	33.0	3.6
	M	38 891.4	6 406.4	2 784.7	287.2	424.8	70.0	32.4	3.3
Thailand	Both	26 484.1	702.9	4 706.0	56.1	288.4	7.7	55.2	0.7
	F	11 180.5	610.3	1 599.6	39.2	121.8	6.6	18.3	0.4
	M	15 303.6	790.6	3 106.4	72.1	166.6	8.6	36.9	0.9
The former Yugoslav Republic of Macedonia	Both	814.5	690.4	50.6	21.9	8.8	7.5	0.4	0.2
	F	391.5	681.8	5.8	5.2	4.2	7.4	0.0	0.0
	M	423.0	698.5	44.8	37.7	4.6	7.5	0.4	0.4
Timor-Leste	Both	26 423.1	12 820.9	1 056.6	302.8	289.1	140.3	12.5	3.6
	F	13 535.9	13 401.8	594.4	347.6	148.2	146.7	7.0	4.1
	M	12 887.2	12 262.6	462.2	259.8	141.0	134.1	5.5	3.1
Togo	Both	172 757.5	14 691.9	24 074.9	1 200.4	1 898.5	161.5	289.4	14.4
	F	75 760.7	12 924.6	14 022.9	1 402.3	832.9	142.1	168.5	16.8
	M	96 996.9	16 448.8	10 052.0	999.7	1 065.6	180.7	121.0	12.0
Tonga	Both	164.7	1 295.6	21.4	81.9	1.8	14.1	0.2	0.9
	F	93.9	1 516.6	8.8	69.6	1.0	16.5	0.1	0.8
	M	70.7	1 085.5	12.7	93.3	0.8	11.8	0.1	1.1
Trinidad and Tobago	Both	482.7	510.4	28.0	14.8	5.2	5.5	0.3	0.2
	F	222.5	478.3	7.2	7.8	2.4	5.2	0.1	0.1
	M	260.2	541.5	20.7	21.7	2.8	5.9	0.2	0.2
Tunisia	Both	5 683.2	540.5	716.4	42.8	62.0	5.9	8.1	0.5
	F	2 916.9	567.8	428.5	52.3	31.8	6.2	4.9	0.6
	M	2 766.3	514.4	287.9	33.6	30.1	5.6	3.2	0.4

Turkey	Both	17 035.1	251.5	2 769.7	20.8	184.7	2.7	31.2	0.2
	F	8 288.6	250.6	1 223.3	18.7	89.9	2.7	13.6	0.2
	M	8 746.5	252.2	1 546.4	22.7	94.7	2.7	17.5	0.3
Turkmenistan	Both	20 070.6	2 829.6	668.3	64.5	219.7	31.0	7.9	0.8
	F	8 540.0	2 444.6	285.7	55.8	93.5	26.8	3.4	0.7
	M	11 530.5	3 203.2	382.7	73.0	126.2	35.1	4.5	0.9
Tuvalu	Both	NA	NA	NA	NA	NA	NA	NA	NA
	F	NA	NA	NA	NA	NA	NA	NA	NA
	M	NA	NA	NA	NA	NA	NA	NA	NA
Uganda	Both	914 692.1	11 880.8	122 668.0	1 004.7	10 044.5	130.5	1 472.5	12.1
	F	422 630.1	11 083.4	60 827.1	1 003.6	4 638.1	121.6	729.9	12.0
	M	492 062.0	12 663.3	61 840.8	1 005.7	5 406.4	139.1	742.5	12.1
Ukraine	Both	6 546.3	280.5	598.4	13.5	70.7	3.0	5.8	0.1
	F	3 486.0	308.2	309.1	14.4	37.7	3.3	3.1	0.1
	M	3 060.3	254.4	289.3	12.7	33.0	2.7	2.8	0.1
United Arab Emirates	Both	864.3	186.3	66.0	8.0	9.2	2.0	0.6	0.1
	F	485.9	213.9	22.0	5.5	5.2	2.3	0.2	0.0
	M	378.4	159.8	44.0	10.5	4.0	1.7	0.5	0.1
United Kingdom	Both	1 201.2	30.0	218.7	2.9	13.1	0.3	2.5	0.0
	F	551.8	28.3	98.1	2.6	6.0	0.3	1.1	0.0
	M	649.4	31.7	120.7	3.1	7.1	0.3	1.4	0.0
United Republic of Tanzania	Both	1 041 731.9	10 789.1	114 108.2	741.1	11 439.5	118.5	1 359.2	8.8
	F	508 711.1	10 637.3	59 202.8	771.3	5 586.3	116.8	704.8	9.2
	M	533 020.8	10 938.0	54 905.4	711.0	5 853.2	120.1	654.4	8.5
United States of America	Both	4 106.7	20.9	780.7	1.9	44.0	0.2	7.9	0.0
	F	1 880.0	19.6	359.9	1.8	20.2	0.2	3.6	0.0

	M	2 226.8	22.2	420.8	2.0	23.8	0.2	4.3	0.0
Uruguay	Both	170.8	71.3	13.7	2.8	1.8	0.8	0.1	0.0
	F	74.6	63.5	4.0	1.6	0.8	0.7	0.0	0.0
	M	96.2	78.7	9.8	3.9	1.0	0.9	0.1	0.0
Uzbekistan	Both	55 718.4	1 749.8	8 942.2	159.3	607.7	19.1	105.9	1.9
	F	24 968.8	1 627.0	4 231.2	154.7	272.3	17.7	50.1	1.8
	M	30 749.6	1 864.1	4 711.1	163.7	335.4	20.3	55.8	1.9
Vanuatu	Both	1 416.2	4 114.2	104.1	164.5	15.4	44.9	1.2	1.9
	F	666.7	4,010.9	39.3	130.0	7.3	43.7	0.5	1.5
	M	749.4	4,210.7	64.8	196.1	8.2	45.9	0.8	2.3
Venezuela (Bolivarian Republic of)	Both	15 909.9	534.9	1 113.0	19.1	173.7	5.8	13.2	0.2
	F	6 898.5	474.6	477.6	16.7	75.3	5.2	5.6	0.2
	M	9 011.4	592.6	635.4	21.4	98.4	6.5	7.6	0.3
Viet Nam	Both	176 592.3	2 275.5	5 157.4	36.7	1 929.6	24.9	57.7	0.4
	F	69 334.7	1 887.1	1 755.6	26.0	757.3	20.6	18.8	0.3
	M	107 257.6	2 624.6	3 401.9	46.5	1 172.3	28.7	39.0	0.5
Yemen	Both	376 758.6	9 245.2	11 148.7	158.6	4 132.0	101.4	130.6	1.9
	F	214 536.5	10 763.4	5 987.9	173.9	2 353.2	118.1	70.3	2.0
	M	162 222.1	7 791.8	5 160.9	143.9	1 778.8	85.4	60.2	1.7
Zambia	Both	309 264.4	10 966.3	29 062.8	623.5	3 394.8	120.4	347.3	7.5
	F	147 139.2	10 532.6	14 186.8	612.4	1 615.6	115.7	169.4	7.3
	M	162 125.2	11 392.1	14 876.1	634.4	1 779.2	125.0	177.9	7.6
Zimbabwe	Both	224 757.2	8 850.7	29 028.2	700.6	2 467.9	97.2	348.2	8.4
	F	113 435.3	8 978.0	15 935.1	771.0	1 245.9	98.6	191.2	9.3
	M	111 321.9	8 724.7	13 093.1	630.5	1 222.0	95.8	157.0	7.6

NA, not available

F, females; M, males

Table 7. Death rate per 100 000 children attributable to the joint effects of household and ambient air pollution in 2016, by WHO region, the world, and income group, by sex

WHO region	Income group	Death rate per 100 000, boys < 5 years	Death rate per 100 000, girls < 5 years	Death rate per 100 000, boys 5–14 years	Death rate per 100 000, girls 5–14 years
African	LMIC	190.5	177.4	11.6	14.2
	HIC	5	3.5	1.5	1.3
Americas	LMIC	15.2	13.2	0.7	0.6
	HIC	0.3	0.3	0	0
Eastern Mediterranean	LMIC	94.6	102.8	3.7	3.5
	HIC	5.2	5.4	0.3	0.4
European	LMIC	9.1	8.4	0.6	0.5
	HIC	0.3	0.2	0	0
South-East Asia	LMIC	68.8	81.8	2.1	2.9
	HIC	NA	NA	NA	NA
Western Pacific	LMIC	21.4	19.5	1	1.1
	HIC	0.4	0.3	0	0
All	LMIC	87.6	89.9	4.1	5
	HIC	0.7	0.6	0	0.1
World		79.6	81.6	3.7	4.5

LMIC, low- and middle-in come country; HIC, high-income country
NA, not available

Table 8. Population attributable fraction (PAF) of childhood mortality due to ambient air pollution, by WHO region and income level, 2016

WHO region	Income level	Children < 5 years (%)	Children 5–14 years (%)
African	LMIC	28	29
	HIC	17	17
Americas	LMIC	15	16
	HIC	8	7
Eastern Mediterranean	LMIC	32	33
	HIC	37	38
European	LMIC	20	20
	HIC	12	13
South-East Asia	LMIC	35	35
	HIC	NA	NA
Western Pacific	LMIC	25	22
	HIC	11	11
All	LMIC	30	29
	HIC	17	15
World		30	29

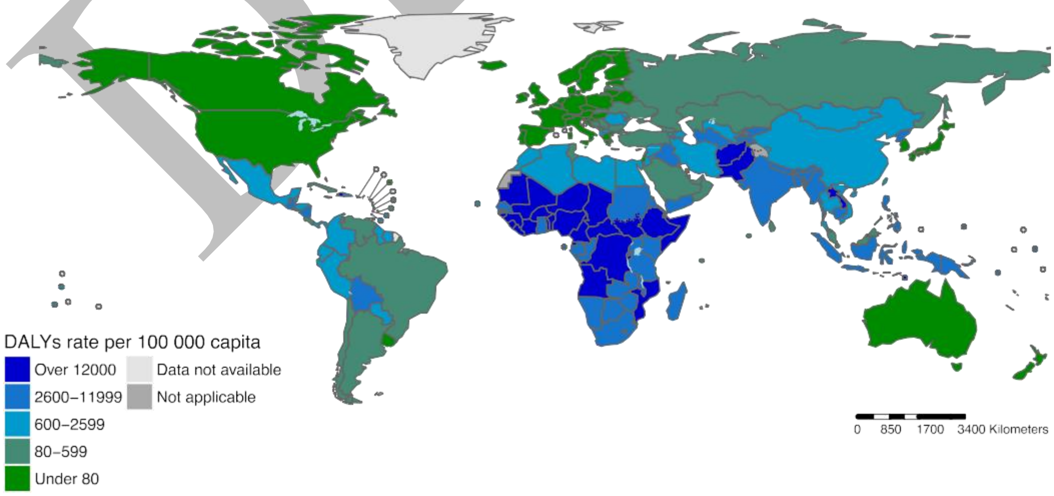
LMIC, low- and middle-in come country; HIC, high-income country
NA, not available

Table 9. Population attributable fraction (PAF) of childhood mortality due to household air pollution, by WHO region and income level, 2016

WHO region	Income level	Children < 5 years (%)	Children 5–14 years (%)
African	LMIC	53	52
	HIC	9	9
Americas	LMIC	23	22
	HIC	1	0
Eastern Mediterranean	LMIC	38	33
	HIC	4	4
European	LMIC	9	8
	HIC	1	0
South-East Asia	LMIC	43	42
	HIC	NA	NA
Western Pacific	LMIC	38	38
	HIC	0	0
All	LMIC	46	46
	HIC	2	1
World		46	46

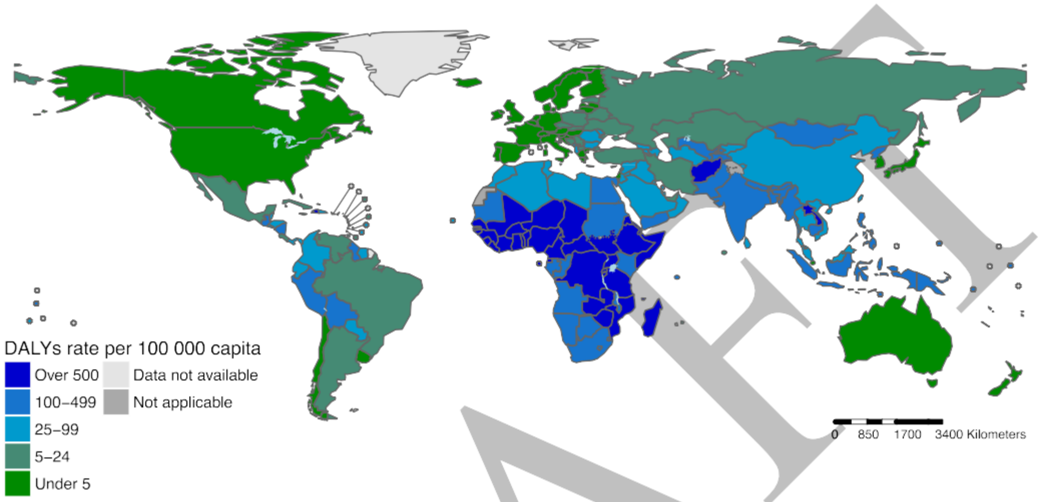
LMIC, low- and middle-in come country; HIC, high-income country
NA, not available

Fig. 15. Disability-adjusted life years (DALYs) per 100 000 capita due to acute lower respiratory infections associated with the joint effects of ambient and household air pollution in children under 5 years of age in 2016



Source: see Annex 2

Fig. 16. Disability-adjusted life years (DALYs) rate per 100 000 due to acute lower respiratory infections associated with the joint effects of ambient and household air pollution in children 5–14 years of age in 2016



Source: see Annex 2

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Contents

Foreword

In a world built on the ability to see, vision, the most dominant of our senses, is vital at every turn of our lives. The newborn depends on vision to recognize and bond with its mother; the toddler, to master balance and learn to walk; the schoolboy, to walk to school, read and learn; the young woman to participate in the workforce; and the older woman, to maintain her independence.

Yet, as this report shows, eye conditions and vision impairment are widespread, and far too often they still go untreated. Globally, *at least* 2.2 billion people have a vision impairment, and of these, at least 1 billion people have a vision impairment that could have been prevented or is yet to be addressed.

As usual, this burden is not borne equally. It weighs more heavily on low- and middle-income countries, on older people, and on rural communities. Most worrying is that projections show that global demand for eye care is set to surge in the coming years due to population growth, ageing, and changes in lifestyle.

Clearly, we have no choice but to take on this challenge. It is time to make sure that as many people as possible in all countries can see as well as current health technologies and health systems allow.

But it is important to recognize and build on the many successes in eye care of the last decades. One such success has been the WHO-endorsed SAFE strategy for trachoma elimination. Implemented in over 30 countries, it has so far resulted in eight countries eliminating trachoma as a public health problem. Other examples include public–private partnerships to provide spectacles in Pakistan, Sri Lanka, and South Africa.

The *World report on vision* sets out concrete proposals to address challenges in eye care. The key proposal is to make integrated people-centred eye care, embedded in health systems and based on strong primary health care, the care model of choice and scale it up widely.

People who need eye care must be able to receive high-quality interventions without suffering financial hardship. Including eye care in national health plans and essential packages of care is an important part of every country's journey towards universal health coverage.

WHO is committed to working with countries to improve the delivery of eye care, in particular through primary health care; to improving health information systems for eye care; and to strengthening the eye care workforce –three enabling factors for implementing integrated people-centred eye care.

But WHO cannot achieve this task alone. International organizations, donors, and the public and private sectors must work together to provide the long-term investment and management capacity to scale up integrated people-centred eye care.

Our hope is that, building on past efforts, we can successfully take on this challenge and help countries prevent eye conditions and vision impairment more effectively and provide quality eye care services according to the needs of their populations.

Dr Tedros Adhanom Ghebreyesus
Director-General
World Health Organization

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Abbreviations

CDTI	community-directed treatment with ivermectin
CRPD	Convention on the Rights of Persons with Disabilities
CUSUM	cumulative sum (analysis)
DALYs	disability-adjusted life years
ECSAT	eye care service assessment tool (WHO)
GBD	Global Burden of Disease
HIS	health information system
ICD	International Classification of Diseases
ICF	International Classification of Functioning, Disability and Health
IPEC	integrated people-centred eye care
MoH	Ministry of Health
PHC	primary health care
QoL	quality of life
SDG	Sustainable Development Goal
TADDS	tool for assessment of diabetes and diabetic retinopathy (WHO)
UHC	universal health coverage
UN	United Nations
VEGF	vascular endothelial growth factor
WHA	World Health Assembly
WHO	World Health Organization

Executive summary

The global need for eye care is projected to increase dramatically in the coming decades posing a considerable challenge to health systems. Despite concerted action during the past 30 years, significant challenges remain. The *World report on vision* seeks to stimulate action in countries to address these challenges by proposing integrated people-centred eye care (IPEC) as an approach to health system strengthening that builds the foundation for service delivery to address population needs. IPEC refers to eye care services that are managed and delivered to assure a continuum of promotive, preventive, treatment and rehabilitative interventions against the spectrum of eye conditions, coordinated across the different levels and sites of care within and beyond the health sector, and according to their needs throughout the life course. IPEC will also contribute to achieving universal health coverage (UHC) and Sustainable Development Goal 3 (SDG3): “Ensure healthy lives and promote well-being for all at all ages”.

Vision, eye conditions and vision impairment

Vision, the most dominant of our senses, plays a critical role in every facet and stage of our lives. We take vision for granted, but without vision, we struggle to learn to walk, to read, to participate in school, and to work.

Vision impairment occurs when an eye condition affects the visual system and one or more of its vision functions. Vision impairment has serious consequences for the individual across the life course. Many of these consequences can, however, be mitigated by timely access to quality eye care and rehabilitation.

Eye conditions that can cause vision impairment and blindness – such as cataract, trachoma and refractive error – are, for good reasons, the main focus of prevention and other eye care strategies; nevertheless, the importance of eye conditions that do not typically cause vision impairment – such as dry eye and conjunctivitis – must not be overlooked. These conditions are frequently among the leading reasons for presentation to eye care services all countries.

Global magnitude: eye conditions and vision impairment

Eye conditions are remarkably common. Those who live long enough will experience at least one eye condition during their lifetime. Globally, at least 2.2 billion people have a vision impairment or blindness, of whom at least 1 billion have a vision impairment that could have been prevented or has yet to be addressed. More reliable data on the met and unmet eye care needs, however, are required for planning. Also, the burden of eye conditions and vision impairment is not borne equally. The burden tends to be greater in low- and middle-income countries and underserved populations, such as women, migrants, indigenous peoples, persons with certain kinds of disability, and in rural communities. Population growth and ageing, along with behavioural and lifestyle changes, and urbanization, will dramatically increase the number of people with eye conditions, vision impairment and blindness in the coming decades.

The costs of addressing the coverage gap

The costs of the coverage gap for unaddressed refractive errors and cataract globally are estimated to be $14.3 billion US dollars. These are the additional costs that would be required to the current health system using an immediate time horizon. This financial investment is needed immediately; it requires appropriate planning and relies on additional investment to strengthen existing health systems.

Today, millions of people live with vision impairment or blindness that could have been prevented but, unfortunately, was not. While the exact number is unknown, it is estimated that 11.9 million people globally have moderate or severe vision impairment or blindness due to glaucoma, diabetic retinopathy and trachoma that could have been prevented. The estimated costs of preventing the vision impairment in these 11.9 million would have been US$5.8 billion. This represents a significant opportunity missed in preventing the substantial personal and societal burden associated with vision impairment and blindness.

Addressing eye conditions and vision impairment

A range of effective strategies are available to address the needs associated with eye conditions and vision impairment across the life course. These include health promotion, prevention, treatment and rehabilitation strategies, some of which are among the most feasible and cost-effective of all health care interventions to implement.

Successes and remaining challenges in eye care

Concerted action during the past 30 years has yielded many successes: global advocacy efforts have been launched; World Health Assembly resolutions adopted; and actions plans implemented. Recent scientific and technological developments promise to further accelerate these advances. Nonetheless, progress is not keeping pace with population eye care needs. Major challenges lie ahead. Firstly, eye care needs globally will rise sharply due to changes in demographics and lifestyle. Secondly, data are often lacking and health information systems weak, thus hampering planning. Thirdly, eye care is frequently poorly integrated into health systems, for example, in national health strategic plans and health information systems; and the eye care workforce is poorly coordinated.

Advancing UHC through eye care

Making eye care integral to UHC will contribute to reaching SDG target 3.8.[1] For this to happen quality eye care services need to be provided according to population needs and the cost of priority eye care interventions cannot expose the user to catastrophic expenditures. To facilitate the choices that countries must make when implementing UHC, WHO is developing an online data repository detailing WHO-recommended interventions and their resource implications. Part of this repository will also be a package of eye care interventions which will contribute to progressing the agenda of eye care as part of UHC forward.

IPEC

IPEC can help address the significant eye care challenges that many countries face. IPEC adopts a health-system perspective with four strategies: (i) engaging and empowering people and communities; (ii) reorienting the model of care based on a strong primary care; (iii) coordinating services within and across sectors; and (iv) creating an enabling environment, specifically the inclusion of eye care in national health strategic plans, the integration of relevant eye care relevant data within health information systems, and the planning of the eye care workforce according to population needs.

1 SDG 3.8: "Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all."

Conclusion and recommendations

Health systems face unprecedented challenges in meeting the current and projected eye care needs of the world's population. There is no choice but to take on these challenges. The premise of the World Report on Vision is that integrated people-centred eye care has the potential to accelerate action and meet these challenges. For this to become a reality, this report recommends five important actions:

1. Make eye care an integral part of universal health coverage.
2. Implement integrated people-centred eye care in health systems.
3. Promote high-quality implementation and health systems research complementing existing evidence for effective eye care interventions.
4. Monitor trends and evaluate progress towards implementing integrated people-centred eye care.
5. Raise awareness and engage and empower people and communities about eye care needs.

Introduction

Everyone, if they live long enough, will experience at least one eye condition in their lifetime that will require appropriate care. Globally, at least 2.2 billion people have a vision impairment or blindness, of whom at least 1 billion have a vision impairment that could have been prevented or has yet to be addressed. Tens of millions have a severe vision impairment and could benefit from rehabilitation which they are not currently receiving. The burden of eye conditions and vision impairment is not borne equally: it is often far greater in low- and middle-income countries, among older people and in women, and in rural and disadvantaged communities.

Fortunately, thanks to concerted action taken over the past 30 years, progress has been made in many areas. In 1999, the global initiative for the elimination of avoidable blindness, “Vision 2020: the Right to Sight”, intensified global advocacy efforts, strengthened national prevention of blindness programmes and supported the development of national eye care plans. This momentum was maintained by four WHA resolutions: WHA56.26 (2003); WHA59.25 (2006); WHA62.1 (2009), and WHA66.11 (2013). The 2009 and 2013 resolutions were accompanied by WHO action plans, the most recent of which, “Universal eye health: a global action plan 2014–2019”, called for universal access to comprehensive eye care services and set an ambitious global target to reduce “prevalence of avoidable visual impairment by 25% by 2019”. A report presented at the Seventieth WHA in May 2017 detailed the considerable progress made in implementing the 2014–2019 global action plan (resolution WHA66.4). At the same time, there has been a sharp increase in the number of population-based surveys undertaken to measure vision impairment and blindness around the world. Importantly, eye care has become an area of health care with many highly cost-effective interventions for health promotion, prevention, treatment and rehabilitation to address the entire range of needs associated with eye conditions and vision impairment across the life course.

Yet significant challenges remain. Chief among these are inequalities in coverage; addressing unmet needs and ensuring services are planned and provided according to population needs; uneven quality of eye care services; workforce shortages; fragmented services that are poorly integrated into health systems; gaps in data, particularly related to monitoring trends and evaluating progress; and lack of implementation, impact and health systems research related to eye care. In addition, population ageing (a third more people predicted to be aged over 60 years by 2030), coupled with lifestyle changes (less time spent outdoors, and increasingly sedentary life-styles and unhealthy eating habits), are causing the number of people with eye conditions and vision impairment to increase. Available data provide an incomplete picture of the met and unmet needs for eye care; nonetheless, the health systems of countries face considerable challenges. Such challenges include addressing the unmet eye care needs, continuing to provide eye care for those whose needs are being met, and preparing for a projected consistent increase in numbers of those needing eye care.

The *World report on vision*, building on achievements to date, aims to galvanize action to address these challenges. Building on WHO's existing Framework on integrated people-centred health services, integrated people-centred eye care (IPEC) is the key proposal of the report. IPEC is defined as services that are managed and delivered so that people receive a continuum of health promotive, preventive, treatment and rehabilitative interventions to address the full spectrum of eye conditions according to their needs, coordinated across the different levels and sites of care within and beyond the health sector, that adopts people's perspectives as participants and beneficiaries of these services, throughout their life course. IPEC also has the potential to contribute to the progress towards UHC in relation to eye care and to achieving SDG 3: "Ensure healthy lives and promote well-being for all at all ages".

The *World report on vision* is directed at policy-makers, practitioners, public health specialists, researchers, and academics, as well as ministries of health, civil society, and development agencies.

Aims

The overall aims of the report are:

- To raise awareness of the global magnitude and impact of eye conditions and vision impairment and the need to address gaps in data, particularly regarding met and unmet eye care needs;
- To draw attention to effective strategies to respond to eye care needs;
- To take stock of progress, and identify the main challenges facing the field of eye care;
- To emphasize the need for making eye care an integral part of UHC;
- To make the case for IPEC as the way forward;
- To make recommendations for action to be implemented by all countries to improve eye care.

Scope

This report makes the case that integrated people-centred eye care is the care model of choice and can help meet the challenges faced. *Chapter 1* highlights the critical importance of vision; describes eye conditions that can cause vision impairment and those that typically do not; reviews the main risk factors for eye conditions; defines vision impairment and disability; and explores the impact of vision impairment. *Chapter 2* provides an overview of the global magnitude of eye conditions and vision impairment and their distribution. *Chapter 3* presents effective promotive preventive, treatment, and rehabilitative strategies to address eye care needs across the life course. *Chapter 4* starts by taking stock of global advocacy efforts to date, the progress made in addressing specific eye conditions and vision impairment, and recent scientific and technological advances; it then identifies the remaining challenges facing the field. *Chapter 5* describes how making eye care an integral part of universal health care (including developing a package of eye care interventions) can help address some of the challenges faced by countries. *Chapter 6* presents IPEC and explains the need for engaging and empowering people and communities, reorienting the model of care based on a strong primary care and the need for coordinating services within and across sectors; and creating an enabling environment.

The report ends with five recommendations for action that can be implemented by all countries to improve eye care.

Moving forward

It is the intention of WHO and all involved in the preparation of the *World report on vision,* that the report will lead to greater awareness and increased political will and investment to implement its recommendations for action to strengthen eye care so that the field can meet the current and future challenges it faces.

Chapter 1

Vision, eye conditions and vision impairment

In a global society built on the ability to see, vision impairment has far-reaching consequences for individuals, their families and carers.

While some eye conditions cause vision impairment, many do not and yet can still lead to personal and financial hardships because of the treatment needs associated to them.

Vision impairment occurs when an eye condition affects the visual system and one or more of its vision functions. A person who wears spectacles or contact lenses to compensate for their vision impairment, still has a vision impairment.

"Disability" refers to the impairments, limitations and restrictions that a person with an eye condition faces in the course of interacting with her or his environment – physical, social, or attitudinal.

Timely access to quality care has a major influence on the impact of eye conditions.

Vision

In a global society built on the ability to see, vision plays a critical role in every facet and stage of life.

Vision plays a critical role in every facet and stage of life.

Vision is the most dominant of the five senses and plays a crucial role in every facet of our lives. It is integral to interpersonal and social interactions in face-to-face communication where information is conveyed through non-verbal cues such as gestures and facial expressions *(1, 2)*.

Globally, societies are built on the ability to see. Towns and cities, economies, education systems, sports, media and many other aspects of contemporary life are organized around sight. Thus, vision contributes towards everyday activities and enables people to prosper at every stage of life.

From the moment of birth, vision is critical to child development. For infants, visually recognizing and responding to parents, family members, and caregivers facilitates cognitive and social development and the growth of motor skills, coordination and balance *(3)*.

From early childhood to adolescence, vision enables ready access to educational materials and is pivotal to educational attainment *(4, 5)*. Vision supports the development of social skills to foster friendships, strengthen self-esteem and maintain well-being *(6)*. It is also important for participation in sports and social activities that are essential to physical development, mental and physical health, personal identity and socialization *(7)*.

In adulthood, vision facilitates participation in the workforce, contributing to economic benefits and a sense of identity *(8, 9)*. It also contributes towards the enjoyment of many other areas of life that are often designed around the ability to see, such as sports or cultural activities.

Later in life, vision helps with maintaining social contact and independence *(10-12)* and facilitates the management of other health conditions *(13-15)*. Vision also helps to sustain mental health and levels of well-being, both of which are higher among those with good vision *(16-18)*.

Eye conditions

While some eye conditions cause vision impairment, many typically do not yet can still lead to personal and financial hardships.

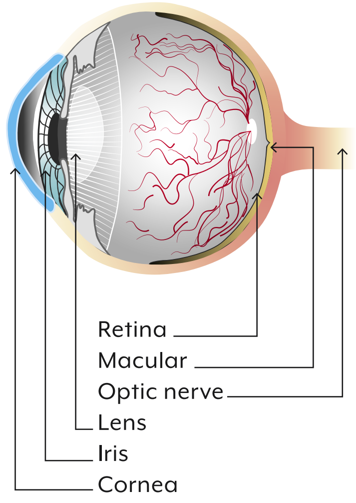
Eye conditions encompass a large and diverse range of morbidities that affect different components of the visual system and visual function (Box 1.1). Given their range, classifying eye conditions is a challenge; one way is to distinguish conditions that do not typically cause vision impairment from those that can (Tables 1.1 and 1.2).

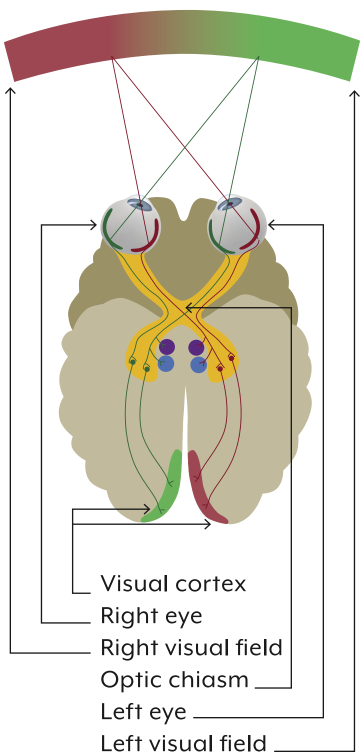
Some eye conditions cause vision impairment, many do not.

The importance of eye conditions that typically do not cause vision impairment should not be understated. These conditions can be troublesome and painful, and are frequently among the leading reasons for presentation to eye care services in all countries. For example, published data from the emergency departments of major health facilities in the high-income countries of Australia, the United States of America and Saudi Arabia reveal that conjunctivitis, a generally benign and self-limiting condition, is the most common reason for patient presentation *(19-22)*. Data gathered from health facilities in low- and middle-income countries show similar trends, with eye conditions that are typically non-vision-threatening, such as conjunctivitis, lid abnormalities, pterygium and dry eye, consistently ranked among the top reasons for clinic attendance *(23-27)*.

Eye conditions that can cause vision impairment and blindness are, with good reason, the main focus of prevention and intervention strategies. Notable, however, is that a considerable proportion of people with eye conditions in this category who receive timely diagnosis and treatment will not develop vision impairment or blindness. For example, of the estimated 196 million people globally with age-related macular degeneration *(28)*, 10.4 million (5.3%) have moderate or severe distance vision impairment or blindness from more severe forms of the condition *(29)*. Similarly, an estimated 64 million people globally have glaucoma *(30)*, of which 6.9 million (10.9%) only are reported to have moderate or severe distance vision impairment or blindness resulting from more severe forms of the condition *(29)*.

Also worthy of mention, is that certain conditions that do not typically cause vision impairment (as described in Table 1.1), may do so, if left untreated. For example, untreated cases of a form of conjunctivitis caused by gonococcal infection can result in vision impairment when bacteria penetrates the cornea causing corneal ulceration and scarring *(31)*. This emphasizes the importance of early identification and timely treatment for all eye conditions (as discussed in Chapter 3).





Box 1.1 The visual system and vision functions

Visual system

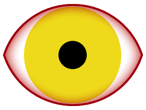
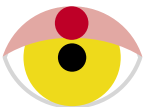
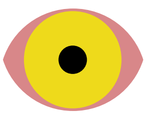
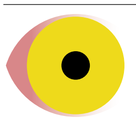
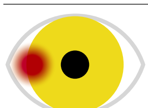
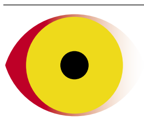
The visual system encompasses the eyes, optic nerves, and pathways to and between different structures in the brain. Structures at the front of the eye (the cornea and lens) focus light entering the eye onto the retina. In the retina, light is converted into nerve impulses which travel through the optic nerves and pathways to a specific part of the brain known as the visual cortex. These impulses are then transmitted to many other parts of the brain where they integrate with other inputs (such as from hearing or memory) to enable a person to understand the surrounding environment and respond accordingly.

Vision functions

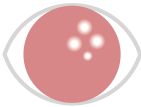
The visual system enables the vision functions which support a variety of activities and occupations:

- Visual acuity is the ability to see details clearly, regardless of the distance of the object.
  - Distance visual acuity is used in many everyday situations, such as reading a blackboard, signposts or bus numbers, or when recognizing people across a room. It is important for many occupations and recreational activities, such as playing sports.
  - Near visual acuity is important for all near tasks, such as reading and writing. It is also used in many occupations and recreational activities, such as tea picking, sorting grains and using mobile phones and computers.
- Colour vision has a very practical role, allowing differentiation of objects of a similar size and shape, such as medication; it is also important for occupations such as electrical work, aviation and fashion.
- Stereopsis/binocular vision (depth perception) allows judgement of distances and the speed of approaching objects. It is important for many near tasks, such as pouring liquids into a glass or threading a needle.
- Contrast sensitivity refers to the ability to distinguish an object from its background, which may often involve distinguishing shades of grey. It is especially important in situations of low light, such as driving at night.
- Vision in the peripheral visual fields, as well as the central part of the visual field, assists in moving around safely, by detecting obstacles and movement in a person's side vision. It is important for safe driving and for many occupations and sports.

Common eye conditions that do not typically cause vision impairment (Table 1.1)

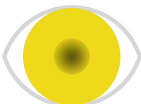
	**Blepharitis** Inflammation of the eyelids near the base of the eyelashes characterized by redness and irritation of the eye and eyelid.
	**Chalazion and hordeolum (stye)** Common eyelid disorders resulting from a blocked gland or localized infection that can cause pain.
	**Conjunctivitis** Inflammation of the conjunctiva (the clear membrane lining the inside of the eyelids and covers the white part of the eye) most commonly caused by allergy or infection.
	**Dry eye** Due to an inadequate tear production that can result in irritation and blurred vision.
	**Pterygium and pinguecula** Abnormal growths on the conjunctiva that can cause pain. In advanced cases, pterygium can encroach on the cornea and cause vision loss.
	**Subconjunctival haemorrhage** Broken blood vessels underneath the conjunctiva.

Common eye conditions that can cause vision impairment including blindness (Table 1.2)



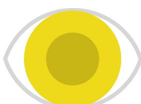
Age-related macular degeneration

Damage to the central part of the retina responsible for detailed vision leads to dark patches, shadows or distortion of the central vision. The risk of developing macular degeneration increases with age.



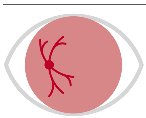
Cataract

Cloudiness in the lens of the eye, leading to increasingly blurred vision. The risk of developing cataract increases with age.



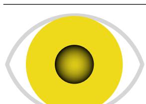
Corneal opacity

A group of conditions causing the cornea to become scarred or cloudy. Opacity is most commonly caused by injury, infection or vitamin A deficiency in children.



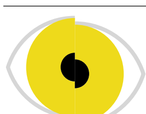
Diabetic retinopathy

Damage to blood vessels in the retina which become leaky or blocked. Vision loss most commonly occurs due to swelling in the central part of the retina which can lead to vision impairment. Abnormal blood vessels can also grow from the retina, which can bleed or cause scarring of the retina and blindness.



Glaucoma

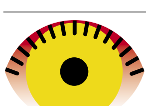
Progressive damage to the optic nerve. Initially, loss of vision occurs in the periphery and can progress to severe vision impairment (this is known as open angle glaucoma, the most common type and the type generally referred to in this report).



Refractive error

Due to an abnormal shape or length of the eye ball; light does not focus on the retina resulting in blurred vision. There are several types of refractive error; those most commonly referred to in this report are:

- *Myopia* – difficulty seeing distant objects (near-sightedness).
- *Presbyopia* – difficulty seeing objects at near distance with increasing age (i.e. after 40 years of age).



Trachoma

Caused by a bacterial infection. After many years of repeated infections, the eyelashes can turn inwards (known as trichiasis) which can lead to corneal scarring and, in some cases, blindness.

Risk factors for, and causes of, eye conditions

Risk factors for, and causes of, eye conditions include ageing, genetics, lifestyle exposure and behaviours, infections, and various health conditions. Many eye conditions are multifactorial in origin.

Many risk factors increase the likelihood of developing, or contributing to the progression of, an eye condition. These include ageing, lifestyle exposure and behaviours, infections, and a range of health conditions.

Ageing is the primary risk factor for many eye conditions.

Ageing is the primary risk factor for many eye conditions. The prevalence of presbyopia, cataract, glaucoma and age-related macular degeneration increase sharply with age *(28, 30, 32, 33)*. Genetics also play a role in the development of some eye conditions including glaucoma, refractive error and retinal degenerations such as retinitis pigmentosa *(34-36)*. Ethnicity *(30)* is an example of another non-modifiable risk factor that is related to a greater risk of developing some eye conditions.

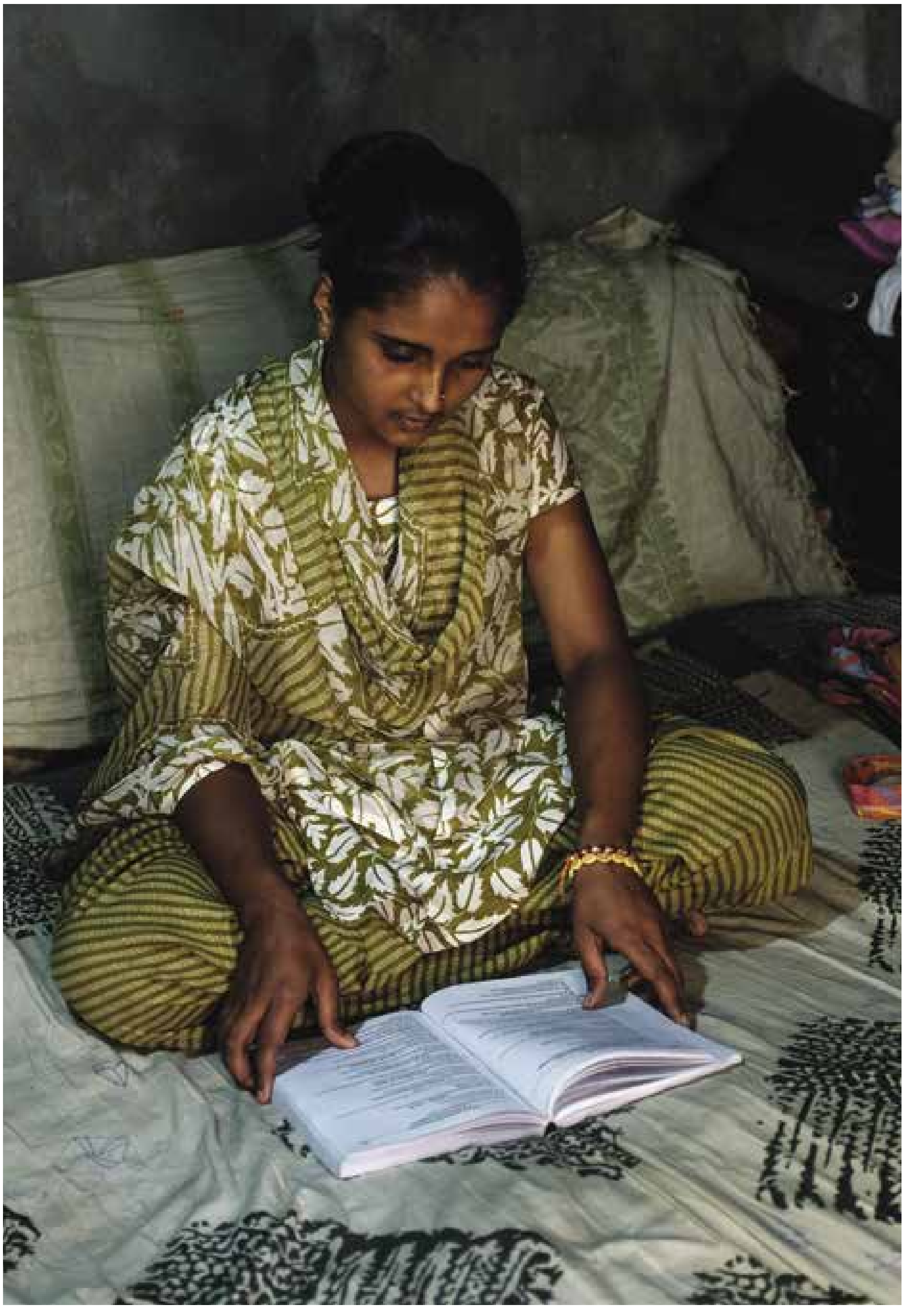
Lifestyle exposures or behaviours are also linked to many eye conditions. Smoking is the primary modifiable risk factor for age-related macular degeneration *(37)* and plays a part in the development of cataract *(38)*. Nutrition may also play an important role in eye conditions. For example, vitamin A deficiency, resulting from chronic malnutrition in children, can cause corneal opacity *(39)*. Additionally, occupations and recreational activities, such as farming or mining and contact sports, are linked consistently to greater risk of ocular injury *(40)*.

Ocular infections from bacterial, viral or other microbiological agents can affect the conjunctiva, cornea, eyelids and, more rarely, the retina and optic nerve; conjunctivitis is the most common of these *(41)*. Trachoma, the leading infectious cause of blindness worldwide, is caused by the bacterium *chlamydia trachomatis (42)*. Environmental risk factors, including hygiene, sanitation and access to water, are also important in influencing the transmission of the trachoma bacterium *(43)*. Other infections that can cause vision impairment and blindness include measles *(44)*, *onchocera volvulus (45)* and the *toxoplasma gondii* parasites *(46)*, to name a few.

Certain health conditions may lead to a range of ocular manifestations; these include, but are not limited to, diabetes *(47)*, rheumatoid arthritis *(48)*, multiple sclerosis *(49)* and pre-term birth *(50)*. Additionally, some medications increase the susceptibility of developing certain eye conditions; the long-term use of steroids, for example, increases the risk of developing cataract *(51)* and glaucoma *(52)*.

The origins of many eye conditions are multifactorial, with a range of risk factors interacting to increase both the susceptibility to, and the progression of, a condition. Diabetes duration, high haemoglobin A1c, and high blood pressure, for example, are important risk factors for diabetic retinopathy *(53)*. Another example is myopia, where an interplay between genetic and environmental risk factors, including intensive near vision activity (as a risk factor) and longer time spent outdoors (as a protective factor), may play an important role in the onset and progression of the condition *(36)*.

Access to quality eye care is a significant factor in the risk of progression of eye conditions and treatment outcomes *(54-57)*. Effective interventions are available to prevent, treat, and manage most major eye conditions (further details are provided in Chapter 3). It is important to note that although some conditions, such as trachoma, can be prevented, others, such as glaucoma or cataract, cannot, but can be treated to reduce the risk of vision impairment.



Vision impairment

Vision impairment occurs when an eye condition affects the visual system and one or more of its vision functions.

According to the International Classification of Functioning, Disability and Health (ICF), an "Impairment" is a general term used to describe a *problem* in the function or structure of a person's body due to a health condition *(58).* This definition is compatible with the International Classification of Diseases 11th Edition (ICD 11) *(59)*. Accordingly, a vision impairment results when an eye condition affects the visual system and one or more of its vision functions.

Vision impairment occurs when an eye condition affects the visual system and one or more of its vision functions.

Typically, population-based surveys measure visual impairment using exclusively visual acuity, with severity categorized as mild, moderate or severe *distance* vision impairment or blindness, and *near* vision impairment (Box 1.2). However, in the clinical setting, other visual functions are also often assessed, such as a person's field of vision, contrast sensitivity and colour vision.

Box 1.3 provides details of the evolution of the concept and definition of vision impairment during the past few decades.

It is important to note that, as described in Box 1.4, most published data on "vision impairment" are based on measures of "presenting visual acuity" and do not include individuals whose vision impairment is compensated for with spectacles or contact lenses. For this reason, there is no global estimate of the total number of people with vision impairment (see Chapter 2). Previously, it was appropriate for the eye care field to rely on "presenting visual acuity" because it provided an estimate of the unmet eye care needs. However, to plan services and monitor progress effectively, it is important to have information on both the met and the unmet needs of eye care. This is particularly important given that individuals with refractive errors have an ongoing need for eye care services.

Box 1.2 Visual acuity measurement, and classification table for the severity of visual impairment

Visual acuity

Visual acuity is a simple, non-invasive measure of the visual system's ability to discriminate two high contrast points in space.

Distance visual acuity is commonly assessed using a vision chart at a fixed distance (commonly 6 metres (or 20 feet) *(55)*. The smallest line read on the chart is written as a fraction, where the numerator refers to the distance at which the chart is viewed, and the denominator is the distance at which a "healthy" eye is able to read that line of the vision chart. For example, a visual acuity of 6/18 means that, at 6 metres from the vision chart, a person can read a letter that someone with normal vision would be able to see at 18 metres. "Normal" vision is taken to be 6/6.

Near visual acuity is measured according to the smallest print size that a person can discern at a given test distance *(60)*. In population surveys, near visual impairment is commonly classified as a near visual acuity less than N6 or m 0.8 at 40 centimetres *(61)*, where N refers to print size based upon the point system as used in the printing business and 6 is a font size equivalent to newspaper print.

Classification of severity of vision impairment based on visual acuity in the better eye

Category	**Visual acuity in the better eye**	
	Worse than:	**Equal to or better than:**
Mild vision impairment	6/12	6/18
Moderate vision impairment	6/18	6/60
Severe vision impairment	6/60	3/60
Blindness	3/60	
Near vision impairment	N6 or M 0.8 at 40cm	

Typically, epidemiological surveys measure the degree of visual impairment and blindness according to the above classification table using visual acuity *(61)*. Severe visual impairment and blindness are also categorized according to the degree of constriction of the central visual field in the better eye to less than 20 degrees or 10 degrees, respectively *(62, 63)*.

Box 1.3. Evolution of the classification of vision impairment

The classification of vision impairment using visual acuity has changed over time:

- In 1972, a WHO study group established categories of vision impairment and blindness in order to facilitate the collection of population-based data in a uniform format. At that time, the prevalence of vision impairment was calculated based on best-corrected (i.e. tested with spectacles if usually worn, or a pinhole) in the better eye. The cut-off for categorizing vision impairment was a best-corrected visual acuity of less than 6/18, while blindness was categorized as a best-corrected visual acuity of less than 3/60.
- In 2010, the classification of vision impairment was updated based on the premise that (i) the use of "best corrected" visual acuity overlooks a large proportion of people with vision impairment due to uncorrected refractive error; and (ii) there was no distinction between those who have varying levels of blindness (e.g. no perception of light and those that have light perception but still measure less than 3/60 in the better eye). As a result, "best-corrected" visual acuity was replaced with "presenting" visual acuity (i.e. the visual acuity of a person as she or he presents to the examination); blindness was further subcategorized into three distinct levels of severity.
- Recently, some investigators have adopted a more stringent cut-off for categorizing vision impairment (i.e. a visual acuity of less than 6/12 in the better eye) in recognition of a growing body of evidence that milder reductions in visual acuity impacts every day functioning of individuals.

Box 1.4 Changing the way vision impairment is reported

The measure of vision impairment typically reported in population-based surveys is based on visual acuity in the better eye of a person as presented in examination. If spectacles or contact lenses are worn – for example to compensate for vision impairment caused by a refractive error – visual acuity is measured with the person wearing them; thus they will be categorized as not having a vision impairment.

Measuring "presenting visual acuity" is useful for estimating the number of people who need eye care, including refractive error correction, cataract surgery or rehabilitation. However, it is not appropriate for calculating the total number of people with vision impairment. For this reason, the term "presenting distance vision impairment" is used in this report, but only when describing previous published literature that defines vision impairment based on the measure of "presenting visual acuity".

To calculate the total number of people with vision impairment, visual acuity needs to be measured and reported without spectacles or contact lenses.

Much of the published literature does not report on unilateral vision impairment, with most opting to focus solely on bilateral vision impairment. However, a (smaller) body of literature *(64)* shows that unilateral vision impairment impacts on visual functions, including stereopsis (depth perception) *(64)*. As with bilateral vision impairment, persons with unilateral vision impairment are also more prone to issues related to safety (e.g. falls) and maintaining independent living *(65).* Further studies report that patients who undergo cataract surgery in both eyes have more improved functioning than patients who undergo surgery in one eye only *(66).*

Vision impairment can worsen as an underlying eye condition progresses. Nevertheless, effective interventions are available for most eye conditions that lead to vision impairment. These include:

a) Refractive errors, the most common cause of vision impairment, can be fully compensated for with the use of spectacles or contact lenses, or corrected by laser surgery.

b) Vision impairment caused by some age-related conditions, such as glaucoma, have no cure and cannot be corrected. However, effective treatments and surgical interventions are available which can either delay or prevent progression.

c) Vision impairment caused by other age-related conditions, such as cataract, can be corrected through surgical interventions. Given that cataracts worsen over time, people left untreated will experience increasingly severe vision impairment which can lead to blindness and significant limitations in their overall functioning.

In cases where vision impairment or blindness cannot be prevented – such as advanced age-related macular degeneration (particularly the "dry" form of the condition) – rehabilitation services are required to optimize functioning in everyday life.

The examples described above underscore two important issues: first, effective interventions exist for the vast majority of eye conditions that can cause vision impairment; and secondly, access to interventions can significantly reduce, or eliminate, vision impairment or its associated limitations in functioning. The range of available interventions are described in more detail in Chapter 3.

Vision impairment and disability

Disability refers to the impairments, limitations and restrictions that a person with an eye condition faces in the course of interacting with her or his environment – physical, social, or attitudinal.

In the ICF, disability encompasses impairments, the difficulties a person may have in carrying out activities such as self-care, and the problems they experience in involvement in everyday life situations, such as going to school or work *(67)*.[1] According to the ICF, the disability experienced is determined not only by the eye condition, but also by the physical, social and attitudinal environment in which the person lives, and the possibility of accessing quality eye care, assistive products (such as spectacles), and rehabilitation services.

Disability refers to the impairments, limitations and restrictions that a person with an eye condition faces in the course of interacting with her or his environment – physical, social, or attitudinal.

A person with an eye condition experiencing vision impairment or blindness and facing environmental barriers, such as not having access to eye care services and assistive products, will likely experience far greater limitations in everyday functioning, and thus higher degrees of disability.

Addressing the eye care needs of people with vision impairment or blindness, including rehabilitation, is of utmost importance to ensure optimal everyday functioning. In addition, an urgent need is required for a broad societal response to fulfil the rights of persons with long-term impairments (as required by the Convention on the Rights of Persons with Disabilities (CRPD)), so that people with severe vision impairment or blindness participate in society on an equal basis with others.

Consequences for individuals

Vision impairment has serious consequences across the life-course, many of which can be mitigated by timely access to quality eye care and rehabilitation.

Not meeting the needs, or fulfilling the rights, of people with vision impairment, including blindness, has wide-reaching consequences. Existing literature shows that insufficient access to eye care and rehabilitation and other support services can substantially increase the burden of vision impairment and degree of disability at every stage of life *(68, 69)*.

Young children with early onset severe impairment can experience delayed motor, language, emotional, social and cognitive development *(70)*, with lifelong consequences. School-age children with vision impairment can also experience lower levels of educational achievement *(71, 72)* and self-esteem than their normally-sighted peers *(73)*.

1 This is consistent with the understanding of disability in the United Nations Convention on the Rights of Persons with Disabilities.

Studies have consistently established that vision impairment severely impacts quality of life (QoL) among adult populations *(10, 65, 74-76)* and a large proportion of the population rank blindness as among their most feared ailment, often more so than conditions such as cancer *(77, 78)*. Adults with vision impairment often have lower rates of workforce participation and productivity *(79, 80)* and higher rates of depression and anxiety *(16-18)* than the general population. In the case of older adults, vision impairment can contribute to social isolation *(81-83)*, difficulty walking *(84)*, a higher risk of falls and fractures, particularly hip fractures *(85-91)* and a greater likelihood of early entry into nursing or care homes *(92-94)*. It may also compound other challenges such as limited mobility or cognitive decline *(95, 96)*.

Vision impairment has serious consequences across the life-course, many of which can be mitigated by timely access to quality eye care and rehabilitation.

In general terms, people with severe vision impairment experience higher rates of violence and abuse, including bullying and sexual violence *(97-100)*; are more likely to be involved in a motor vehicle accident *(101, 102)*; and can find it more difficult to manage other health conditions, for example being unable to read labels on medication *(13-15)*.

While the number of people with severe vision impairments is substantial, the overwhelming majority have vision impairments that are mild or moderate *(61)*. Yet very little is known about the consequences of mild and moderate vision impairment on, for example, infant and child development, educational achievement, workforce participation, and productivity. Nonetheless, it is evident that, without access to quality eye care and provision of proper spectacles or contact lenses, mild or moderate vision impairment can affect significantly an individual's cognitive, social and economic well-being *(103)*.

Impact on family members and carers

Support from family members, friends, and other carers is often crucial but can have an adverse impact on the carer.

Family members, friends and other carers are often responsible for providing physical, emotional and social support for those with severe vision impairment *(104)*. Examples of such support include accompanying children to school; assistance with activities of daily living (e.g. shopping, cooking, cleaning); financial help to buy assistive devices to improve their functioning in the home, to increase their attendance at medical and/or rehabilitation services, to pay for external carers; and emotional support during difficult times *(104, 105)*.

Evidence suggests that support from family members has a positive influence on those with vision impairment and can lead to improved adaptation to vision impairment, greater life satisfaction *(106, 107)*, fewer depressive symptoms *(106)* and improved uptake of rehabilitative services and assistive products *(108)*. However, providing such support may have detrimental consequences on the caregiver and lead to an increased risk of physical and mental health conditions *(109),* such as anxiety *(110)* and depression *(111).* This is more likely to occur when the caregiver has difficulty balancing their own needs with those of the family member, or when money is short *(104).*

Over and above the support of family, friends and other care givers, a societal response is essential. Member States need to recognize their obligations to fulfil all the requirements contained in the 31 articles of the CRPD.

Impact on society

Vision impairment poses an enormous global financial burden due to productivity loss.

The 2017 Global Burden of Disease (GBD) Study ranked vision impairment, including blindness, the third cause among all impairments for years lived with disability *(112).* In addition, the societal burden of vision impairment and blindness is substantial given its impact on employment, QoL and the related caretaking requirements.

Vision impairment also poses an enormous global financial burden as demonstrated by previous research that has estimated costs of productivity loss *(79, 80, 113, 114).* For example, a recent study among nine countries estimated that the annual cost of moderate to severe vision impairment ranged from US$ 0.1 billion in Honduras to as high as US$ 16.5 billion in the United States of America *(113),* while annual global costs of productivity losses associated with vision impairment from uncorrected myopia and presbyopia alone were estimated to be US$ 244 billion and US$ 25.4 billion, respectively *(79, 80).* Of particular note, the economic burden of uncorrected myopia in the regions of East Asia, South Asia and South-East Asia were reported to be more than twice that of other regions and equivalent to more than 1% of gross domestic product *(80).*

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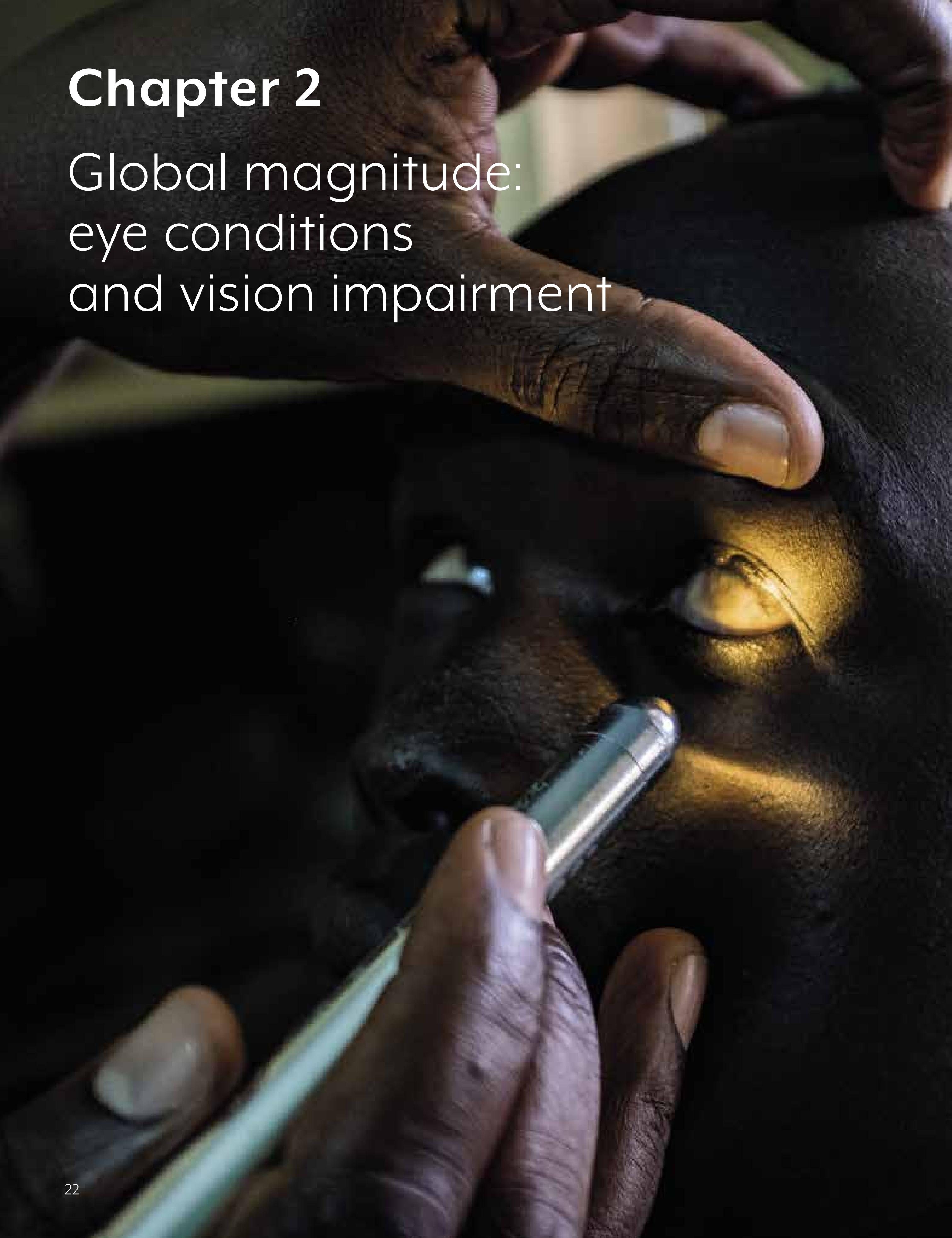
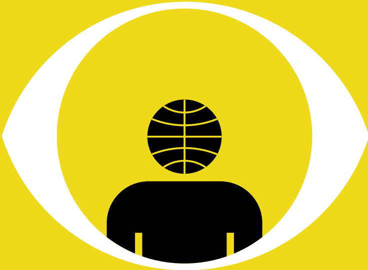
Chapter 2

Global magnitude: eye conditions and vision impairment





Globally, at least 2.2 billion people have a vision impairment, of whom at least 1 billion have a vision impairment that could have been prevented or has yet to be addressed.

Eye conditions are remarkably common. Yet accurate estimates of the global magnitude of eye conditions are lacking.

The burden of most eye conditions and vision impairment is not borne equally. Inadequate access to eye care is a major cause of the uneven distribution.

An improved understanding of the magnitude of eye care needs that are currently being met by the health system is critical for effective planning.

Eye care is a good investment. Preventing eye conditions and vision impairment will lead to improved productivity and reduce informal and intangible costs.

In the coming decades, if the projected increase in older people is not met with increased access to eye care services, there will be a substantial increase in the number of people with vision impairment and blindness.

Global magnitude: eye conditions

Eye conditions are remarkably common. Yet estimates of the global magnitude of some eye conditions are lacking.

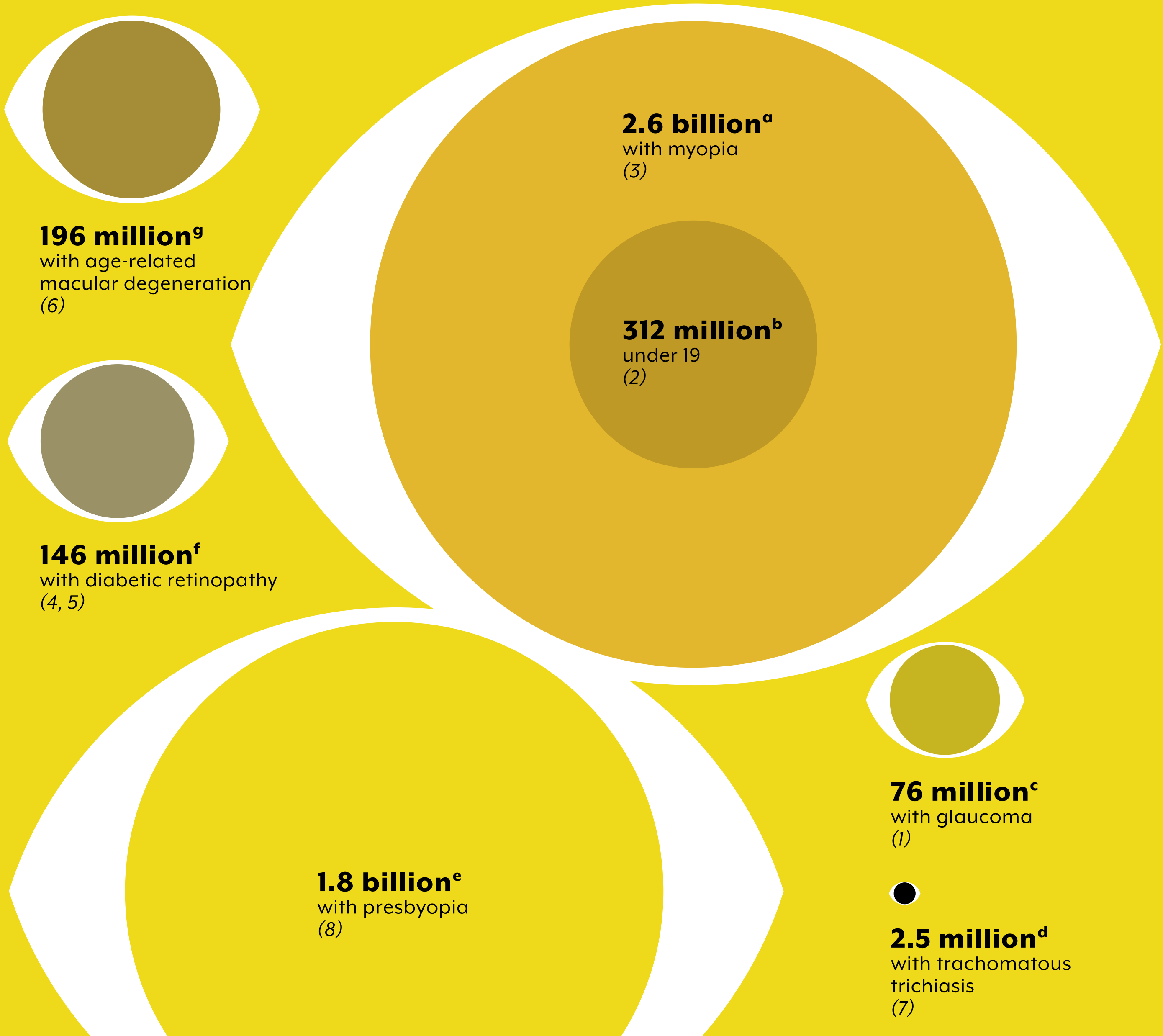
Everyone, if they live long enough, will experience at least one eye condition in their lifetime. For example, many people will have had conjunctivitis as a child, will need spectacles due to presbyopia at some point after 40 years of age, or require cataract surgery later in life.

Eye conditions are remarkably common.

Estimates of the number of people globally with eye conditions that can cause vision impairment demonstrate just how common such conditions are (Fig. 2.1) *(1–7)*. However, since a person can have more than one eye condition, these figures cannot simply be summed to derive a global estimate of the total number of people affected by eye conditions that can cause vision impairment. Global estimates of the number of people with, and prevalence of, at least one eye condition are not available.

Although reliable global estimates are lacking for the prevalence of eye conditions that do not typically cause vision impairment but are common reasons for care-seeking behaviour, some data are available. A review of 20 population-based studies from around the world estimated the global prevalence of pterygium to be 10.2% *(9)*, with rates ranging from 2.8% in an urban area of Australia, to as high as 33% in rural China *(10, 11)*. Subnational epidemiological data on the prevalence of dry eye syndrome among adults aged 40 years and older have also been documented in many countries, with rates as low as 8% reported in the United States of America *(12)* to higher than 30% in some regions of Taiwan and China *(13, 14)*.

Figure 2.1 Global estimates of numbers of people affected by selected eye conditions that can cause vision impairment



a 2.6 billon (uncertainty interval, 1.97–3.43) people of all ages with myopia in 2020

b 312 million (95% CrI, 265 million to 369 million) aged under 19 years with myopia in 2015

c 76 million (95% credible intervals (CrI), 51.9–111.7) people (40 to 80 years of age) with glaucoma in 2020

d 2.5 million people of all ages with trachomatous trichiasis in 2019

e 1.8 billion (confidence interval [CI], 1.7–2.0) people of all ages with presbyopia in 2015

f 146 million adults with diabetic retinopathy was calculated by applying the global prevalence of any diabetic retinopathy (34.6%) reported by Yau et al. [2012] to the estimated global number of adults aged over 18 years of age with diabetes in 2014 (422 million) that was reported in the WHO Global Report on Diabetes, 2016.

g 195.6 million (95% CrI 140–261) people aged 30 to 97 years with age-related macular degeneration in 2020

Global magnitude: vision impairment

Globally, at least 2.2 billion people have a vision impairment.

Globally, at least 2.2 billion people have a vision impairment. In at least 1 billion – or almost half – of these cases, vision impairment could have been prevented or has yet to be addressed.

Accurate estimates of the total number of people globally with vision impairment cannot be calculated based on current available data. This is because population-based surveys do not typically report vision impairment in those who wear spectacles or contact lenses to compensate for the vision impairment from a refractive error. Nonetheless, it can be assumed with confidence that at least 2.2 billion people globally have a vision impairment or blindness (Box 2.1). This figure takes into consideration those with near vision impairment due to presbyopia (1.8 billion, including both addressed and unaddressed presbyopia), and moderate to severe distance vision impairment or blindness due to unaddressed refractive error (123.7 million, e.g. myopia or hypermetropia)[1], cataract (65.2 million), age-related macular degeneration (10.4 million), glaucoma (6.9 million), corneal opacities (4.2 million), diabetic retinopathy (3 million), trachoma (2 million), and other causes (37.1 million), including those causes that were not classified in surveys or do not fit into any of the aforementioned categories. In addition, this figure also takes into consideration 188.5 million people with mild vision impairment in which the causes are unknown.

Box 2.1. Data sources used to calculate the global number of people with vision impairment

The estimate of at least 2.2 billion people globally having a vision impairment is based on recently published epidemiological data on i) the global magnitude of near vision impairment (Fricke et al. [2018] *(8))* and; ii) the global magnitude and causes of bilateral distance vision impairment and blindness (the Vision Loss Expert Group;* Bourne et al. [2017]) *(15, 16)*).

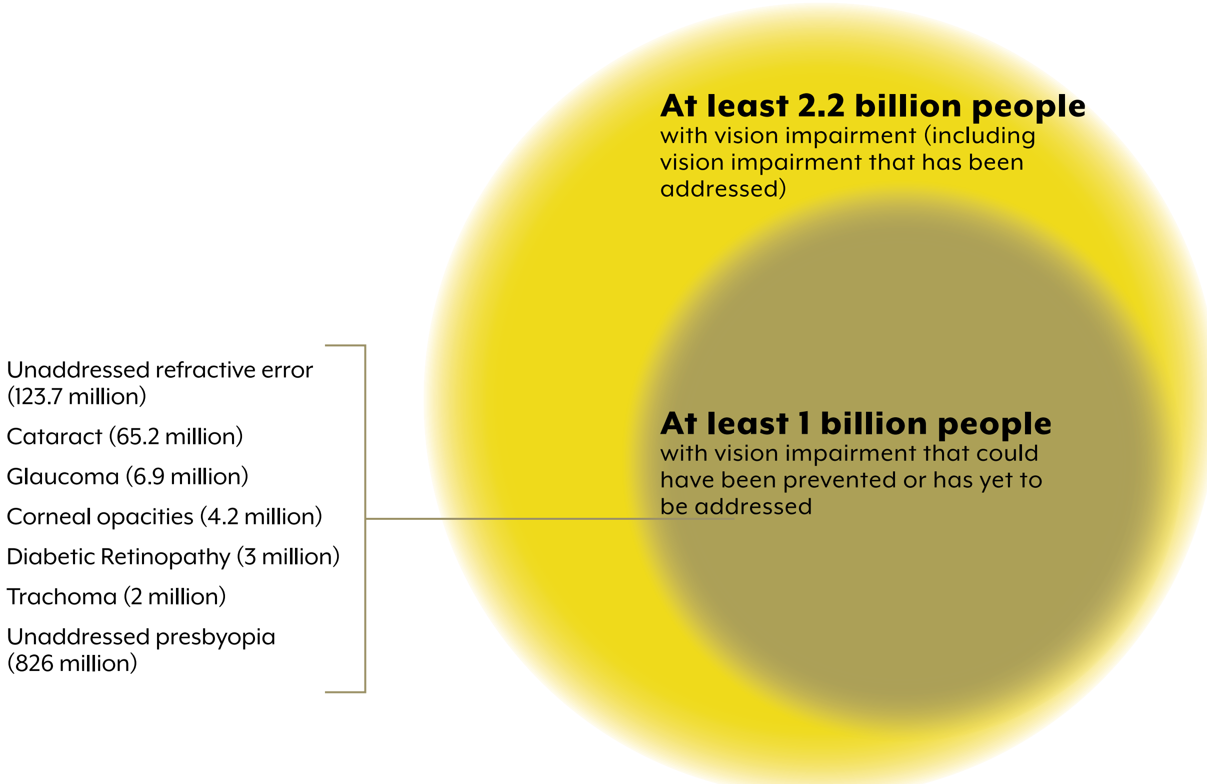
* The Vision Loss Expert Group is an expert group of mainly ophthalmologists and optometrists in ophthalmic epidemiology

Of the 2.2 billion people with vision impairment globally, available data suggest a conservative estimate of at least 1 billion people with moderate or severe distance vision impairment or blindness that could have been

1 Given individuals can have both presbyopia and distance vision impairment due to unaddressed refractive error, it is possible that there is some overlap between the 123.7 million people with vision impairment or blindness due to unaddressed refractive error and the 1.8 people with near vision impairment caused by presbyopia.

prevented or has yet to be addressed[2] (Fig. 2.2). This number includes those with moderate or severe distance vision impairment or blindness due to unaddressed refractive error (123.7 million), cataract (65.2 million), glaucoma (6.9 million), corneal opacities (4.2 million), diabetic retinopathy (3 million), and trachoma (2 million) *(16)*, as well as near vision impairment caused by unaddressed presbyopia (826 million) *(8)*.

Figure 2.2 Estimated global number of people with vision impairment and those with vision impairment that could have been prevented or has yet to be addressed



The estimate of 1 billion, however, certainly represents an underestimation as data on the prevalence and causes of vision impairment in child populations is limited and likely to reflect an underestimation of the actual number of children with vision impairment. Additionally, the proportion of vision impairment and blindness cases due to age-related macular degeneration (estimated at 10.4 million) that could have been prevented is unknown *(16)*. Lastly, data on the causes of vision impairment for 188.5 million people globally living with mild distance vision impairment *(15)*, and millions of others with moderate to severe distance vision impairment or blindness *(16)*, are not available and therefore it is not possible to determine whether their vision impairment could have been prevented or has yet to be addressed.

2 Defined as vision impairment or blindness that could have been prevented or has yet to be addressed by known, cost-effective means.

The costs of addressing the coverage gap[3]

The cost gap for vision impairment or blindness that could have been prevented or has yet to be addressed is an additional $14.3 billion US dollars.

The costs of the coverage gap for unaddressed refractive errors[4] and cataract[5] globally are estimated to be $14.3 billion US dollars. These are the additional costs that would be required to the current health system using an immediate time horizon.

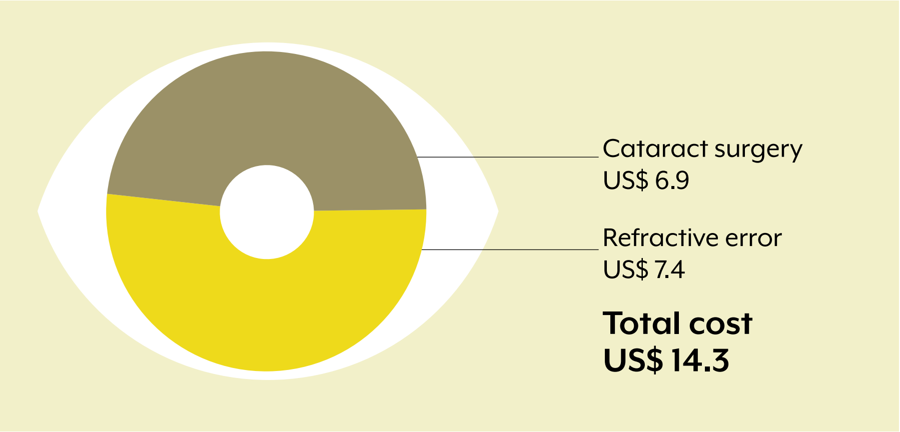
This financial investment is needed immediately; it requires appropriate planning and relies on additional investment to strengthen existing health systems. For example, WHO has estimated that in order to achieve the global health targets set for 2030, low- and middle-income countries will need to invest in an additional 23 million health workers, and build more than 415000 new health facilities[6]. The estimated US$ 14.3 billion represent an additional investment to these health workforce and infrastructure needs.

Today, millions of people live with vision impairment or blindness that could have been prevented but, unfortunately, was not. While the exact number is unknown, it is estimated that 11.9 million people globally have moderate or severe vision impairment or blindness due to glaucoma, diabetic retinopathy and trachoma that could have been prevented. The estimated costs of preventing the vision impairment in these 11.9 million would have been US$5.8 billion.[7] This represents a significant opportunity missed in preventing the substantial personal and societal burden associated with vision impairment and blindness.

3 Background information on the estimated costs can be found in: https://www.who.int/publications-detail/world-report-on-vision
4 This includes 123.7 million people with moderate or severe distance vision impairment or blindness and 826 million people near vision impairment
5 This includes 65.2 million people with moderate or severe distance vision impairment or blindness due to cataract.
6 Stenberg K, Hanssen O, Edejer TT, Bertram M, Brindley C, Meshreky A, et al. Financing transformative health systems towards achievement of the health Sustainable Development Goals: a model for projected resource needs in 67 low-income and middle-income countries. The Lancet Global Health. 2017;5(9):e875–e87.
7 The costs that would have been required to prevent vision impairment due to corneal opacities are not included in these estimates. While it is acknowledged that cost-effective interventions are available to prevent the majority of cases of vision impairment and blindness due to corneal opacities (e.g. those caused by injury, vitamin A deficiency, measles infection), the available data do not provide an accurate breakdown of the causes.

It is important to note that the cost estimates presented in this section do not provide the basis for country planning; rather they represent global estimates of addressing the current backlog of moderate or severe vision impairment or blindness due to preventable or addressable causes only. The costs of care required for those who will incur eye conditions and vision impairment in the future are not included. In addition, the ongoing care required for those whose eye care needs are already being met are not taken into account.

Breakdown of costs (US$ billions)



Distribution[8]

The distribution of the burden of most eye conditions and vision impairment is not equitable. The main dimensions on which distribution varies are region and income level, age and gender, and area of residence.

Eye conditions

By region and income level

Many eye conditions are unevenly distributed globally. Children in Africa and Asia are at greatest risk of acquiring measles, rubella and vitamin A deficiency disorder and their associated eye-related complications *(17-19)*. Trachoma, the main cause of infectious vision impairment, is still to be eliminated in some parts of 44 countries of Africa, Central and South America, Asia, Australia and the Middle East *(7)*.

The overall prevalence of myopia is highest in high-income countries of the Asia-Pacific region (53.4%), closely followed by East Asia (51.6%)

The overall prevalence of myopia is highest in high-income countries of the Asia-Pacific region (53.4%), closely followed by East Asia (51.6%) *(3)*, while in country estimates among adolescents in urban areas of China and South Korea have reported rates as high as 67% and 97%, respectively *(20)*.

With respect to common age-related eye conditions, glaucoma is most prevalent in Africa (4.8%) and Latin America and the Caribbean (4.5%) *(1)*. Of note, persons of African descent and Latin American heritage residing in high-income countries, such as the United States of America, also have high rates of glaucoma *(21, 22)*. Regional heterogeneity also exists for age-related macular degeneration, with the highest reported prevalence in Caucasian populations in Europe (57.4% of people aged 45–85 years for any age-related macular degeneration) *(6)*.

Regional comparisons of the total number of people with selected eye conditions are provided in Annex 1.

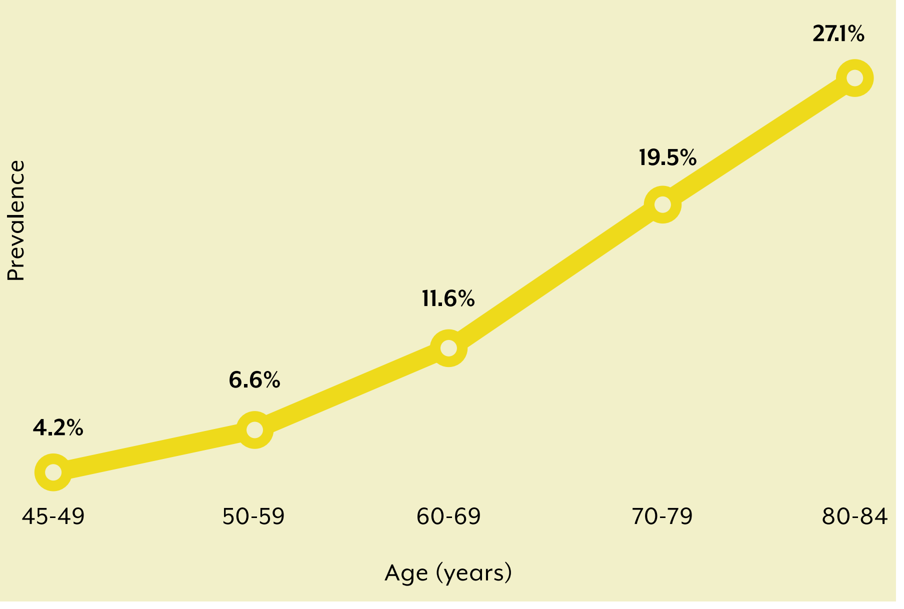
By age and gender

Distribution of eye conditions varies across ages due to the typical age of onset. While some eye conditions, such as myopia *(20)*, retinopathy of

8 WHO regions cannot be used in all instances as evidence for the section of the report on the distribution of eye conditions and vision impairment was derived from publications that adopted different regional classifications. Thus data relating age-related macular degeneration and glaucoma used the regional classifications of Europe, Asia, Africa, Northern America, Latin America and the Caribbean, and Oceania, whereas data on myopia and near and distance vision impairment were categorized according to Global Burden of Disease regions: i) Central Europe, Eastern Europe and Central Asia; ii) High Income; iii) Latin America and Caribbean; iv) North Africa and Middle East; v) sub-Saharan Africa; vi). South-East Asia, East Asia and Oceania. A list of countries included within each of these regions is provided in Annex 2.

prematurity *(23)* and amblyopia *(24)* occur in childhood, the risk of others, including cataract, presbyopia, glaucoma and age-related macular degeneration, increase with age. Presbyopia rarely develops before 40 years of age *(8)*. The overall prevalence of age-related macular degeneration is estimated to increase 7-fold, from 4.2% in those aged 45–49 years, to 27.2% in those aged 80–85 years (Fig. 2.3) *(6)*; similar age-related trends have been observed for glaucoma *(1)*. The prevalence of cataract also increases sharply with age. A recent review of population-based surveys in China estimated the national prevalence of age-related cataract to be 73% in those aged 85–89 years, approximately 11 times higher than in those aged 45–49 years *(25)*.

Figure 2.3 Age-group specific prevalence estimates for (any) age-related macular degeneration



Adapted from: Wong WL, Su X, Li X, Cheung CM, Klein R, Cheng CY, et al. Global prevalence of age-related macular degeneration and disease burden projection for 2020 and 2040: a systematic review and meta-analysis. The Lancet Global health. 2014;2(2):e106–16.

At a global level, no strong association exists between gender and many eye conditions, including glaucoma, age-related macular degeneration, and diabetic retinopathy *(1, 5, 6)*. However, rates of cataract and trachomatous trichiasis are higher among women, particularly in low- and middle-income countries *(26-28)*. Women may be more susceptible to trachoma than men due to greater contact with children in their role of the primary caretaker of the household *(26)*. While greater life expectancy may contribute to the higher prevalence of cataract among women in these settings, other factors have also been implicated (details provided below).

The prevalence of vision impairment in low- and middle-income regions is estimated to be four times higher than in high-income regions.

By area of residence

Area of residence is an important determinant of many eye conditions. For example, trachoma is largely found in poor, rural communities that have inadequate access to water, sanitation and health care *(29)*. Rural populations also face greater barriers to accessing eye care due to distances to travel and poor road quality, among other factors *(30, 31)*. Therefore, it is not surprising that a lower cataract surgical coverage and associated higher prevalence of cataract has been reported in rural areas of many countries *(27, 28, 32, 33)*. Area of residence may likewise be an important determinant of childhood myopia. Unlike cataract, higher rates of childhood myopia have been found in urban populations of China and Australia *(34-38)*. These may be due to the impact of lifestyle differences (e.g. children living in rural areas spend more time outdoors), urbanization and/or differences in school systems and demographic characteristics such as socioeconomic status and ethnicity *(36)*.

Vision impairment

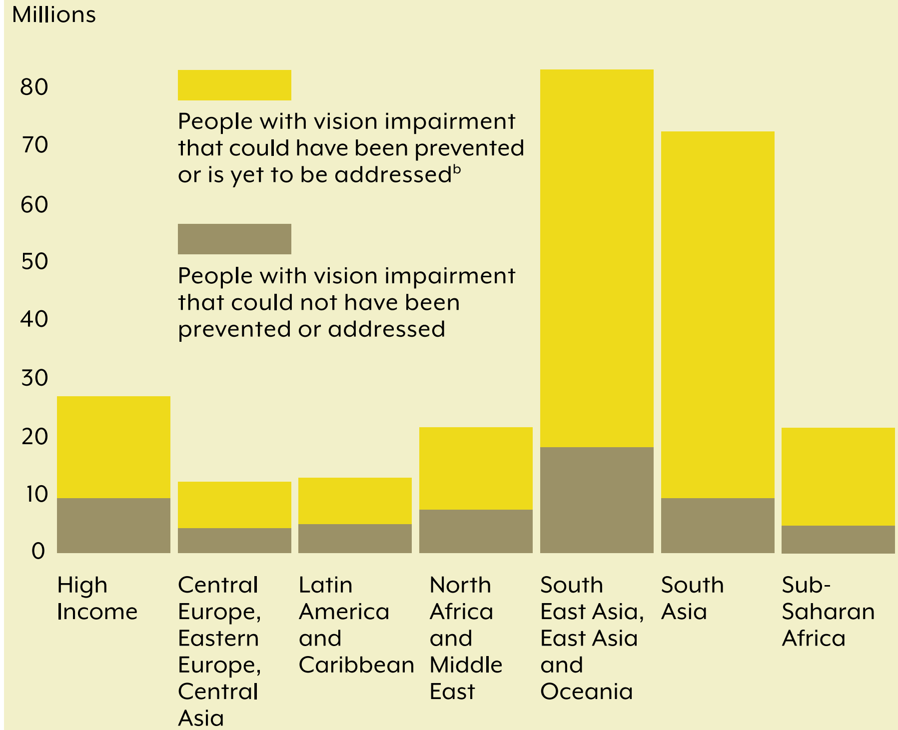
All estimates of distance vision impairment and blindness discussed in this section use the definition of "presenting visual acuity" and therefore do not include those who wear spectacles or contact lenses that compensate for their vision impairment. This group do not, therefore, reflect the distribution of the total number of people with distance vision impairment. As described in Chapter 1, the term "presenting distance vision impairment" is used in this report when describing these cases.

By region and income level

Considerable variation is observed in the distribution of *presenting distance vision impairment* between regions (Fig. 2.4) and country income level. The prevalence in many low- and middle-income regions is estimated to be four times higher than in high-income regions *(15)*. Three Asian regions alone (representing 51% of the world's population) account for 62% of the estimated 216.6 million people in the world with moderate and severe bilateral *presenting distance vision impairment*: South Asia (61.2 million); East Asia (52.9 million); and South-East Asia (20.8 million) *(15)*. In line with these estimates, the prevalence of bilateral blindness in low- and middle-income regions of western and eastern sub-Saharan Africa (5.1%) and South Asia (4.0%) are reported to be eight times higher than in all high-income countries (<0.5%) *(15, 39)*.

The prevalence of any near vision impairment is highest in regions with longer life expectancies.

Figure 2.4 Regional comparison[a] of total number of people with bilateral moderate to severe distance vision impairment or blindness and estimated proportion with vision impairment that could have been prevented or has yet to be addressed

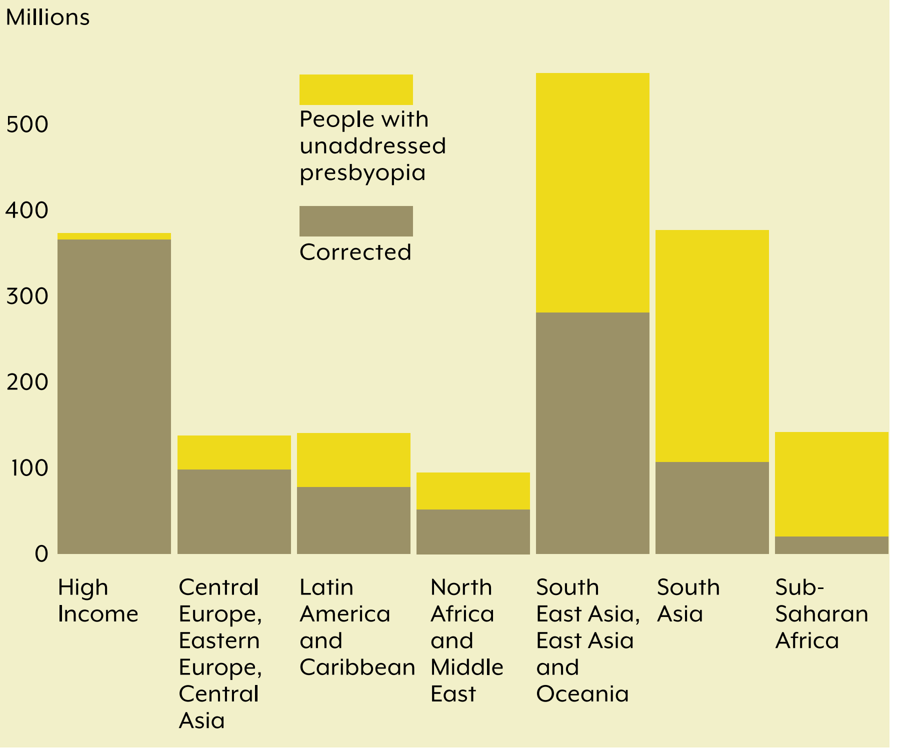


a By Global Burden of Disease regions
b Based on the number of people with moderate to severe distance vision impairment or blindness caused diabetic retinopathy, trachoma, corneal opacity, glaucoma, unaddressed refractive error and cataract.

Adapted from: Flaxman SR, Bourne RRA, Resnikoff S, Ackland P, Braithwaite T, Cicinelli MV, et al. Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis. The Lancet Global Health. 2017;5(12):e1221–e34

The prevalence of any near vision impairment is highest in regions with longer life expectancies (Fig. 2.5), while the greatest burden of near vision impairment yet to be addressed, occurs in low- or middle-income countries *(8)*. For example, rates of unaddressed near vision impairment are estimated to be greater than 80% in western, eastern and central sub-Saharan Africa, while comparative rates in high-income regions of North America, Australasia, Western Europe, and of Asia-Pacific are reported to be lower than 10% *(8)*.

Figure 2.5 Regional comparison of presbyopia showing total number of people with presbyopia and proportion of cases with near vision impairment resulting from unaddressed presbyopia



Adapted from: Fricke T TN, Resnikoff S, Papas E, Burnett A, Ho S, Naduvilath T, Naidoo K. Global prevalence of presbyopia and vision impairment from uncorrected presbyopia: systematic review, meta-analysis and modelling. Ophthalmology. 2018.

Indigenous populations and ethnic minorities

Most countries with indigenous peoples and ethnic minorities have no data on the burden of vision impairment for these groups. However, those that do consistently report higher rates of *presenting distance vision impairment* among these population subgroups *(40-43)*. For example, recent epidemiological surveys conducted in Australia (2015), and Chiapas State, Mexico (2015) *(44, 45)*, reported rates of *presenting distance vision impairment* in indigenous adult populations approximately two times higher than in the general population. In line with these findings, a survey in Nakuru, Kenya reported the odds of being blind were 2.5 times higher in indigenous Kalenjin people than in the non-indigenous population *(46)*.

There is some evidence from high-income countries that ethnic minorities are more commonly afflicted by vision impairment. For example, African–American and Hispanic individuals residing in the United States of America experience a higher prevalence of *presenting distance vision impairment* and blindness when compared with non-Hispanic Caucasian individuals *(47)*. While, in the United Kingdom, those of African descent and South Asian heritage with diabetes are reported to have a higher prevalence of vision impairment *(42)*.

By age and gender

Given that age is the principal risk factor for many eye conditions, the prevalence of *presenting distance vision impairment* is much greater in older age groups. It has been estimated that 80% of bilateral *presenting distance vision impairment* and blindness, and two thirds of near vision impairment occur in persons aged 50 years or older *(47, 48)*. While the prevalence of *presenting distance vision impairment* in this age group has been studied extensively, comparatively little population-based data are available for vision impairment for all ages.

Women, on average, live longer than men, and are thus at greater risk of developing eye conditions associated with ageing. For example, in a national survey in Nigeria, the prevalence of mild and moderate *presenting distance vision impairment* in women was approximately 30% higher than in men *(49)*. However, even after controlling for age, global estimates suggest that women with moderate and severe *presenting distance vision impairment* outnumber men by approximately 7% *(15)*.

By area of residence

There is a paucity of recent survey data from countries making direct (i.e. within survey) comparisons of the prevalence of vision impairment and blindness between urban and rural populations. However, previous studies that have, including those conducted in China *(50)* and Ghana *(51)*, indicate that people in rural areas are at higher risk of distance vision impairment and blindness than their urban counterparts. In addition, indirect (i.e. between survey) comparisons between urban and rural populations in the same country supports the view that vision impairment tends to be more prevalent amongst rural populations. For example, in India, the age-specific prevalence of *presenting distance vision impairment* in an urban population of Delhi (19.7% in 60-69 year olds) was approximately one-third lower than that of a rural population in northern India (28% in 60-69 year olds) *(52, 53).*

Access and barriers to eye care services

The use of eye care services is uneven, and is determined by the availability, accessibility, affordability, and acceptability of such services.

The prevalence of eye conditions and vision impairment is influenced by the use of eye care services that prevent vision impairment or maintain or restore vision. The significant variations in the use of eye care services existing between populations contribute to those in the distribution of eye conditions and vision impairment.

Eye conditions and vision impairment are influenced by the use of eye care services.

Several national and subnational surveys have reported the use of eye care services being generally greater in high-income than in low- and middle-income countries *(54-60)*. Cataract surgery coverage rates – an indicator of eye care service provision within populations – also show marked variations by income level: subnational population surveys conducted in Viet Nam, Yemen and Malawi reported rates lower than 40%, while rates higher than 80% were reported in countries such as Uruguay, Argentina and Australia *(61, 62)*. It is important to emphasize that there some are exceptions: a sub-national survey from Iran, for example, reported cataract surgery coverage rates of over 90% *(62)*.

The use of eye care services is influenced by multiple interdependent factors, including the availability, accessibility, affordability, and acceptability of services. The impact of these factors on the distribution of eye conditions and vision impairment is discussed in this section.

Availability

A shortage of trained human resources is one of the greatest challenges to increasing the availability of eye care services and reducing the prevalence of vision impairment and blindness that could have been prevented or has yet to be addressed. The distribution of the eye care workforce should be based on population needs. Unfortunately, this is not the case currently *(63-65)*. For example, in many countries, eye care needs are higher in rural settings where there are very few health workers involved in eye care *(63, 65, 66)*.

Globally, ophthalmologists are responsible primarily for performing eye surgery and treating all common eye conditions, such as glaucoma, diabetic retinopathy and age-related macular degeneration. A recent (2019) study of the ophthalmology workforce covering 198 countries (i.e. 94% of the global population) reported that, while the number of practising ophthalmologist is increasing in most countries, there is inequitable distribution, and a significant shortfall in the current and projected number of ophthalmologists *(67)*. This is particularly important in many low- and middle-income countries. Critical human resource shortages have also been identified for optometrists and other allied ophthalmic personnel, such as opticians, refractionists, orthoptists, ophthalmic assistants, ophthalmic nurses etc *(68, 69)*. Several of these are the key professional groups involved in the management of refractive error worldwide. Due to this serious shortage of ophthalmologists and optometrists, other allied ophthalmic personnel play a major role in the provision of a broad range of eye care services, particularly in low- and middle-income countries, and at primary health care (PHC) level.

The integration of eye care services within primary health care is fundamental.

Even where health workers are available, essential ophthalmic equipment to manage ocular conditions frequently is not, particularly in the public sector of some low- and middle-income settings *(70)*. For example, the results of an ophthalmic equipment survey of 173 health care settings (56% tertiary hospitals) located predominantly in regions of Africa (70.5%) and South-East Asia (13.3%) revealed that more than 60% of services did not have a photocoagulation laser – a primary intervention for vision-threatening diabetic retinopathy *(70, 71)*. A recent national survey of practice patterns and management of glaucoma in Nigeria reported that only approximately 30% of ophthalmologists had access to laser equipment, while basic diagnostic equipment was not available in 15–20% of clinics *(72)*.

A considerable shortage of corneal graft tissue and limited access to corneal transplant programmes also exist in many countries[9]. Improved data on donation rates and population needs, coupled with clear policies and legislation and supportive governance oversight on both donation and transplantation, are required for Member States to establish sustainable corneal banking programmes.

The reality that the vast majority of eye care services in low- and middle-income countries are provided in secondary or tertiary hospitals, which are principally located in urban areas, adds to the inequity in access. This highlights the importance of both strengthening the integration of eye care services within primary health care, and ensuring an effective referral pathway to secondary and tertiary care settings for timely treatment of eye conditions.

Accessibility

Many barriers – related, for example, to gender, socioeconomic status, and perceived cost of eye care – can prevent patients from accessing services. In some settings, women do not have the same access to eye services as men. Reviews of population-based surveys conducted in low- and middle-income countries consistently reported that women are significantly less likely to undergo cataract surgery than men *(28, 62)*. This gender inequity in the use of eye care services could be

9 Gain P, Jullienne R, He Z, Aldossary M, Acquart S, Cognasse F, et al. Global survey of corneal transplantation and eye banking. JAMA Ophthalmol. 2016;134(2):167-73.

explained by a range of socioeconomic and cultural factors, including greater challenges for women in travelling to health services due to limited financial decision-making power and minimal experience in travelling outside their community *(73, 74)*. This gender disparity is not present in all countries, however: recent reports from high-income settings in Australia and Canada found that men used eye care services less frequently than women *(54, 75)*. A growing body of evidence also suggests that people who have disabilities, such as a hearing, physical, or intellectual disability, face greater challenges in accessing eye care services than those who do not *(76-79)*.

Socioeconomic status has also consistently been reported as a key determinant of the use of eye care services *(56, 80, 81)*, with a tendency for eye care use to decrease with increasing socioeconomic disadvantage.

People who have disabilities face greater challenges in accessing eye care services than those who do not.

Poor eye health literacy is associated with suboptimal adherence to eye examination guidelines, and poorer eye health outcomes *(82-84)*. Additionally, lack of knowledge of the availability of services has been identified as a barrier to eye care use among high risk populations, including homeless *(85, 86)* and refugee *(87)* populations in high-income countries. Older people tend to use eye care services less frequently, often considering a reduction in vision as part of the normal ageing process, and unaware that many eye conditions can be treated or that rehabilitation may improve their functioning *(88)*.

In the absence of accessible eye care services, people with eye or vision problems, particularly in low-income settings, resort to self-medication using local remedies, or access local informal providers such as drug sellers, or traditional or spiritual healers. These interventions can be harmful and can also delay accessing more appropriate care. For example, in the Nigeria national survey almost half of the participants who had undergone a procedure for cataract had been couched (a traditional procedure) and almost three quarters of these eyes were blind *(89)*.

Perceived high costs have been cited as a barrier to accessing eye care in a number of settings *(90-92)*. In some cases, for example treating cataract or diabetic retinopathy, the costs combined with the lack of sufficient information about the benefits may result low willingness to pay associated to insufficient information about the benefits *(33, 93, 94)*.

Affordability

Affordability of eye care services is influenced by income level, direct costs (e.g. costs of treatment, or purchasing spectacles, contact lenses or low vision devices), indirect costs, and health insurance status. Many eye conditions, such as refractive error and diabetic retinopathy, affect adults of working age. Therefore, it is not surprising that indirect costs of care, including the loss of productivity and foregone earnings for the patient and caregiver, are common reasons for non-attendance at eye care appointments *(94, 95)*. In other circumstances, a failure to access care can be more an issue of opportunity costs, where basic living needs (e.g. food production for family) outweigh concerns related to eye health *(96)*.

Direct costs, including costs involved in accessing eye care, transport to appointments and related pharmaceutical interventions, have also been cited extensively as primary barriers to accessing care, particularly in low- and middle-income countries *(33, 94)*. This may be partly explained by the fact that approximately 50% of people in low- and middle-income countries live more than one hour of a city (compared with 10% in high-income countries) *(97)*, making transport to eye care services challenging. Nonetheless, direct costs have also been cited as a key barrier to accessing eye care in high-income countries, particularly for people living in rural areas or those with low socioeconomic status *(98)*.

Direct costs, including transport to appointments and related pharmaceutical interventions are barriers to accessing care.

Further evidence of the impact of direct eye care costs is found in studies that have reported consistently that patients without health insurance have notably lower rates of use of eye care services than those with insurance *(58, 99, 100)*. This becomes a greater issue when services in the public sector are limited due to human resource shortages and when most people either do not have the required health insurance coverage for, or cannot afford, treatment in the private-for-profit sector. A recent review of health system dynamics in Trinidad and Tobago revealed that private sector optometrists and ophthalmologists provide 80% of all eye care, while less than 20% of the adult population were reported to have health insurance that covers care provided by the private sector *(101)*. It is therefore unsurprising that a recent population-based survey in Trinidad and Tobago reported that a lack of health insurance was a key risk factor for vision impairment among adults *(102)*.

Acceptability

The acceptability of eye care is seldom considered but has substantial consequences on the use of services and subsequent eye health outcomes. It is a multifaceted concept that is related to the characteristics of the health workforce (e.g. sex, language, culture, age); the degree to which a person understands an intervention; and whether the person considers the intervention will achieve the expected outcome *(103)*.

Previous literature has reported that the acceptance of wearing spectacles is often influenced by factors such as cosmesis, the belief that spectacles identify the wearer as having a disability, or that vision worsens with continued spectacle wear *(104, 105)*. A distrust of service quality has been cited as a barrier to the uptake of eye care services. For example, a study among children in China reported that a low acceptance of free or low-cost spectacles was related to parental beliefs that the spectacles were of poor quality *(106)*. A distrust of service quality, along with fear of the procedure, have also been cited consistently as barriers to the uptake of cataract surgery and other services in many countries *(106-108)*.

The role of cultural factors in health service acceptability has also been explored. For example, indigenous peoples are more likely to access eye care if it is culturally appropriate and well-integrated within their community-based health service *(109)*. Similarly, higher levels of patient engagement and satisfaction have been reported when there is concordance in language and/or ethnicity between patients and health care professional *(110)*. In some cultures, gender-sensitivities may also arise when care is provided by a health care worker of the opposite gender.

Acceptance of wearing spectacles is often influenced by factors such as cosmesis, the belief that spectacles identify the wearer as having a disability, or that vision worsens with continued spectacle wear.

Projections of eye conditions

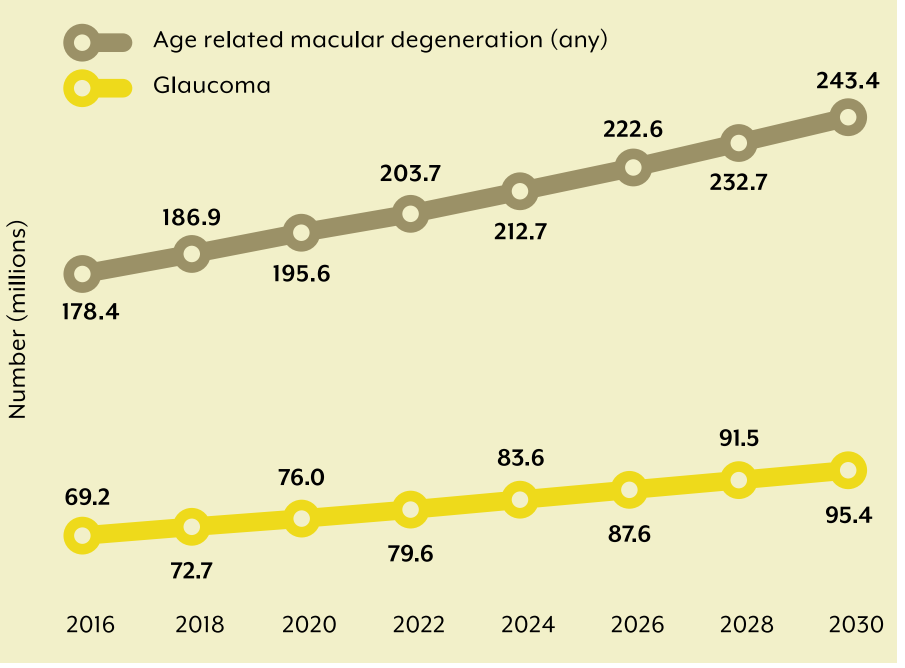
Population ageing, coupled with environmental and lifestyle changes, will lead to a dramatic increase in the number of people with vision impairment and blindness.

Population ageing

Population ageing will impact significantly the number of people with eye conditions. By 2030, the number of people worldwide aged 60 years and over is estimated to increase from 962 million (2017) to 1.4 billion, while numbers of those aged over 80 years will increase from 137 million (2017) to 202 million *(111)*. These population changes will lead to considerable increases in the numbers of people with major eye conditions that cause vision impairment.

The number of people with the age-related eye condition glaucoma, for example, has been projected to increase 1.3 times between 2020 (76 million) and 2030 (95.4 million); and those with age-related macular degeneration, 1.2 times between 2020 (195.6 million) and 2030 (243.3 million) (Fig. 2.6) *(1, 6)*. Similarly, the number with presbyopia is projected to increase from 1.8 billion in 2015, to 2.1 billion in 2030 *(8)*. As most people over the age of 70 will develop cataract, the number with this condition will also increase substantially. Population ageing will also lead to an increase in the number of people with other eye conditions, including those that do not usually cause vision impairment, such as dry eyes.

Figure 2.6 Projected number of people worldwide with glaucoma and age-related macular degeneration (to year 2030)



Adapted from: Tham YC, Li X, Wong TY, Quigley HA, Aung T, Cheng CY. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. Ophthalmology. 2014;121(11):2081–90; and Wong WL, Su X, Li X, Cheung CM, Klein R, Cheng CY, et al. Global prevalence of age-related macular degeneration and disease burden projection for 2020 and 2040: a systematic review and meta-analysis. The Lancet Global Health. 2014;2(2):e106–16.

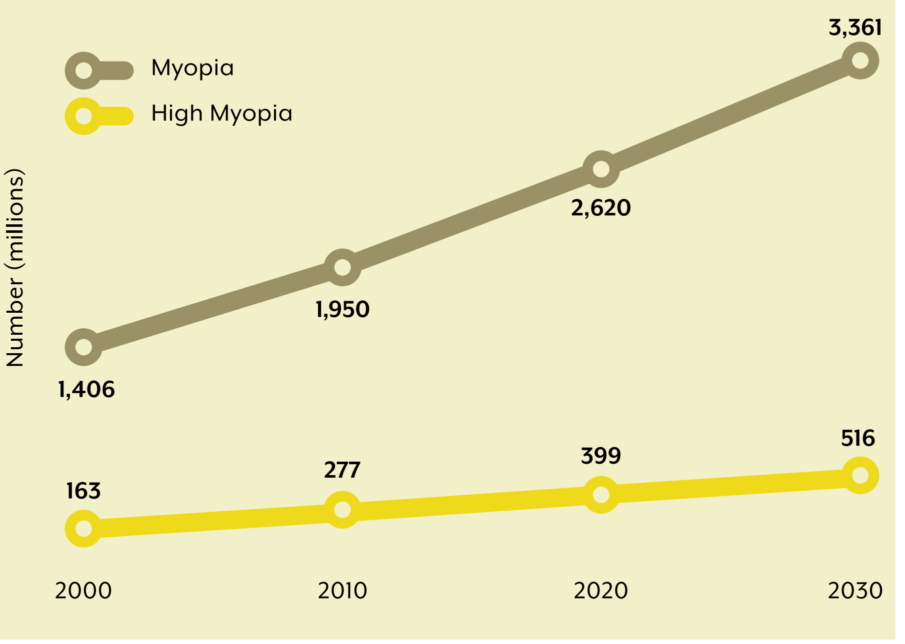
Lifestyle

Changes in lifestyle are also likely to result in an increased number of people with eye conditions. For example, reduced time spent outdoors, increased near work and increased rates of urbanization, among other factors, may contribute towards a substantial increase globally in the number of people with myopia. According to estimates that take into account the growth in urbanization and in the human development index, the number of people with myopia will increase from 1.95 billion in 2010 (uncertainty interval (UI) 1422 million to 2543 million) to 3.36 billion in 2030 (UI 153 million to 589 million) *(3)*. During the same period, the number of people with high myopia, often associated with severe complications, is projected to increase from 277.2 million in 2010 (UI 153 million to 589 million) to 516.7 million in 2030 (UI 298 to 1082 million) (Fig. 2.7) *(3)*.

Lifestyle changes have also led to an increase in the number of people with diabetes across all countries during the past thirty years *(112)*. If trends continue, the number of people with diabetic retinopathy is estimated to increase from 146 million in 2014 to 180.6 million in 2030 (1.2-fold) *(113)*.

Health systems face unprecedented challenges in meeting the current and projected demands of eye care needs.

Figure 2.7 Projected number of people estimated to have myopia and high myopia for each decade, 2000–2030



Adapted from: Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. Ophthalmology. 2016;123(5):1036–42

Extent of challenges ahead for health systems

Based on current data (as presented in this chapter), it is evident that health systems face unprecedented challenges in meeting the current and projected demands of eye care needs. In addition to addressing the coverage gap of the known global eye care needs – i.e. of at least 1 billion people with vision impairment that could have been prevented or has yet to be addressed, and tens of millions of others with vision impairment or blindness who could benefit from rehabilitation – health systems are also required to sustain care for those whose needs are currently being met and are receiving appropriate care. The magnitude of met need is currently unknown and, as discussed in Chapter 6, health systems will be required to collect data systematically on the met needs in order to be able to conduct effective planning.

Ageing, population growth, and the fact that the prevalence of vision impairment and many eye conditions increases in older age, will also lead to a substantial increase in the number of people that need eye care globally. Anticipated increases in the burden of myopia and diabetes due to lifestyle changes will further confound this problem. These demographic changes will impact profoundly the already strained health systems and eye care workforces.

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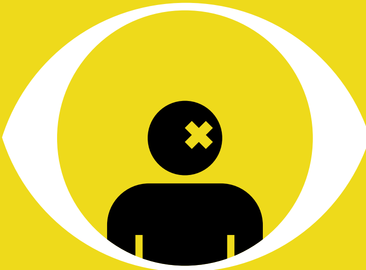
Chapter 3

Addressing eye conditions and vision impairment



Effective interventions are available for health promotion, prevention, treatment and rehabilitation to address the entire range of needs associated with eye conditions and vision impairment across the life course. Some are among the most feasible and cost-effective of all health care interventions to implement.

When vision impairment and blindness cannot be treated, everyday functioning can be optimized through rehabilitation interventions.

Strategies to address eye care needs

There are effective interventions to address the needs associated with eye conditions and vision impairment.

A range of effective interventions are available to reduce the risk of acquiring an eye condition or vision impairment, and to mitigate the impact.

As presented in Chapter 1, the range of eye conditions is diverse and while some conditions can cause vision impairment or blindness, others typically do not. Although a few eye conditions can be prevented (e.g. trachoma and most causes of corneal opacity in children), this is not possible for most. Each eye condition requires a different response.

Fortunately, there are effective interventions covering promotion, prevention, treatment and rehabilitation which address the needs associated with eye conditions and vision impairment; some are among the most cost-effective and feasible of all health care interventions to implement. This section provides an overview of key interventions; those highly relevant to adults and children are illustrated in Table 3.1.

Health promotion

Interventions for health promotion have the potential to increase the adoption of healthy behaviours that affect eye conditions and vision impairment, as well as the uptake of eye care services.

Interventions for health promotion aim to empower people to increase control over their health and its promotive factors through health literacy efforts, rather than by targeting specific risk factors or health conditions. To date, interventions for health promotion in the field of eye care have received less attention and investment than those for prevention and treatment *(1, 2).* Thus, it is unsurprising that eye- and vision-related outcomes are not included in the evaluation of health promotion programmes. Although public health education campaigns linking smoking and blindness have proved effective in increasing awareness and encouraging smokers to seek cessation supports *(3-5)*, there is no evidence to suggest that such interventions impact the prevalence of vision impairment.

Only a few key evaluated examples of interventions for health promotion have been found successful in increasing the adoption of health promoting behaviours and the uptake of eye care services *(6).* Health promotion campaigns targeting improved awareness of the importance of regular eye examinations and the use of eye care services have been shown to be effective among older populations and those with diabetes *(7, 8)*. The use of health promotion activities (e.g.


EJERCICIOS OCULARES
Paso 1:
Mirar hacia arriba
Paso 2:
Mirar hacia abajo
Paso 3:
Mirar hacia la derecha
Paso 4:
RECUERDA:
Debemos mantener una adecuada iluminación para evitar esforzar nuestra vista.

posters, brochures and health talks) prior to the implementation of outreach eye screening services, conveying messages such as "get your eyes checked" have similarly been successful in increasing uptake of services *(1)*.

The promotion of eye protective behaviours can also be considered interventions for health promotion and may include compliance with spectacle wear, time spent outdoors, and the use of sunglasses among school-aged students *(9-11)*. While these interventions are shown to be effective in some settings, a recent Cochrane review suggests that further research is required *(12)*.

Prevention

There are two categories of preventive interventions in the field of eye care.

Eye conditions that can be targeted effectively with preventive interventions include trachoma, onchocerciasis and myopia. In addition, the prevention or management of other health conditions can be effective in reducing incidence of secondary ocular conditions.

Preventive interventions in the field of eye care generally fit into two categories: (i) interventions that aim to prevent the incidence of eye conditions before they occur by targeting the causes and risk factors; and (ii) measures taken to prevent eye conditions that are secondary to other health conditions. Those addressing trachoma, onchocerciasis and myopia, for example, fit into the former category. Given that onchocerciasis is transmitted by blackflies, earlier control programmes consisted of vector control within communities in endemic regions, followed by establishing sustainable community-directed mass drug administration with ivermectin *(13)*. With trachoma, an effective package of interventions (the "SAFE" strategy) is available, which prevents the transmission of infection (through mass drug administration and environmental sanitation interventions, such as latrines, clean running water, and face cleaning) and visual impairment (by eyelid surgery) (Box 3.1) *(14)*. Preventative lifestyle changes among children, including a combination of increased time spent outdoors and decreased near-work activities, can slow the progression of myopia which reduces the risk of high myopia and its complications *(9, 15)*.

Interventions to prevent health conditions such as vitamin A deficiency, measles and rubella, through vitamin A supplementation and immunization, are highly effective in reducing the risk of corneal opacities that can occur secondary to these conditions *(16, 17)*. With diabetes, the optimal management of key risk factors, such as hyperglycaemia and hypertension, can also prevent or delay onset, and reduce the progression, of diabetic retinopathy *(18, 19)*.

Changes in legislation, such as compulsory seat belt use and restrictions on the use of fireworks, have resulted in a reduction in ocular injuries, and are well documented *(20, 21)*. Targeted campaigns to improve awareness of trauma prevention strategies, such as the use of protective eye wear in high-risk activities and industries (e.g. certain sports or agricultural activities) may also be effective in reducing eye injuries. Despite this, a recent Cochrane review suggests that the overall impact of preventive educational interventions on the risk of ocular injuries is short-lived and further research is required in this area *(22)*.

Box 3.1 The elimination of trachoma in previously endemic countries through the implementation of preventative interventions

Brief history

Landmark trials in the 1990s demonstrated the effectiveness of the antibiotic azithromycin *(23, 24)* for reducing the prevalence of active trachoma, and established the place of facial cleanliness campaigns for trachoma control *(25)*. In 1993, WHO endorsed the "SAFE strategy" for trachoma elimination *(26)*. SAFE incorporates multiple strategies to address specific stages of the path to blindness in trachoma, including: Surgery for trichiasis to minimize vision impairment; Antibiotics to clear ocular *Chlamydia trachomatis* infection, and Facial cleanliness and Environmental improvement (particularly improved access to water and sanitation) to reduce *Chlamydia trachomatis* transmission *(26)*.

The WHO Alliance for the Global Elimination of Trachoma by 2020 (GET2020) was established in 1996 and, soon after, the 1998 WHA, in resolution WHA51.11, called on endemic countries to take all actions necessary to achieve the GET2020 goal *(27)*. As a result, antibiotics, facial cleanliness and environmental improvement have been delivered to entire districts in which prevalence of the active trachoma sign "trachomatous inflammation—follicular" is greater than or equal to 5%.

Progress

Evidence of substantial progress against trachoma is now available. The SAFE strategy is being implemented, partially or at scale, in at least 32 countries *(28)*. The estimated number of people worldwide living in districts where the A, F and E components of SAFE need to be implemented for trachoma elimination purposes has decreased from 1517 million in 2002 to 142 million in 2019, while the number of people with trichiasis has fallen from 7.6 million to 2.5 million in the same period *(14)*. Eight countries – Cambodia, Ghana, the Islamic Republic of Iran, Lao People's Democratic Republic, Mexico, Morocco, Nepal and Oman – have now been validated by WHO as having eliminated trachoma as a public health problem; a further five – China, Gambia, Iraq, Myanmar, and Togo – have reported achieving elimination prevalence targets *(14)*.

Treatment

The treatment of eye conditions targets curing as well as addressing symptoms and progression. Treatment also aims to prevent or slow progression towards vision impairment.

Cataract and refractive error are the two leading causes of vision impairment; treatment can address vision impairment and restore vision. Treatment for cataract is a surgical intervention involving the removal of the opaque lens in the eye and the implantation of an artificial intraocular lens. Cataract surgery is highly cost-effective *(29)* and results in significant improvements to QoL *(30)*. While spectacles are undoubtedly the most common intervention used worldwide to compensate for refractive error (Box 3.3), contact lenses and laser refractive surgery are an effective alternative and becoming increasing popular, particularly in high-income settings *(31)*.

Treatment of eye conditions targets curing as well as addressing symptoms and progression.

Treatment for other noncommunicable eye conditions are often more challenging, with longer-term follow-up essential to slow the progression of the condition. For example, the prevention of vision impairment from diabetic retinopathy, glaucoma and retinopathy of prematurity, requires early detection, often before the patient is symptomatic. For diabetic retinopathy and retinopathy of prematurity, this involves routine screening to detect the "vision-threatening" stages of the condition, followed by laser therapy or other treatments to reduce the risk of vision impairment or blindness *(32, 33)* (Box 3.2). In the case of glaucoma, ongoing management is required to reduce the risk of further progression through a number of possible interventions including a therapeutic eye drop regimen, laser therapy, surgery, or a combination of these *(34)*. Effective therapeutic interventions, in the form of continuous or intermittent anti-vascular endothelial growth factor (anti-VEGF) intraocular injections, are currently available for the neovascular form of age-related macular degeneration (AMD) (only) *(35, 36)*.

Treatment is available for many eye conditions that do not typically cause vision impairment, such as dry eye, conjunctivitis and blepharitis. Treatment of these conditions is often directed at alleviating the symptoms. In advanced cases of pterygium when vision is affected, surgical intervention is often required *(37)*. Research has demonstrated that the treatment of eye conditions that do not typically cause vision impairment can pose a substantial economic burden on the patient and on society *(38)*.

Box 3.2 Long-term impact of retinal screening on diabetes-related visual impairment in the working age population: the English National Screening Programme *(39)*

A national systematic diabetic retinopathy screening programme was established in England in 2003 where all individuals with diabetes aged 12 years and over are invited for an annual diabetic eye screening appointment. In line with current recommendations for high resource settings, patients are sent reminders to attend screening. Since 2008, the programme has achieved near comprehensive population coverage (i.e. >80% annual coverage).

In the programme, screening is performed by well-trained screeners who measure visual acuity, instil drops for pupil dilation, carry out two-field retinal photography. Images are then digitally transferred to a centralized location (e.g. established grading centre) for retinal grading by specially trained non-physician technicians. Prior to their involvement in the programme, a minimum qualification is required for screeners and graders *(40)*. In addition, all graders undertake monthly test sets of images and their results are compared to a guide grade. Audit and internal and external quality assurance schemes are also embedded in the service.

Robust sensitivities and specificities for the detection of diabetic retinopathy and sight-threatening diabetic retinopathy (moderate disease or worse) have been reported in this programme *(41)*. Individuals with sight-threatening diabetic retinopathy are referred for timely ophthalmology assessment and management. In addition, all those with poor-quality images are referred for assessment of retinal status via slit lamp examination.

In 2015-16, the diabetic retinopathy screening programme in England screened 2 144 007 people with diabetes (83% coverage) *(39)*. After 7 years of screening for treatable diabetic retinopathy, a review of the blindness registry in England revealed that the condition was no longer the most common cause of blindness in the working age population *(42)*. This provides compelling evidence that systematic diabetic retinopathy screening, coupled with timely treatment of sight-threatening disease, can reduce vision impairment and blindness.

Box 3.3 Spectacles

WHO considers spectacles or contact lenses *functioning interventions*, as they do not eliminate or cure refractive error by treating its causes *(43)*; rather they are used to compensate for common refractive errors such as myopia, hypermetropia and presbyopia. In the same way, the incorporation of prisms into spectacles can be used to compensate for double vision that occurs due to a range of causes.

Spectacles are also used in the context of vision rehabilitation. This comes, for example, in the form of convex lenses that are incorporated into spectacles to magnify the image to help individuals with low vision to perform their near-tasks comfortably.

Spectacles are also an assistive device and are part of the WHO Priority Assistive Products List.[1] WHO defines assistive devices and technologies as those whose primary purpose is to maintain or improve the functioning and independence of an individual to facilitate participation and to enhance overall well-being *(44)*.

1 See: https://www.who.int/phi/implementation/assistive_technology/global_survey-apl/en/.

Rehabilitation

Vision impairment and blindness caused by many major eye conditions (e.g. glaucoma and age-related macular degeneration) cannot be treated, and rehabilitation will be required.

Rehabilitation aims to optimize the everyday functioning of those with vision impairment or blindness that cannot be treated in their environment, by maximizing the use of residual vision and providing practical adaptations to address the social, psychological, emotional, and economic consequences of vision impairment *(45)*.

Vision impairment and blindness caused by many major eye conditions cannot be treated, and rehabilitation will be required.

The main eye conditions causing vision impairment in adults, and addressed by vision rehabilitation, are glaucoma, AMD, corneal opacities and diabetic retinopathy. The main conditions in children and young adults include congenital, genetic, and acquired eye conditions.

A broad range of vision rehabilitation interventions are available, including optical magnifiers, environmental modification (e.g. improved lighting), reading using Braille, screen readers, smartphone wayfinders, counselling and home skills training, such as orientation and mobility training with white canes to ensure safe ambulation *(46, 47)*. Many eye conditions can impact different components of vision function (e.g. visual acuity, contrast, peripheral vision), thus vision rehabilitation interventions need to be tailored to individual needs and priorities.

Vision rehabilitation interventions greatly assist people with a visual impairment and blindness *(48, 49)*. Additional research is required, however, to determine not only the most efficient and cost-effective interventions but also optimal outcome measures for rehabilitation *(50, 51)*. WHO is currently developing a package of evidence-based rehabilitation interventions to include vision rehabilitation *(52)*. A case example of an integrated low vision rehabilitation service is provided in Box 3.4.

Box 3.4 An integrated low-vision rehabilitation service: a case example from Sri Lanka *(53)*

Prior to 2008, vision rehabilitation services for the whole of Sri Lanka were provided by three low-vision clinics only, located within tertiary hospital settings. However, when Sri Lanka's first national eye care plan was developed in 2007, low vision was included and the necessary links with education, rehabilitation, and social services were established.

With support from international NGOs and the Ministry of Health (MoH), the strengthening of Sri Lanka's vision rehabilitation services began in 2008. Initially, this involved solidification of the existing tertiary level services, so they could competently provide visual skills training, orientation and mobility training, and counselling services for people with low vision. Following this, ten secondary level clinics, with strong referral links to the three tertiary clinics, were then established within existing district hospitals. Existing eye care practitioners from the eye units of these hospitals were trained to provide the services, including comprehensive low-vision assessment, prescription and dispensing of low-vision devices, as well as training in the use of such devices. People with complicated needs were referred to the nearest tertiary low-vision clinic for further management.

The establishment of these clinics improved the accessibility of vision rehabilitative services across the country and, within only two years following implementation, nearly 8000 people (of whom 10% were children) with vision impairment had received low-vision rehabilitation services. While it is acknowledged that this is a small proportion only of the total number of people with vision impairment in Sri Lanka, it represents a five-fold increase in the number of people accessing low-vision rehabilitation services when compared with the previous three years.

Adapted from: Yasmin S. An integrated low vision service: Sri Lanka. Community eye health. 2012;25(77):16.

Table 3.1 Common eye conditions across the life course and the strategies used in response

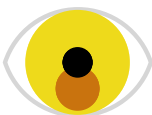
● strategy is very relevant to the eye condition

• strategy is somewhat relevant.

N.B. Rehabilitation is a type of strategy very relevant for all conditions that cause vision impairment that cannot be treated.

Common eye conditions amongst children

Corneal scarring from measles infection and vitamin A deficiency



Type of Strategy

Promotive	•
Preventive	●
Treatment	•

Common causes: Vitamin A deficiency and measles infection

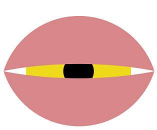
Can cause vision impairment: Yes

Promotion: Nutrition education regarding a healthy, vitamin A-rich diet, and the importance of measles immunization and vitamin A supplementation

Prevention: Measles can be prevented through immunization. It is recommended that children with measles infection should be treated with high dose vitamin A to reduce the risk of corneal ulceration (54). Routine vitamin A supplementation of pre-school-aged children is associated with a clinically meaningful reduction in blindness in children (16, 17). Guidelines for the prevention of vitamin A deficiency recommend that high-dose supplements should be given to children aged 6–59 months in settings where vitamin A deficiency is a public health problem. Large-scale implementation within these settings has been shown to be cost-effective (17). The 2011 WHO guidelines on vitamin A supplementation focus on supplementation and include food-based interventions such as food fortification, to ensure longer-term sustainability.

Treatment: In some cases, the vision impairment or blindness caused by the corneal opacity can be treated by an optical iridectomy.

Corneal scarring from conjunctivitis of the newborn (“ophthalmia neonatorum”)



Type of Strategy

Promotive	N/A
Preventive	●
Treatment	●

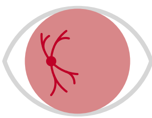
Causes: *Chlamydia trachomatis* or *Neisseria gonorrhoeae* infection acquired during childbirth.

Can cause vision impairment: Yes

Prevention: Ophthalmia neonatorum can be prevented before birth by treating the mother’s infection. After birth, the infection can be prevented by ocular prophylaxis (i.e. cleaning the eyelids and instilling an antiseptic or antibiotic shortly after birth).

Treatment: Intensive topical and systemic antibiotics

Retinopathy of prematurity



Type of Strategy

Promotive	•
Preventive	●
Treatment	●

Cause: Abnormal development of the retinal blood vessels in preterm infants.

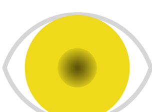
Can cause vision impairment: Yes

Promotion: Health promotion regarding the benefits of a course of antenatal steroids for women with threatened preterm delivery *(55)*.

Prevention: i) Interventions to reduce preterm birth *(56)*; ii) A course of antenatal steroids to mothers with threatened preterm delivery; iii) High quality neonatal care immediately following birth to address risk factors (e.g. sepsis, poor oxygen management, failure to gain weight, fewer blood transfusions).

Treatment: Systematic retinal screening of preterm infants, starting a few weeks after birth, using local, evidence-based screening criteria followed by urgent treatment of infants developing the vision-threatening signs of ROP. Laser treatment significantly reduces the risk of vision impairment or blindness *(32)*. Follow up throughout childhood and adolescence is required to detect and manage complications, such as high myopia.

Congenital and developmental cataract



Type of Strategy

Promotive	•
Preventive	•
Treatment	●

Causes: Most bilateral cases are of unknown cause. Known causes include intrauterine infection and metabolic disorders, or they are hereditary. Trauma is the most common cause of unilateral cataract.

Can cause vision impairment: Yes

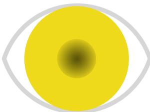
Promotion: As early surgery gives better visual outcomes, health promotion is required for parents and health workers so that children with signs of cataract (white pupils) are urgently referred.

Prevention: Rubella immunization, if this is included in national immunization policies.

Treatment: Screening in newborns is recommended to ensure early diagnosis and timely referral for surgery. Cataract surgery requires a well-equipped and competent surgical team *(57-59)*. Following cataract surgery, long-term follow up with optical correction and amblyopia therapy is required *(57)*. Visual rehabilitation may be needed for children with poor visual outcomes.

Common conditions amongst adults

Cataract



Type of Strategy

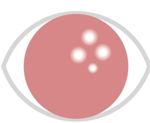
Promotive	●
Preventive	N/A
Treatment	●

Can cause vision impairment: Yes

Promotion: Given the few well-established modifiable risk factors for cataract, including UV-B exposure, cigarette smoking, cortico-steroid use and diabetes, are also associated with other adverse health outcomes, interventions aimed at improving their control should be promoted.

Treatment: Treatment involves one-time surgery under local anaesthesia, which can be performed as a day case. Cataract surgery involves removing the opaque lens and implantation of an intraocular lens *(60)*. Surgery at an early stage can prevent worsening of vision impairment or restore vision if undertaken later.

Age-related macular degeneration



Type of Strategy

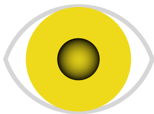
Promotive	N/A
Preventive	●
Treatment	●

Can cause vision impairment: Yes

Prevention: Cigarette smoking is the main modifiable risk factor. Thus, smoking cessation has been recommended in some clinical practice guidelines for patients who have, or are at risk of, age-related macular degeneration *(61)*.

Treatment: There are two types of advanced age-related macular degeneration (AMD) that can lead to vision impairment and blindness, atrophic ("dry") and neovascular ("wet"). Effective therapeutic options, which are currently only available for neovascular AMD, consist of repeated injections of anti-vascular endothelial growth factor (VEGF) agents. Anti-VEGF treatment and monitoring requires optical coherence tomography (OCT) imaging, which are not commonly available in many low- and middle-income countries and there is a paucity of data on the use and effectiveness of anti-VEGF in these settings *(62)*. There are currently no evidence-based treatments for dry age-related degeneration. Life-long monitoring is required.

Glaucoma



Type of Strategy

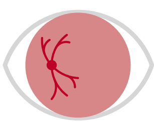
Promotive	●
Preventive	N/A
Treatment	●

Can cause vision impairment: Yes

Promotion: Given glaucoma is asymptomatic in the early stages, appropriately designed health promotion initiatives targeting early detection through improved awareness of the importance of regular eye examinations can be effective in increasing the use of eye care services among older populations *(8)*.

Treatment: General population screening for glaucoma is not currently considered to be cost-effective in most settings *(63)*. Therefore, routine eye examinations are recommended for high-risk individuals as early detection is essential for the protection of visual function. The only proven, and generally accepted, treatment to reduce the risk of further progression of glaucoma is to lower intraocular pressure *(34)*. Reduction of intraocular pressure can be achieved by a number of interventions including a therapeutic eye drop regimen, laser therapy, surgery, or a combination of these *(34)*.

Diabetic retinopathy



Type of Strategy

Promotive	●
Preventive	●
Treatment	●

Cause: Diabetes

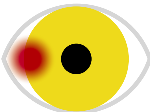
Can cause vision impairment: Yes

Promotion: Health promotion initiatives can be important to raise awareness of the importance of regular eye examinations among people with diabetes *(7)*.

Prevention: After diabetes onset, optimal management of key diabetic retinopathy risk factors (e.g. hyperglycaemia and hypertension) can prevent or delay the onset and progression of diabetic retinopathy *(18, 19)*.

Treatment: Given the majority of vision impairment from diabetic retinopathy is avoidable through early detection and timely treatment, periodic screening among individuals with diabetes has long been endorsed. Screening can be undertaken using ophthalmoscopy by trained eye-care personnel (e.g. ophthalmologists or optometrists) or retinal imaging with interpretation. Effective referral and timely treatment of sight-threatening diabetic retinopathy with laser or other interventions is highly effective in preventing vision impairment or blindness *(64)*. Life-long monitoring is required.

Pterygium



Type of Strategy

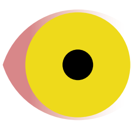
Promotive	N/A
Preventive	•
Treatment	●

Can cause vision impairment: In advanced cases

Prevention: Avoidance of proposed environmental risk factors may prevent development of pterygium. The wearing of sunglasses may protect against UV radiation, wind and dust.

Treatment: Lubricating drops are often used to alleviate symptoms such as irritation and redness. Surgical removal is warranted if the pterygia encroaches on the visual axis (central part of the cornea) *(65)*

Dry eyes



Type of Strategy

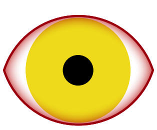
Promotive	N/A
Preventive	N/A
Treatment	●

Causes: The numerous causes of dry eye include, but are not limited to, contact lens wear, certain autoimmune conditions (e.g. Sjogren's, rheumatoid arthritis), blepharitis, lid disorders, some medications and ageing.

Can cause vision impairment: Not typically

Treatment: Lubricating eye drops provide the most readily available means of alleviating symptoms of dry eye by increasing the tear volume. In more severe cases, punctal occlusion may be effective in improving tear retention, however evidence is inconclusive *(66)*. When indicated, the appropriate management of lid conditions such as blepharitis (see below) can be effective in reducing dry eye symptoms.

Blepharitis



Type of Strategy

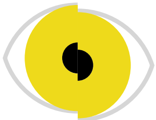
Promotive	N/A
Preventive	N/A
Treatment	●

Can cause vision impairment: No

Treatment: Blepharitis is usually a chronic condition that cannot be permanently cured. Effective treatment regimens include warm compresses, eyelid cleansing and massage, antibiotics, anti-inflammatory agents, or a combination thereof *(67)*.

Common conditions among children and adults

Refractive errors



Can cause vision impairment: Yes

Prevention: Presbyopia, hypermetropia and astigmatism cannot be prevented. In the case of myopia, on the other hand, increasing children's time spent outdoors and reducing near-work activity might delay the onset and progression of myopia, which reduces the risk of high myopia and its complications *(9, 15)*. There are also a range of optical, pharmacological, behavioural and surgical interventions to delay the onset or slow down the progression of myopia to more advanced forms and severe complications, however further research is required *(68)*.

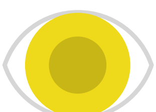
Treatment: Screening for refractive errors is recommended among children (only) in order to avoid the negative impact of uncorrected refractive error on academic performance *(12)*.

Reduced visual acuity from refractive error can be effectively compensated for with spectacles or contact lenses. Laser refractive surgery and, less commonly, intraocular lenses are used to correct the refractive error.

Type of Strategy

Promotive	N/A
Preventive	●
Treatment	⬤

Corneal opacity due to injury



Causes: Ocular injury

Can cause vision impairment: Yes

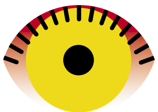
Promotion/Prevention: Interventions focused on public and occupational safety through regulatory and policy measures, such as wearing seat belts and restricting use of fireworks, can reduce the risk of eye injuries *(20, 21)*. Targeted health promotion to improve awareness of trauma prevention strategies, including wearing of protective eye wear in high risk activities and industries (e.g. certain sports, agricultural activities) may also be effective in reducing eye injuries. However, more research is required to investigate the effectiveness of educational interventions in preventing eye injuries *(22)*.

Treatment: In some cases, the vision impairment or blindness caused by the corneal opacity can be treated with a corneal transplant to restore vision. Shortage of corneal tissue is a present challenge.

Type of Strategy

Promotive	●
Preventive	●
Treatment	⬤

Trachoma



Cause: Infection with the bacterium *Chlamydia trachomatis*

Can cause vision impairment: Yes

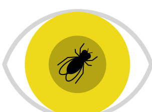
Promotion/Prevention: Antibiotic treatment to reduce the risk of, or clear, ocular *Chlamydia trachomatis* infection *(69)* and Facial cleanliness and Environmental improvements, particularly improved access to water and sanitation, to prevent C. trachomatis transmission *(26)*. Antibiotics, facial cleanliness and environmental improvements are delivered to entire districts in which the prevalence of the active trachoma sign "trachomatous inflammation – follicular" is above 5%.

Treatment: Surgery for trichiasis to prevent vision impairment or blindness from corneal opacity.

Type of Strategy

Promotive	●
Preventive	●
Treatment	●

Onchocerciasis



Cause: Infection with *Onchocerca volvulus*

Can cause vision impairment: Yes

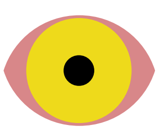
Prevention: Onchocerciasis is transmitted by blackflies and can lead to vision impairment and blindness. There is no vaccine or medication to prevent infection. Ongoing onchocerciasis control programmes are implemented in endemic regions and consist of mass drug administration of ivermectin using community-directed treatment. Vector control has been an additional strategy *(13)*.

Treatment: WHO recommends treating onchocerciasis with ivermectin at least once annually for 10–15 years *(13)*.

Type of Strategy

Promotive	N/A
Preventive	●
Treatment	●

Conjunctivitis



Common causes: Allergy or bacterial or viral infection

Can cause vision impairment: Not typically

Promotion/Prevention: The transmission of viral and bacterial conjunctivitis can be prevented through hygiene measures (e.g. handwashing), while the avoidance of allergens can be effective in preventing allergic conjunctivitis.

Treatment: Bacterial conjunctivitis can be treated with antibiotic drops, and allergic conjunctivitis can be treated with anti-inflammatory agents.

Type of Strategy

Promotive	●
Preventive	●
Treatment	●

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Chapter 4

Successes and remaining challenges in eye care

Global concerted action during the past 30 years to address eye conditions and vision impairment has resulted in progress in many areas.

Scientific and technological advances have opened a wide range of clinical and research opportunities that have the potential to accelerate future action.

Moving forward, challenges remain, particularly related to changing population demographics; data collection and its integration in health information systems; integration of eye care in health strategic plans; workforce; and coordination with the private sector.

Global concerted action

Thanks to concerted action taken during the past 30 years in addressing eye conditions and vision impairment, and the scientific and technological advances made in the field of eye care, the sector has a strong platform of success on which to build future actions.

Advocacy

Global concerted action during the past 30 years has resulted in progress in many areas.

Considerable efforts have been made during the past 30 years to address eye conditions and vision impairment which has resulted in progress in many areas. The global initiative for the elimination of avoidable blindness, "Vision 2020: The Right to Sight" *(1)* was launched in 1999 by WHO to intensify and accelerate activities for the prevention of blindness with the goal of eliminating avoidable blindness by 2020. The initiative has been pivotal in achieving unified and coordinated advocacy for key priorities for action in the field of eye care at a global, regional and national level; it has been also been instrumental in strengthening national prevention of blindness programmes, committees and focal points, as well as supporting the development of national eye care plans and advocating for stronger evidence in the field. Four WHA resolutions adopted in 2003 (WHA56.26), 2006 (WHA59.25), 2009 (WHA62.1) and 2013 (WHA66.11) have maintained this momentum *(2, 3)*.

While the aims and principles of the original initiative have remained the same, they have been built upon with additional plans over the years. The initial Vision 2020 initiative concentrated on the main causes of blindness for which cost-effective interventions were available, such as cataract, trachoma, onchocerciasis and childhood blindness. Subsequently, in recognition of the importance of noncommunicable conditions and the impact milder forms of vision loss on QoL, the 2006 plans focused not only on the elimination of avoidable blindness, but also included vision impairment, particularly the correction of refractive error.

The WHA resolutions of 2009 and 2013 were accompanied by WHO action plans which identified clear objectives and activities for Member States, the WHO Secretariat and International Partners. The most recent action plan, *Universal Eye Health: A global action plan 2014–2019 (3)*, included a further dimension around universal access to comprehensive eye care services and set an ambitious global target to reduce the "prevalence of avoidable visual impairment by 25% by 2019".

Evidence of the impact of these concerted efforts was presented to Member States at the Seventieth WHA in May 2017 in a report highlighting the progress made towards achieving the indicators included within the 2014–2019 global action plan (resolution WHA66.4). At the Assembly, 56 Member States reported having developed a national eye health plan, or strategies supported by the action plan, while many others reflected the action plan within their broader national health plans. More than 50 Member States also reported that establishing a national eye health committee or a similar coordinating mechanism had been critical to implementing the action plan *(4)*.

The consistent call for more evidence on visual impairment and eye care services has led to a significant increase in the number of population surveys undertaken to measure blindness and vision impairment, with more than 60 population-based surveys from 35 countries being conducted since 2010 (and approximately 300 surveys from 98 countries since 1980) *(5)*. Knowledge generated through these surveys has been pivotal to increasing advocacy and informing suitable public health strategies.

Eye conditions and vision impairment

Substantial progress has been made in addressing specific eye conditions and vision impairment. The number of children and adults with eye infections and blindness due to vitamin A deficiency *(6)*, onchocerciasis *(7)* and trachoma *(8, 9)* has decreased in all regions during the past 30 years *(10)*. This is due to the implementation of large-scale public health initiatives that have led to improvements in hygiene measures, nutrition and immunization coverage, as well as the distribution of antibiotics, ivermectin, and vitamin A. In addition to the successes of the preventive interventions for active trachoma, the number of people worldwide who need operations for trachomatous trichiasis has decreased substantially during the past decade: from 8.2 million in 2007 *(8)* to 2.5 million in 2019 *(11)*.

Cataract is the leading cause of blindness globally and has been a primary focus of many programmes aimed at meeting the Vision 2020 objectives. As a result, many low- and middle-income countries have seen substantial increases in rates of cataract surgery *(12, 13)*. For example, India was successful in increasing its cataract surgery rate by almost nine-fold between 1981 and 2012 *(14)*. These endeavours have resulted in modest reductions in the global proportion of cases of vision impairment and blindness attributable to cataract between 1990 and 2015 *(15)*.

It is clear that investments during the past 30 years have produced considerable dividends, with a recent meta-analysis of population-based studies for the GBD reporting an ongoing reduction in the age-standardized prevalence of distance vision impairment and blindness among the adult population since 1990 (3.83% in 1990 compared with 2.90% in 2015) *(5)*. Furthermore, modest reductions have been achieved in the proportion of adults with vision impairment or blindness specifically due to preventable or treatable causes *(5)*. It is important to note, however, that reductions in prevalence are not keeping pace with population ageing and growth, thus, the number of adults affected by vision impairment is increasing.

Scientific and technological advances

Scientific and technological advances have also opened a wide range of clinical and research opportunities in the field of eye care. For example, optical coherence tomography has significantly shaped the clinical practice of eye care during the past 15 years *(16)*, assisting diagnosis of a range of eye conditions and guiding treatment regimens for glaucoma, diabetic retinopathy and age-related macular degeneration. The adoption of telehealth solutions has been effective in improving access to a range of eye care services, particularly for those living in rural and remote areas of many countries *(17–19).* Several emerging technologies in the field of eye care, including the use of mobile-based software applications for vision assessment *(20, 21)* and cataract surgery benchmarking *(22)*, and artificial intelligence technologies for the detection of a range of eye conditions including diabetic retinopathy *(23–26)*, offer further hope for enhancing access and quality of health care to the most neglected communities. However, further research is required in real-world settings prior to widespread adoption of these technologies. The use of big data analytics also has the potential to improve knowledge of service use and the surveillance and aetiology of eye conditions *(27)*, and for the monitoring surgery outcomes *(28)*.

In the context of treatment, advances in surgical techniques for cataract, coupled with improvements in intraocular lens design and the increased availability of low-cost, high-quality intraocular lenses *(29)*, has led to significant improvements (in terms of the quality of visual outcome of patients, safety and surgical volume) in cataract surgical service delivery *(30, 31)*. The introduction of anti-VEGF injections has revolutionized the treatment of age-related macular degeneration and resulted in a reduction in the incidence of blindness from neovascular age related macular degeneration in high-income countries *(32, 33)*. Nonetheless, while it is clear that both anti-VEGF therapy and optical coherence tomography play a major role in the prevention of blindness, currently their accessibility is scarce in many low- and middle-income countries due to cost implications *(34, 35)*. Scientific advances in treatment for people with human immunodeficiency virus (HIV) has rendered HIV-related ocular infections largely prevented, although immune recovery uveitis has emerged as a complication *(36)*. Further scientific advances in the fields of nanomedicine and tissue engineering offer hope for improvements in treatment of glaucoma and age-related macular degeneration, and surgery for corneal opacities *(37–39)*.

Technology advances have changed vision rehabilitation. The development of smart phones, voice recognition, and accessibility features in computer operating systems, have dramatically enhanced access to information and communication for individuals with vision impairment and blindness *(40)*. Digital audio books are widely available in increasing numbers for those with print-reading disability. Individuals with vision impairment can navigate using GPS, or use electronic canes to assist in detecting nearby obstacles *(41)*. Although further research is required, retinal implants could potentially offer an innovative solution to restoring sight to those with little functional vision *(42)*.

It is important to recognize that the examples provided here are by no means exhaustive, and as a result of the rapid pace of innovation in the field of eye care, there are likely to be further noteworthy technological advances during the coming decades.

Challenges moving forward

While it is evident that substantial progress has been made to improve access to eye care services, this has not kept pace with population eye care needs.[1] As outlined in Chapter 2, at least 1 billion people worldwide have vision impairment that could have been prevented or has yet to be addressed. Furthermore, global eye care needs will increase substantially due to increasing urbanization, demographic and behavioural and lifestyle trends.

Challenges remain in ensuring that quality services are planned and provided according to population needs.

Changing population demographics

As described in Chapter 2, the number of people aged 60 years and over is estimated to increase by 54%: from 962 million in 2017, to 1.4 billion in 2030, and to 2.1 billion by 2050 *(43)*. An increase in life expectancy and population growth will compound the situation. Therefore, despite the interval improvements in the age-standardized prevalence of vision impairment described earlier, the combination of a growing and ageing population will significantly increase the total number of people with eye conditions and vision impairment, since prevalence increases as people age *(5)*.

Despite being more feasibly addressed, cataract and uncorrected refractive error remain major items on the unfinished agenda of public health *(44, 45)*. Close to 200 million people worldwide currently have moderate to severe presenting distance vision impairment or blindness caused by cataract or uncorrected refractive error, while an estimated 826 million have near vision impairment caused by unaddressed presbyopia. This figure is expected to increase substantially since cataract and presbyopia development are an inevitable part of ageing. Projected increases in myopia, however, are believed to be driven largely by environmental factors (e.g. decreased time spent outdoors and increased near-work activities).

It is clear that there is a growing need to expand the coverage of interventions for cataract and refractive error in order to meet the current and future demand for these conditions; a report from the United States of America estimated that in order to maintain the current surgical coverage, an additional 4.3 million cataract operations per year will be required by 2036 *(46)*. The main challenges in meeting these

1 Population eye care needs describes the volume and type of need for eye care from all individuals within a given population. It includes the need for eye care across all health strategies, health promotion, prevention, treatment and rehabilitation. The need for eye care can arise from eye conditions that can or do not commonly cause vision impairment, as well as other health conditions that can impact vision function, such as diabetes.

growing demands include the ability to provide access to cataract and refractive services to underserved populations, and ensuring quality of service delivery over time *(47)*. Although increases in cataract surgical rates have been documented in many countries *(12, 13)*, recent evidence suggests that post-operative vision results are, at times, suboptimal *(47)*.

New strategies are also needed to address the challenges related to the rapid emergence of noncommunicable chronic eye conditions, such as diabetic retinopathy, glaucoma, age-related macular degeneration, complications of high myopia and retinopathy of prematurity. In contrast to the single or short-term interventions required for cataract *(48)*, these conditions require a comprehensive range of interventions for their management as well as long-term care which will have a profound impact on an already strained health system and eye care workforce. Based on the projected burden of diabetes alone, it is estimated that, by 2040, there will be a 50% increase in the number of people worldwide requiring access to routine (i.e. yearly or biennially, depending on setting) retinal examination *(49)* for diabetic retinopathy *(50)*.

In many low-income countries cataract is now the leading cause of addressable blindness in young children, in corneal scarring remains the most common cause of blindness.

Evidence suggests that current coverage of vision rehabilitation services is poor in most countries *(51)*. The change in population demographics, and subsequent rise in the number of people with vision impairment that cannot be treated, will see an increasing demand for such services. Likewise, the number of people with age-related eye conditions not typically causing vision impairment (e.g. dry eye), but often requiring care due to painful and troublesome symptoms, will increase.

Changing priorities among child populations

Of importance is the shift in eye care priorities observed among child populations in low- and middle-income countries during the past couple of decades *(10)*. In many, but not all, low-income countries where blindness from corneal scarring has declined due to the successful implementation of public health initiatives, cataract is now the leading cause of addressable blindness in young children. Despite this, due to slower progress in some countries, corneal scarring remains the most common cause of blindness *(52)*. Early detection and referral is essential, and tertiary eye care services for children, which are inadequate in many low-income countries, are required for the surgical management and follow up.

Due to an increase in the number of preterm births, and survival of premature babies, retinopathy of prematurity has also become a leading cause of blindness among children in many middle-income countries *(53)*, and is a newly emerging challenge in several African countries *(54)*. As a result, there is greater need for high-quality neonatal care, and for integrated retinopathy of prematurity screening and treatment services with long-term follow up.

As in adult populations, the number of children and adolescents with refractive error, particularly myopia, is set to increase substantially in coming decades *(45, 55, 56)*. A recent global systematic review and meta-analysis reported that the number of children and adolescents with myopia is expected to increase by 200 million between the years 2000 and 2050. This increase is likely to be more marked in populations undergoing rapid economic transitions (e.g. East Asia) *(55, 56)* and has important implications for planning eye care services.

Data challenges

This section focuses on the current data challenges in the context of population-based surveys (only). However, it must be acknowledged that the paucity of health services research and implementation research in the field of eye care also hampers the evidence-based planning of eye care programmes and services *(57)*.

The measure of presenting visual acuity in most population-based surveys does not allow for the total number of people with vision impairment to be calculated.

As outlined earlier in this chapter, an increasing number of prevalence surveys have been conducted during the past two decades; these have undoubtedly made major contributions towards the understanding of the epidemiology of vision impairment and blindness. Despite these achievements, robust survey data are lacking in approximately half the world's countries *(58)*, with data gaps particularly pronounced in central and southern sub-Saharan Africa, eastern and central Europe, central Asia, and the Caribbean *(5)*. Moreover, of those countries that have conducted surveys, many of their findings remain unpublished *(59)*, and approximately only 15% have national-level data *(60)*. Thus, smaller regional surveys are often used as a proxy to report the prevalence of vision impairment and blindness for the entire country.

As outlined in chapters 1 and 2, there are also a number of gaps in the global epidemiology of eye conditions and vision impairment. Some of these include a lack of reliable global estimates of the prevalence of (i) eye conditions that do not typically cause vision impairment; (ii) having at least one eye condition; and (iii) unilateral vision impairment and blindness.

Furthermore, and importantly, the measure of presenting visual acuity in most population-based surveys does not allow for the total number of people with vision impairment (i.e. for those with met and unmet needs) to be calculated. As a result, the important indicator of "effective" coverage of refractive error correction cannot be reported. While this indicator, along with that of effective coverage of cataract surgery, can potentially be considered to monitor progress towards universal health coverage (UHC, Chapter 5), this will only be possible if data on the total number of people with vision impairment due to refractive error (i.e. without using spectacles or contact lenses to compensate for the condition) are collected, reported and included in the global prevalence estimates (Box 4.1).

The indicators of effective coverage of refractive error and effective coverage of cataract surgery have been included in the WHO Universal Health Coverage Index.

Box 4.1 "Effective" coverage of refractive error and cataract surgery

The indicators of effective coverage of refractive error and effective coverage of cataract surgery not only capture the magnitude of coverage, but also the concept of "effective" coverage to ensure that people who need health services receive them with sufficient quality to produce the desired gain in vision. Thus, these data are valuable to assess the accessibility and quality of services within a country and should be reported by population-based surveys on a regular basis *(47)*. According to the description included in the WHO UHC Index, the key data points required in the calculation of these indicators include:

Effective coverage of cataract surgery:

i. Prevalent cases of operable cataract (i.e. vision impairment or blindness cases where cataract is the main cause).
ii. Prevalent cases of operated cataract (i.e. all those who have undergone cataract surgery regardless of visual acuity outcome).
iii. Prevalent cases of operated cataract and a good visual outcome (i.e. no longer visually impaired following cataract surgery).

*Effective coverage of refractive error:**

i. Prevalent cases of vision impairment and blindness due to refractive error.
ii. Prevalent cases of refractive error with spectacles or contact lenses.
iii. Prevalent cases of refractive error with spectacles or contact lenses and a good visual outcome (i.e. do not have vision impairment when wearing spectacles or contact lenses)

* Refractive errors that are corrected with laser of lens surgery are not currently included in the calculation of effective coverage of refractive error of the WHO UHC Index, as these procedures are not frequently performed in low-resource settings. However, as the field progresses, it is possible for these procedures to be integrated within the calculation.

Several opportunities exist to strengthen the type of data collected and reported, to ensure that the full benefits of undertaking a survey are secured:

Rapid assessment survey methodologies frequently used in low- and middle-income countries include simplified ophthalmic examinations which makes it difficult to assign a cause to vision impairment and report on the prevalence of many eye conditions. Historically, rapid assessment surveys have focused on the identification of avoidable causes of vision impairment and blindness, such as cataract, refractive error and corneal scarring. However, due to the projected growth in the number of people with noncommunicable eye conditions such as glaucoma, age-related macular degeneration and diabetic retinopathy in the coming decades, there is a need to improve the ability of surveys to identify these posterior segment conditions.

Surveys often employ varied definitions for near and distance vision impairment and blindness, making it difficult to compare findings between studies. For example, the definition of near vision


U.S.A.

impairment varies widely between studies in terms of the testing distance and the font size used. Furthermore, surveys conducted in high-income countries frequently employ more stringent visual acuity cut-offs for distance vision impairment. Greater standardization of definitions of near and distance vision impairment is required.

Most surveys do not incorporate provisions for sample stratification to account for heterogeneous populations. Assuming homogeneity may result in an insufficient quantification of the burden of vision loss in some of the countries' most vulnerable groups, such as indigenous populations, ethnic minorities, people living in poverty and people with disabilities. To reduce inequality, it is important to identify which subgroups of the population are less able to access eye care services.

Previous prevalence surveys have infrequently assessed and reported potential non-response bias, making it difficult to interpret the representativeness of the results. A recent review of 92 blindness prevalence surveys undertaken in low- and middle-income countries and published between 2009 and 2017 *(61)* identified that less than a quarter of researchers report response bias – i.e. the difference between people who participate ("responders") and those who do not ("non-responders") – in ways that affect prevalence estimates.

There is a paucity of population-based data reporting vision impairment for all ages *(62, 63)*. To date, the vast majority of survey methodologies have been undertaken for population subgroups aged 50 years and over, due to the fact that an estimated 80% of vision impairment occurs in this age group. Despite this, it is well-established that eye conditions and vision impairment from uncorrected or under-corrected refractive error and diabetic retinopathy is common at much younger ages. In order to target effectively the needs of people at critical periods throughout the life course, epidemiological studies may need to be more inclusive of younger populations. Alternatively, there may be opportunities to include modules on eye care in child health surveys.

Efforts are already underway to strengthen survey designs to address many of these limitations *(64)*; recommended case definitions for near and distance vision impairment have now been included in the 11th Revision of the ICD–11.[2] The field would also benefit from the development of an eye care survey handbook to support researchers in the conduct of epidemiological studies, including the provision of guidance on study design, survey planning and implementation and possible data collection tools, while taking into consideration factors such as complexity and cost. This would ensure that comparable information is collected and reported and would facilitate future estimations of the global prevalence of vision impairment and other important service coverage indicators.

2 See: https://www.who.int/classifications/icd/en/.

Integration

Eye care is not typically included in health strategic plans.

While the 2014–2019 global action plan *(3)* promoted the implementation of integrated national eye health policies, plans and programmes, much needs to be done in countries for effective integration. Strategic plans for eye care are not currently included in health sector strategic plans in most low- and middle-income countries. It can be assumed that if eye care is not included in health strategic plans, it will frequently not be included in the planning and budgeting of services.

Vertical programmes

Vertical initiatives tend to be short to medium term and have been successful in some situations, most often where there is infectious transmission of a condition *(65)* or where the existing health infrastructure is so weak that there is nothing on which to build or integrate services *(66)*. For example, vertical (disease-specific) programmes have been used as a common and successful model in eye care for specific conditions such as trachoma and onchocerciasis *(65, 67)*.

Eye care is not typically included in health strategic plans.

However, for the most part, these programmes do not address eye care needs across the life course or those associated with ageing and chronic disease; moreover, they appear to have failed to reduce health inequalities between socioeconomic groups in low- and middle-income countries. At times, there may also be perverse incentives that compromise quality and patient safety to achieve high outputs. In addition, vertical programmes can be poorly aligned with population eye care needs *(68–70)*.

Increasing access to services requires renewed efforts to integrate eye care, not only into the planning of the health sector in general, and into specific health programmes in particular (e.g. neonatal care, noncommunicable diseases, primary care and rehabilitation) but also into other sectors, such as education. For example, while there are an increasing number of examples of large scale and effective eye screening exist in the context of school health programmes *(71)*, availability is still lacking in many low- and middle-income countries. In light of the increasing number of children and adolescents with refractive error, high-quality and cost-effective school-based eye-care linked to service provision is of the utmost importance. This requires cooperation between the ministries of health and education, coupled with a national eye-care plan that includes school eye health *(71, 72)*. Although there are some successful examples of eye-care interventions being delivered through other health services *(73)*, to date, progress has been slow in the eye care sector which may reflect a disconnection with the rest of the health system.

Most eye care delivery focuses on the provision of curative interventions at the secondary and tertiary levels of the health system and is often restricted to urban and larger regional settings.

Inequalities in access to eye care services

As outlined in Chapter 2, persistent inequalities remain between different subgroups of the population in accessing eye care services. In general, those not able to access eye care services as required include people living in rural areas, those with low incomes, women, older people, people with disabilities, ethnic minorities, and refugees. Consequently, they have far higher rates of vision impairment and blindness *(5, 74, 75)*. Despite this, the consideration of equity in eye care plans is currently weak *(76)*. For example, one third of countries (9/27, 59% low income or low- to middle-income) that completed the WHO eye care service assessment tool (ECSAT) between 2014–16 reported that there were no government measures in place to ensure equitable distribution of health workers involved in eye care in all geographic areas.

It is important to note that providing equal rates of eye care services between population subgroups does not guarantee the delivery of equitable services. For example, in many of the world's regions, cataract is notably a more common cause of vision impairment and blindness in women than in men *(15)*. Therefore, as women's needs for cataract surgery are greater, an equal number of operations for women and men would not achieve equity.

Most eye care delivery focuses on the provision of curative interventions at the secondary and tertiary levels of the health system and is often restricted to urban and larger regional settings. This adds to inequity in access to effective interventions for early detection and prevention, and greater costs for patients (e.g. travel costs). To assist in addressing this inequity between population subgroups, there is a need for implementation and health systems research to ensure evidence-based planning of future eye care programmes and services.

There is also evidence demonstrating that eliminating user fees, or reducing out-of-pocket payments at the point of delivery, impacts positively on equitable access to services *(77, 78)*. However, eye care medicines and interventions continue to not be integrated into the health insurance schemes in many low- and middle-income countries. For example, fees for cataract surgery and the costs of spectacles and treatment for noncommunicable eye conditions (e.g. glaucoma, diabetic retinopathy, age-related macular degeneration) continue to rely on out-of-pocket payments in many settings *(79)*. Even high-income countries can require out-of-pocket payments for refractive error assessment and correction, or for the purchase of devices, or specialized insurance for vision care. Furthermore, eye care service delivery is frequently led by charity and nongovernmental organizations that act independently from the MoH.

Some low- and middle-income countries (e.g. India, Viet Nam, Rwanda, Philippines, India) have already included cataract surgery and treatment of other eye conditions in their social health insurance schemes (Box 4.2). However, given substantial increases in cataract surgical rates, and the associated costs to the health insurance providers, some countries have introduced limits on the total number of surgical procedures claimable per accredited surgeon (Box 4.3). This can be detrimental to improving cataract surgical coverage and emphasizes the importance of a thorough planning process that takes into consideration population needs, projections and workforce availability to estimate the cost and cost coverage.

Box 4.2 The inclusion of eye care interventions in health insurance schemes in India: the National Programme for Control of Blindness (NPCB)

Brief history

In 1976, India launched its national programme for prevention of visual impairment and control of blindness, currently known as the National Programme for Control of Blindness (NPCB), with an ambitious goal of reducing the prevalence of blindness from 1.4% to 0.3% by the year 2020. Subsequently, a population-based survey conducted in 1986-89 reported a modest increase in prevalence of blindness to 1.49%, with cataract accounting for 80% of blindness cases. On this basis, the Government of India embarked on the World Bank assisted cataract blindness elimination programme targeting seven states (Andhra Pradesh, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu and Uttar Pradesh) where there was a known high prevalence of cataract blindness. This project was highly successful in improving cataract surgery rates (from 1342 per million in 1995 to 3620 per million in 2002) and rates of intraocular lens implantation (increasing from 3% in 1993 to 75% in 2002).

In an effort to decentralize the NPCB, the District Blindness Control Society (DBCS) was formed in each district of India in 1994-95. Subsequent to this (commencing in 2002), the NPCB programme moved to being completely funded by the Government of India without depending on support from external funding agencies. Under this programme, cataract surgery with intraocular implantation is provided free of charge for approximately one third of all cataract surgeries, including all surgeries performed on patients with a poverty certificate. While the initial focus of the programme was on increasing access to cataract surgery with intraocular implantations, funding support was extended in successive years to include a comprehensive coverage of a range of eye care interventions including laser treatment for diabetic retinopathy, glaucoma surgeries, preventions and treatment of ocular trauma, childhood blindness, keratoplasty, squint, vision rehabilitation and screening and lasers for retinopathy of prematurity through successful public–private partnerships. The DBCS reviews the data submitted by the participating hospitals and makes site visits for quality control.

Progress

In 2016-17, the NPCB provided cataract surgery to a total 6.5 million people in India, achieving a cataract surgical rate of over 6000 per million population. During this period, school screening was provided to nearly 32 million children and approximately 750 000 spectacles were distributed. In addition, a total of 1.5 million management/treatment procedures were performed for other eye conditions. As a result of these concerted efforts, an overall reduction in prevalence of blindness was reported from 1.1% in 2001-02 to 0.45% during the years 2015–18.

Box 4.3 Cataract financing under national health insurance – volume, cost control and equity in the Philippines's PhilHealth scheme

In the Philippines, the public health insurance scheme, PhilHealth, covers approximately 90% of the population and is a major source of funding for eye care. Cataract surgery is covered in the benefit package and has long been one of the highest claimed procedures.

Providers are paid a fixed case payment per eye that is the same regardless of the method of cataract extraction (i.e. manual small-incision cataract surgery or phacoemulsification), the type of intraocular lens used (provided it is on the Philippine Food and Drug Administration approved list) and whether the provider is public or private. For senior citizens, the poor and other PhilHealth members whose premiums are sponsored by the government, there is no out of pocket cost to the patient for cataract surgery conducted within government facilities. However, for all other people treated in government facilities, and all of those treated in private facilities, providers can charge above the fixed case payment, with the balance paid by the patient. In the Philippines, 60% of accredited providers are in the private sector.

Significant internal controls are in place for cataract surgery under PhilHealth including pre-authorization requirements, such as verifiable patient information and surgery approval by ophthalmology unit heads. In 2015, the control systems identified unusually high numbers of cataract surgeries being sought for reimbursement. This was driven by some providers seeking to profit from the scheme by providing cataract surgeries that may not have been necessary or that were fraudulent.

In response, PhilHealth restricted the number of cataract surgical procedures claimable per accredited surgeon to 50 per month (not exceeding 10 in any one day), with the exception being when surgery was undertaken as part of a recognized residency training programme. This has resulted in substantially reduced claims for cataract surgery – phacoemulsification surgery, for example, was the 5th highest claimed procedure in 2015 (just over 146 000 claims totalling PHP 2.34 billion) but dropped to 10th position in 2016 (just under 95 000 claims totalling PHP 1.52 billion). The impact of these measures on the provision of equitable access to cataract surgery needs to be investigated.

Although the private sector makes up a significant proportion of the provider landscape in the field of eye care, the exact share is rarely understood.

Coordination with private sector

Although the private sector makes up a significant proportion of the provider landscape in the field of eye care, the exact share is rarely understood *(80–82)*. A risk of strong involvement from the private sector and/or nongovernmental organizations is that it may contribute to governments not taking responsibility for the provision of eye care services as part of national insurance schemes, with negative consequences for disadvantaged groups that cannot afford the costs of private service provision. In some circumstances the challenge may be the lack of regulation of private sector services.

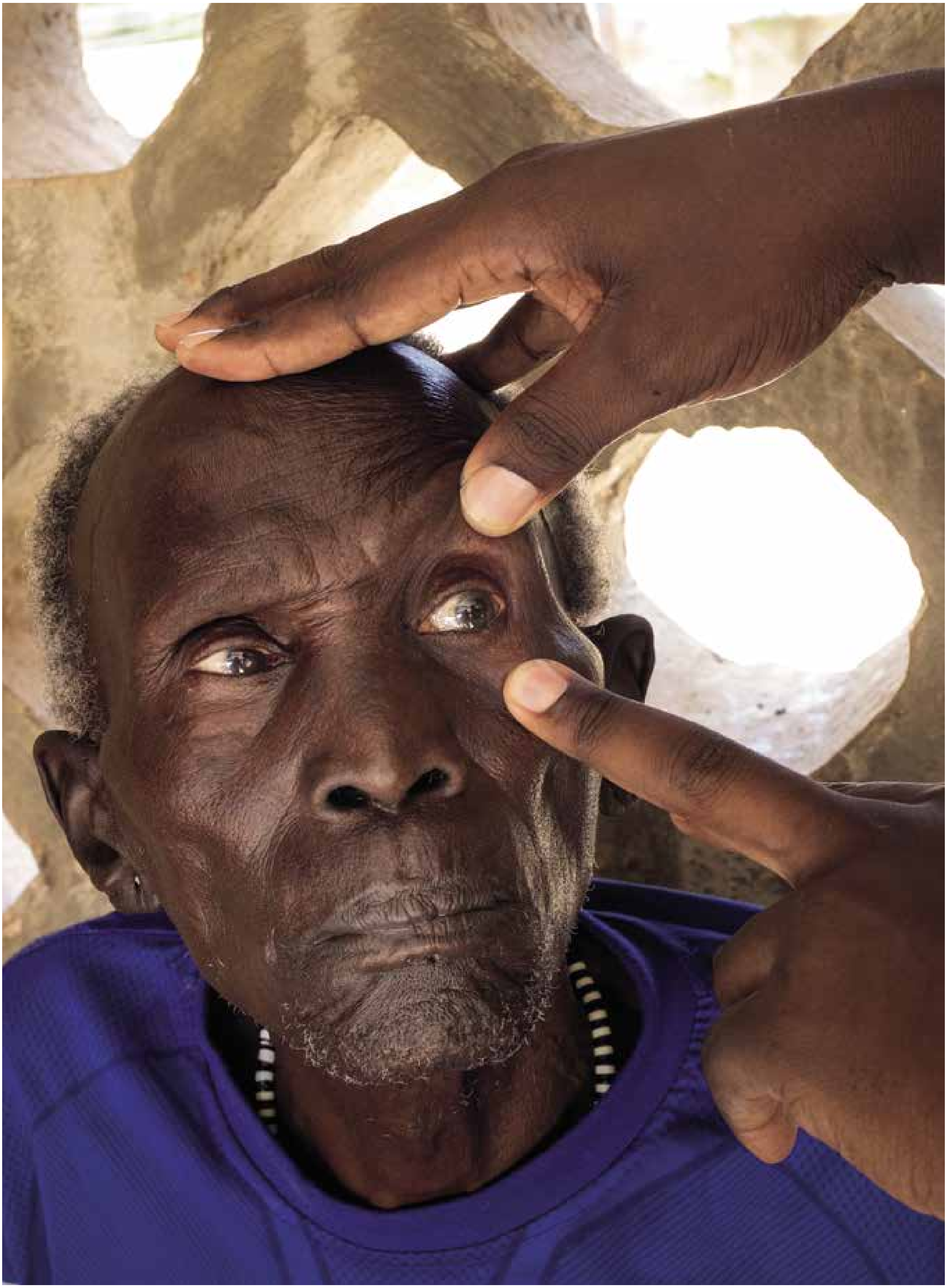
Given the growing demands for eye care services, effective options for public–private partnerships need to be explored as a means to provide affordable eye care *(79, 83)*.

Uncoordinated and unregulated workforce

Several factors accentuate the problems associated with the shortage of health workers in low- and middle-income countries; these include suboptimal distribution (both geographically and across income levels), issues with retention, and poor supervision and coordination of eye care services among health workers which can often result in parallel services, overlap, inefficiencies, and gaps, and poor outcomes *(84)*.

While innovative strategies have emerged which use community-based workers and other cadres, such as optometrists, to deliver eye care and vision services, their impact has been hindered by a lack of coordination, regulation and a systematic integration, resulting in persistent service gaps and inequalities and a lack of standardization of care in many low- and middle-income countries. To be successful, such strategies must occur within the context of needs-based workforce evaluation and planning, that aligns the competencies, composition and deployment and retention of the workforce with population needs and distribution.

Despite significant progress being made in the promotion of training standards for optometrists, optometric technicians and optical technicians *(85)*, the acceptance of optometry as a profession remains an issue in many countries and is an important advocacy issue going forward in many countries *(86)*. For instance, of the countries who recently completed the ECSAT tool (2014–16), one-third (8/24) either did not recognize optometry as a profession or there was no established educational requirement for optometrists. In this context it is important to note that, in some countries, productivity may be diminished because a section of the health workforce, such as optometrists, are not accredited to carry out eye care services independently *(87)*.



Health information systems

Health information systems (HIS) are used to collect, standardize, code and manage information relevant to indicators of health status (including eye conditions and vision impairment); determinants of health (including determinants of eye conditions); and health systems (governance and leadership, workforce, essential medicines, technologies and assistive products and service delivery). Such information is needed by (i) policy-makers to identify and respond to problems with evidence-based solutions, and to allocate resources effectively; (ii) planners to design more effective services, and managers to monitor and evaluate these services; and (iii) clinicians to provide high quality and evidence-based care *(88)*. Thus, HIS underpin health and health-related decision-making in health policy, management and clinical care.

HIS often do not include relevant data on eye conditions and vision impairment, their determinants, and health systems data related to eye care.

Even countries with developed HIS often do not include relevant data on eye conditions and vision impairment, their determinants, and health systems data related to eye care. Consequently, decision-makers at all levels of the health system may lack the information they need to identify problems and needs, to allocate resources optimally or to provide evidence-based services. This can result in a significant gap between what policy-makers, health workers and researchers know and what they need to know to improve the health of the population *(89)*. Furthermore, the situation in eye care is further challenged through the existence of a strong private eye care sector with parallel information systems that do not communicate with public sector information systems.

It is promising that a recent study evaluating 28 national eye care plans from low- and middle-income countries found that almost all countries recognized the need to strengthen their HIS to support the monitoring of eye care services and policy *(76)*. In addition, recent advocacy efforts have also focused on expanding eye care indicators within primary care *(90)*. However, much needs to be done; addressing the challenge of strengthening HIS to include information relevant to eye care is of the outmost importance in the coming years.

The way forward

The challenges ahead are considerable but can be addressed, especially because the field of eye care can build on its many successes. First, effective interventions are available to reduce the risk of acquiring an eye condition or vision impairment and of mitigating the impact. Secondly, as demonstrated through Vision 2020, eye care can rely on a long tradition of effective and coordinated advocacy that progresses towards common goals. Thirdly, a number of scientific and technological advances have been made with the potential to facilitate early diagnoses and accelerate the response.

In addition, there are also windows of opportunity to facilitate progress, the most relevant being the sustainable development goals (SDGs). Eye care services are particularly relevant to achieving SDG3: "Ensure healthy lives and promote well-being for all at all ages", particularly SDG target 3.8 on UHC: "Achieve UHC, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all". Eye care services also contribute to other targets, such as those on neglected tropical disease (target 3.3), mental health (target 3.4), road traffic accidents (target 3.6), and workforce health (target 3c).

Building on successes, considering the political commitment towards achieving SDG3, and moving forward with UHC, Chapters 5 and 6 describe UHC and IPEC and how each can help address the current and future challenges identified in this chapter. Chapter 5 introduces UHC and its contribution to achieving better integration of eye care into health systems and to reducing inequalities by planning and providing quality eye services according to population needs. Chapter 6 presents IPEC through health system strengthening to address these challenges, particularly those related to the eye care workforce, and the coordination and continuity of eye care.

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Chapter 5

Advancing universal health coverage through eye care

Eye care is particularly relevant to SDG 3 on health and well-being, and to target SDG3.8 on UHC.

Eye care needs to be an integral part of UHC to address the challenges arising from changing demographics, inequities in access, and lack of integration.

Collecting and reporting information on the met and unmet eye care needs are key for planning services as part of UHC.

Protection against financial hardship involves ensuring that the costs of eye care do not expose the user to catastrophic spending on health.[1]

A package of eye care interventions is needed to facilitate the integration of eye care into the health sector and UHC to effectively meet population needs.

1 Catastrophic spending on health refers to the proportion of the population with large household expenditure on health as a share of total household expenditure or income. Two thresholds are used to define “large household expenditure on health”: greater than 10% and greater than 25% of total household expenditure or income. (available at: https://unstats.un.org/sdgs/metadata/?Text=&Goal=3&Target=3.8, accessed 13 September 2019)

Universal health coverage

Eye care contributes both to the advancement of SDG 3 on health and well-being, and to the target of UHC.

The United Nations (UN) SDGs define targets for priority areas of action that all 191 UN Member States agreed to achieve by 2030. Eye care is particularly relevant to SDG3 which addresses health and well-being, and also to SDG target 3.8 on UHC – an overarching objective towards which health systems should strive. UHC means that all people have access to the health services they need, when and where they need them, without financial hardship. It includes the full range of essential health services, from health promotion to prevention, treatment, rehabilitation, and palliative care *(1)*. Additionally, UHC is a powerful approach to ensure progress in meeting other health-related SDG3 targets.

Debates and actions around the implementation of UHC take into consideration the following issues:

Make eye care part of universal health coverage.

- Ensuring coverage of the population – i.e. leaving no one behind;
- Ensuring financial health protection and avoiding catastrophic expenditures;
- Providing a package of high-quality integrated and people-centred health services.

It is important to note that each country may have different starting points and pathways as they progress towards UHC; these will depend upon population needs, available resources, the political and social context, and the maturity of the health system, among other factors. However, to attain the overarching goal of UHC a health system approach is required, whereby all health system components are strengthened to provide comprehensive, quality services. Furthermore, the health sector needs to collaborate actively with other relevant sectors and stakeholders to discuss and agree on potential strategies to improve the population's health.

To address many of the challenges identified in Chapter 4 – particularly those relating to changing demographics, inequities in access, and lack of integration – eye care needs to be an integral part of UHC. However, significant work needs to be done given that priority eye care services are still only provided with out-of-pocket payments in a number of countries.

When considering eye care through the lens of UHC, the knowledge and evidence available to date suggest the following messages for policy makers:

(i) Provide quality eye care services according to population needs to improve service coverage and reduce inequalities. This requires assessments of total population eye care needs (i.e. both met and unmet needs);

(ii) Ensure that the cost of priority eye care interventions are included in service packages covered by pre-paid pooled financing;

(iii) Move towards IPEC.

The first two points are addressed in this chapter; the third, on IPEC and its role in eye care, is introduced in Chapter 6.

Quality eye care services according to population needs

Highlighting the importance of quality care is not new in the field of eye care; the quality of cataract surgery, for example, has at times been a concern. Thus, in recent years, greater emphasis has been placed on reporting the population-based measure of effective coverage of cataract surgery (see Chapter 4, Box 4.1) in order to understand both the accessibility and quality of cataract surgery within populations *(2, 3)*. Additionally, in the clinical context, there have been successful examples where the introduction of innovative tools to monitor the quality of cataract surgery has resulted in improved safety and outcomes (Box 5.1).

Collecting and reporting information on the met and unmet eye care needs are key for planning services as part of UHC.

Box 5.1 Monitoring the quality and safety of cataract surgery: a case example from Malaysia

The outcome of cataract surgery is dependent on surgeon skill and therefore monitoring competency is important to ensure patient safety and standard of care. In 2009, an innovative quality monitoring tool, the cumulative sum (CUSUM) analysis, was implemented in the ophthalmology programme in the MoH of Malaysia. The CUSUM is a statistical process control tool that objectively assesses that outcome of consecutive cataract surgery performances over time with reference to predetermined outcome standards.

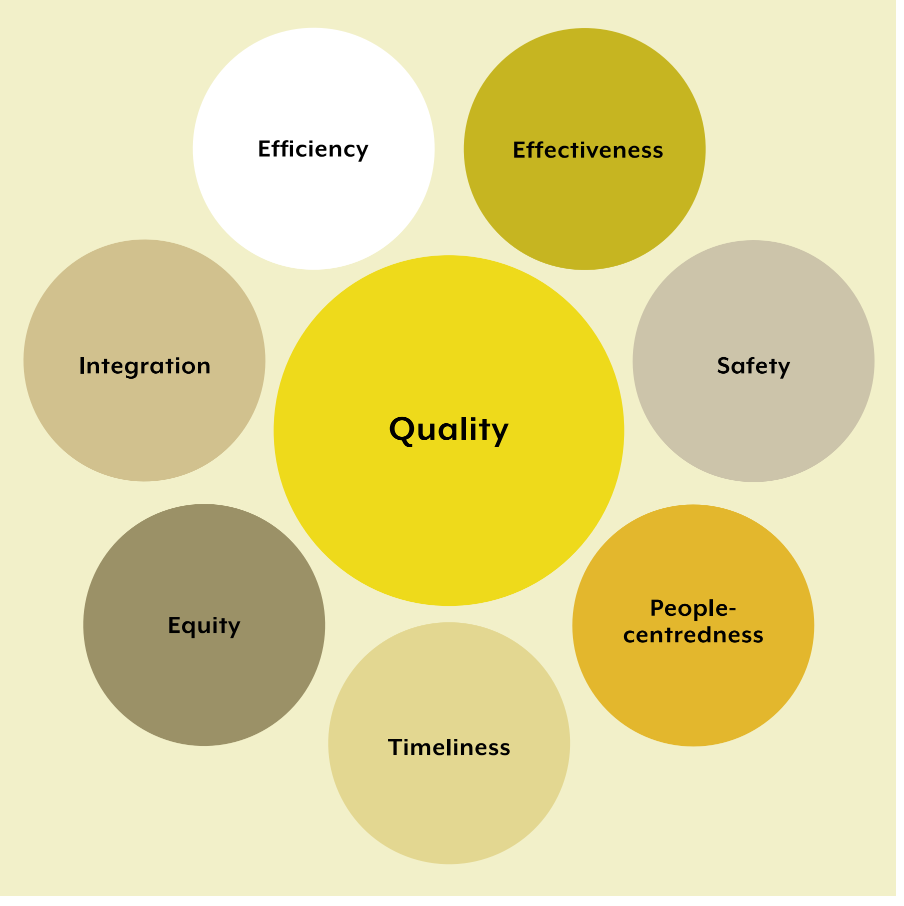
To date, CUSUM has been applied to close to 1300 ophthalmic trainees and consultants in all hospitals in the MoH of Malaysia (estimated to provide 50-70% of all cataract surgeries in the country) for the occurrence of posterior capsular rupture and a post-operative best-corrected visual acuity of worse than 6/18. If trainees CUSUM charts display an unacceptable level of performance, their supervisors provide feedback and impose closer monitoring of subsequent surgeries.

Evidence of impact of this strategy is available. Between 2007 and 2017, the rate of posterior capsular rupture reduced from 4.2% to 2.4%. During a similar period, a modest improvement in the proportion of patients who had a post-operative visual acuity outcome of 6/18 or better was also observed (96.1% (2007) vs. 97% (2016)).

As demonstrated in Box 5.2, many different characteristics need to be taken into consideration to provide high-quality health services. This will require a more deliberate focus on the quality of eye care services from policy makers in countries. High-quality health services are now generally understood to involve the right care, at the right time, responding to the service users' needs and preferences, while minimizing harm and resource waste. The measurable characteristics essential to quality health-care services include being effective, safe, and people-centred; to realize the benefits, they should also be timely, equitable, integrated and efficient (Fig. 5.1) *(4)*. An example of how these characteristics can be applied to eye care services for an individual is presented in Box 5.2.

An assessment of the state of the quality of health care requires consensus on the definition and measurement of indicators for quality at a national level, and needs to be comparable across countries. Therefore, for the eye care sector to move forward, output and outcome indicators need to be defined. In addition, structural measures of quality of eye care for service delivery (inputs), including equipment, human resources, incentives and organizational characteristics, will be required (see Chapter 6, Fig. 6.2).

Figure 5.1 Elements of health-care quality in the context of eye care *(5)*



Box 5.2 Example of how the elements of health-care quality can be applied to eye care services for an individual

Consider Julie, a woman in her sixties who lives with her husband in a rural location. She was diagnosed with type 2 diabetes mellitus 2.5 years ago and has since attended regular diabetes check-ups at the primary care centre. Her blood sugar levels are currently well controlled with medication. During the past few months, Julie has noticed a gradual reduction in her vision; however she attributes this to "normal" changes associated with ageing. Today, she presents to the primary care centre for the routine assessment of her diabetes. Her vision is also checked, and it is noted that Julie has reduced visual acuity in both eyes; her right eye being worse than her left. She is immediately referred to the local eye care provider where she is diagnosed operable cataracts. A thorough retinal examination does not reveal signs of sight-threatening diabetic retinopathy.

The following points illustrate the high-quality care that Julie would receive within the framework of the seven key elements of quality.

- **High-quality care for Julie is people-centred:** the care Julie receives would respect her preferences, needs and values. Julie may understandably be worried and ask many questions. The health-care workers attending her would listen to her questions and concerns, answer patiently, and provide both oral and written information about all aspects of treatment tailored to her needs. The health-care services would be located near to where Julie lives, and she should only be required to travel a further distance for her cataract surgery.
- **High-quality care for Julie is equitable:** the services received by Julie, including the timing of services, would not vary according to her personal demographics (e.g. gender, race), the geographical location in which she resides, or her socioeconomic status.
- **High-quality care for Julie is effective:** the care Julie receives would be based on scientific knowledge and evidence-based guidelines *(6)*. Julie would be reassured that she would receive evidence-based care and that a systematic process would be followed. She would be informed that her cataract surgery should be successful in achieving the desired visual outcome, and that any residual post-operative refractive error or other complications that may impact on vision (i.e. posterior capsular opacity) would be addressed in a timely manner.
- **High-quality care for Julie is safe:** the care Julie receives would minimize harm, including preventable surgical complications and medical errors (e.g. wrong lens implant). Clear guidelines to prevent infections (e.g. endophthalmitis) and medical errors would be in place in the health facility. A thorough review of her medications and allergies would be made, and clear instructions would be given as to how to care for her eye after cataract surgery and when to return for post-operative assessment. In order to minimize the potential for non-attendance at postoperative and subsequent follow-up visits, a specific, identifiable point of contact may be assigned to Julie. Full consideration would be given to the prevention and management of any potential increased risks of surgery related to her diabetes (i.e. post-operative macular oedema); Julie would undergo detailed retinal examination post-operatively to check for signs of

progression of diabetic retinopathy and, if necessary, treatment would be based on clinical guidelines *(7)*.

- **High-quality care for Julie is timely:** Julie's care would keep to a minimum any delays in the provision of services. Timely cataract surgery would be important to allow Julie to function effectively and to maintain adherence to her prescribed diabetic medication regimen. Additionally, it would be important for surgery to be undertaken before the lens opacities obscure the view of her retina, thereby prohibiting assessment of diabetic retinopathy. With proper planning, Julie would not have to experience long waiting times during post-operative follow-up visits. Contact with other health providers involved in her care, such as those required for routine diabetic retinopathy examinations, would be managed by an efficient patient flow system for scheduling or modifying visits and for notifying patients of projected waiting times.
- **High-quality care for Julie is integrated:** the care Julie receives across facilities and providers would be coordinated. Following cataract surgery, she would continue her regular diabetes check-ups at the primary care centre so that her diabetes could be managed. Arrangements would be made for her to undergo regular monitoring of her retina to check for signs of diabetic retinopathy progression; the timing of this would be based on clinical guidelines *(7)*. A social worker would be available to help connect her with the required services.
- **High-quality care for Julie is efficient;** the care Julie receives would avoid a waste of resources. In order to prevent repetition and waste of resources, each of her health providers would be able to track the results of her previous examinations and procedures via an electronic medical record system. Her care would be provided by a cohesive team, with each member working on tasks that match their competencies.

Beyond understanding and monitoring quality, data on population needs for eye care are essential for planning eye care services as part of UHC. These data can best be derived from population-based surveys. As discussed in Chapter 6, to strengthen data collection, these surveys need to be an integral part of HIS.

As outlined in Chapter 4, population-based surveys not only need to provide information on both met and unmet needs for eye care, they must also allow for disaggregated results for subpopulations, such as women, ethnic minorities and indigenous groups. This information should drive eye care planning to reduce inequalities. Overall, priorities should be determined based on population needs; and should not be determined on an ad-hoc basis according to non-transparent factors such as the visibility of certain conditions, a professional's scope of practice or the priorities of development partners or funding bodies. Examples of initiatives introduced to reduce gender inequality are presented in Box 5.3 and Box 5.4.


IS DEAD

Community consultations also provide an important source of information on the eye care needs of populations *(1)*. Consultations are a concrete way in which the public can be engaged in the development of national health plans that, ultimately, affect them, and where they can provide feedback. These consultations improve accountability and transparency and increase the sense of ownership and engagement of the population – especially marginalized groups – transforming them into active stakeholders. This is particularly relevant to eye care, given that some marginalized groups are unequally impacted by eye conditions and vision impairment, and also because eye conditions, in general, are common and have a well-demonstrated impact on individuals over their life course.

Box 5.3 Reducing gender disparities in service uptake by pastoral communities in Kenya

The Coordinated Approach to Community Health (CATCH)[2] project builds on trachoma initiatives to ensure that eye conditions, including cataracts and refractive error, could be diagnosed at trachoma screening clinics, and patients referred and treated. In Kenya, the project predominantly targets poor and marginalized pastoral communities in arid and semi-arid areas.

In these communities, women often experience additional cultural barriers in accessing health services. To address this, CATCH employs strategies to target women, including training female Community Health Workers (CHWs) to mobilize women to attend eye camps, and to engage women who have successfully undergone eye surgery as "Ambassadors of Hope". Women are targeted at strategic locations (e.g. maternal health clinics), and eye screening is carried out at common meeting areas such as water points and markets. Direct targeting also involves door-to-door screening.

By taking services out to remote areas with no health facilities, CATCH enables those women seeking care to remain in their environment, thus causing less interference to their daily responsibilities. Where services are available in a static health facility only, CATCH provides transport to facilitate logistics and reduce costs.

CATCH Kenya achieved a high level of participation of women from the beginning of the project. In the first year, 54.3% of people screened at the CATCH camp were women; this had risen to 58.7% in the third year. The percentage of women receiving surgery for cataracts followed a similar trend. The exception was in the provision of spectacles for reading, where the number of men was consistently higher. Some women perceived spectacles to be for reading only, and as most could not read, had minimal need for these. The demand for spectacles by women increased, possibly because women realized their use for seeing near objects and working with handicrafts. By the third year, half of the spectacles distributed in CATCH camps were to women, which was an encouraging development.

2 District Comprehensive Eye Care (DCEC) project is funded by Seeing is Believing, Standard Chartered Bank's global community investment programme.

Box 5.4 Gender disparities in uptake of cataract surgical services in Khyber Pakhtunkhwa province, Pakistan

In Pakistan, cataracts are the major cause of blindness, despite being treatable with a straightforward and cost-effective surgery. A Rapid Assessment of Avoidable Blindness (RAAB) survey undertaken in the Khyber Pakhtunkhwa province[3], revealed that prevalence of blindness caused by un-operated cataract was 6.5% in women above 50 years of age, compared to 2% in men; and the cataract surgical coverage for women was considerably lower than for men (75% versus 94%).

To explore the reasons for the lower uptake of cataract surgeries by women, focus group discussions were held with female health workers and beneficiaries. These identified cost and logistics of travel as major barriers to accessing services. Many women did not have access to family finances to pay for surgery and travel costs. Women also had less access to information about treatments, due to lower literacy rates, and many saw cataracts as an inevitable consequence of ageing.

Strategies were introduced to target women and make services in Khyber Pakhtunkhwa more gender-sensitive. Partnering hospitals have introduced gender-focused patient satisfaction surveys, and the number of female eye care workers will be increased. To strengthen the referral chain, more female health staff and paramedics will be trained to screen and refer women to hospitals, and female mid-level eye care staff will be trained in partnership with the Pakistan Government. Awareness and information about free cataract surgeries will be spread to better target female audiences including partnerships with women's organisations and audio and video messages on media networks.

Preliminary data shows encouraging trends and it is expected that these strategies will progressively increase the proportion of women accessing cataract services over the three years of the project. The output targets have been discussed with implementing partners and will be closely monitored.

3 Sightsavers' District Comprehensive Eye Care (DCEC) project is funded by Seeing is Believing, Standard Chartered Bank's global community investment programme.

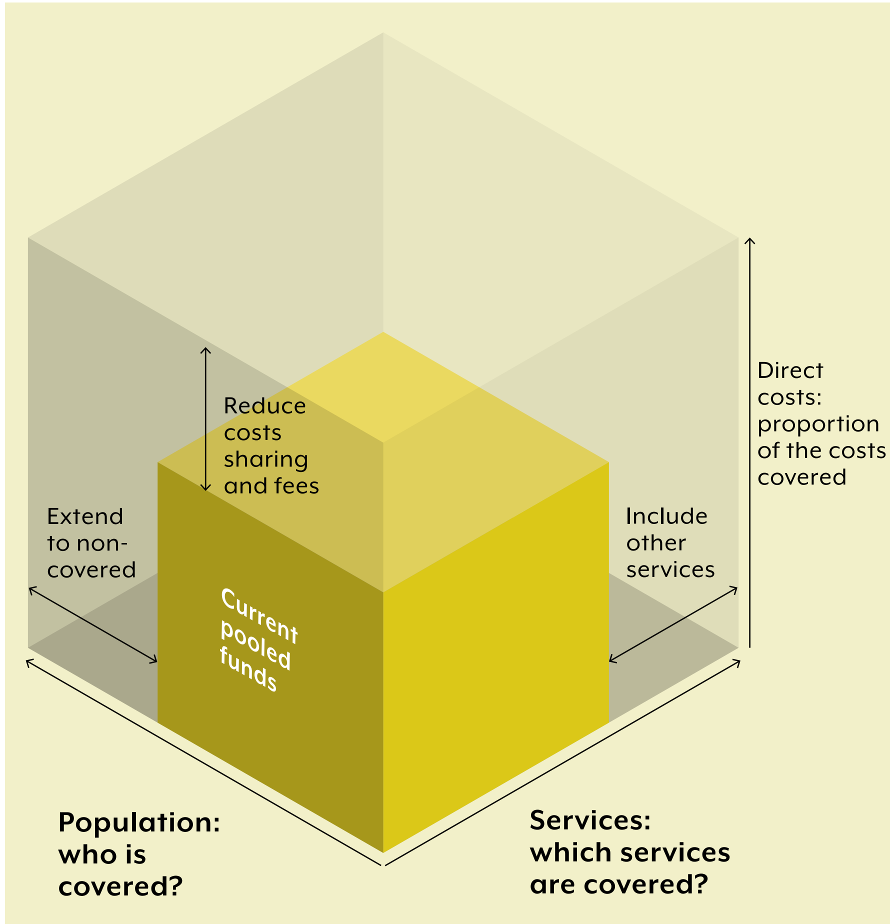
Ensuring that costs are not a barrier to eye care

Protection against financial hardship means ensuring that the cost of eye care does not expose the user to catastrophic expenses.

As outlined in Chapter 2, the costs of attending eye care services pose a significant barrier to access and can severely limit the well-being and life opportunities for individuals, and their families. An important component of UHC for eye care, therefore, is that all people obtain the eye care services they need without risking financial hardship from unaffordable out-of-pocket payments *(8)*.

In general, and as suggested by the 2014 report of the WHO Consultative Group on Equity and UHC *(9)*, to achieve UHC, countries need to advance in three dimensions (Fig. 5.2). First, priority services need to be expanded; secondly, more people need to be covered; and thirdly, out-of-pocket payments need to be reduced *(1)*. In addressing these dimensions, countries need to make important choices including: which services should be covered first; who should be prioritized; and how can out-of-pocket payments be shifted towards prepayment. For example, should interventions, such as the provision of spectacles, be prioritized over interventions needed for a smaller proportion of the population, such as trachoma? Should interventions for eye conditions that affect children be prioritized and included early on in the package, or should they be postponed for a later stage when more resources will be available? Is it possible to effectively work with NGOs for a limited period of time in order to increase the volume of certain interventions, such as cataract surgery?

Figure 5.2 Dimensions of universal health coverage *(1)*



When selecting services, it is useful to adopt three categories of priority: high, medium, and low. Classification of services into these three categories should be based on locally determined criteria, which may include cost-effectiveness, priority to those who are financially worse off (equity), and financial risk protection. When deciding on which services to expand, a useful starting point is, again, cost-effectiveness estimates, integrating these with concern for the financially worse off, and other criteria, such as safety, and health system capacity. The specification and balancing of these criteria need to be guided by robust public deliberation and participatory procedures.

The eye care sector is well positioned to engage in an evidence-based dialogue given that many eye care interventions are highly cost-effective and feasible to implement *(10-13)*. When deciding on extending population coverage for a given set of services, low-income groups, rural populations, and other disadvantaged (in terms of services or health) groups should be prioritized.

Health care is funded by a range of sources, including government budgets, social health insurance agencies, and households. While the median out-of-pocket spending on health represents less than 20% of total health spending in high-income countries, it accounts for more than 40% in low-income countries *(14)*. Out-of-pocket spending is a barrier to accessing health services, especially for those who are poor, and can be a substantial financial burden on those who use the services and their families. Out-of-pocket payments for health services push 100 million people into extreme poverty every year *(14)*. To improve access with financial risk protection, countries should therefore shift from out-of-pocket payments towards mandatory prepayments with pooling of funds. While this may be difficult for some countries, precedence should always be given to high-priority services and disadvantaged groups, including those who are poor. In the case of insurance and other mandatory arrangements for prepayments, countries should ensure that the inability to pay is not a barrier to coverage.[4]

A package of eye care interventions is needed to facilitate the integration of eye care into the health sector and UHC to effectively meet population needs.

To facilitate the choices that countries must make when implementing UHC, WHO is developing an online data repository detailing WHO-recommended interventions and their resource implications. The repository is intended as a global resource to facilitate discussions at country level around what services to provide within health benefit packages. The database will contain information on service delivery implications, health workforce requirements, essential medicines and devices, with links to overall WHO recommendations and guidelines. The global database will be accompanied by extensive guidance on how to carry out a country local contextualization processes to drive country impact, building on existing WHO tools – such as the WHO OneHealth Tool (Box 5.5) – and further expanding existing guidance. The repository will include information on a recommended package of eye care interventions (Box 5.6). The enhanced access to evidence and recommendations, and the accompanying country level tools, will support MoH in planning, budgeting, and integrating eye care interventions to their national health services packages and policies, according to population needs and available resources, and thus, ultimately contribute to moving forward the agenda of eye care as part of UHC.

Box 5.5 The OneHealth Tool

The OneHealth Tool is a software tool designed to inform national strategic health planning and costing in low- and middle-income countries.

The OneHealth Tool considers the demands on the health system, whether from a health-system-wide perspective or a programme-specific perspective. It provides a single framework for planning, costing, impact analysis, budgeting and financing of strategies for all major diseases and health system components. The tool is prepopulated with defaults for disease prevalence and incidence; intervention protocols for promotive, preventive and curative care; and prices of drugs, supplies and equipment – all of which can be changed by the user.

Outputs from an application can help planners answer the following questions:

- What would be the health system resources needed to implement the strategic health plan?
- How much would the strategic plan cost, by year and by input?
- What is the estimated health impact?
- How do costs compare with estimated available financing?

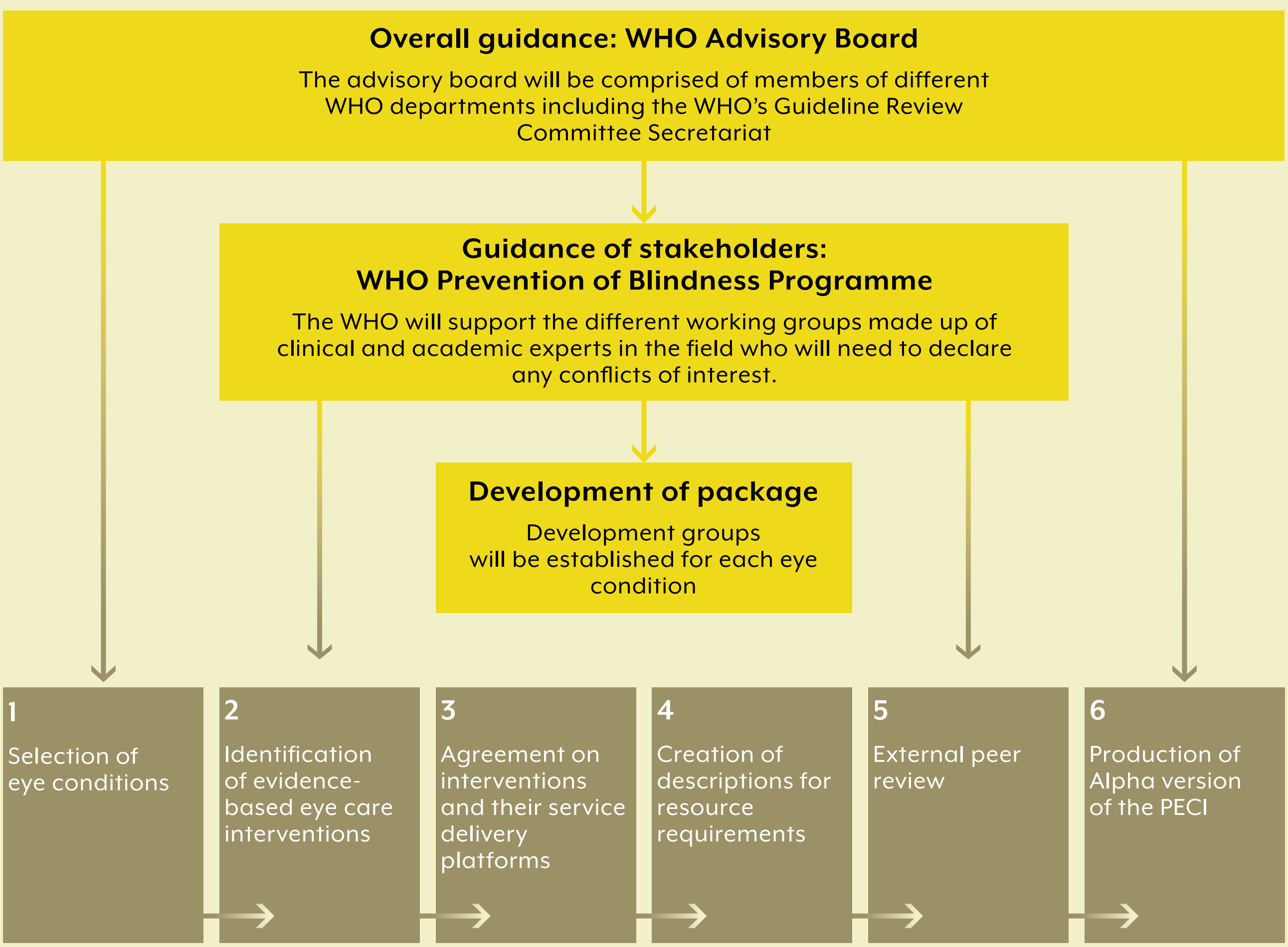
The tool is designed for use by experts involved in national health planning, including government health sector planners, disease-specific programme planners, NGOs, donors, UN agencies, researchers and consultants. Since its release in 2012, the OneHealth Tool has been applied in more than 40 countries.

Interventions for eye care will be added to the OneHealth Tool in 2020.

Box 5.6 Development process of the package of eye care interventions

WHO is developing a package of eye care interventions to facilitate the integration of eye care into the health sector and into UHC. The package will provide a set of evidenced-based and cost-effective interventions including the resource requirements for those interventions such as assistive products, equipment, medicines, consumables and workforce competencies.

The process of developing the package starts with selecting a range of priority eye conditions based on global epidemiological data and proposals from experts in the field. For example, if glaucoma is one of the conditions selected, working groups, comprising clinical and academic experts in the field, will then identify evidence-based interventions for glaucoma by drawing on a range of sources including high-quality clinical practice guidelines and systematic reviews. Following this, a professional working group from each world region will engage in a three-step process towards developing a list of interventions for glaucoma. Once the list has been confirmed, working group members will agree on the appropriate service delivery platform for each intervention (i.e. primary, secondary of tertiary). Finally, the resources required for each intervention will be defined and the final package will undergo a thorough peer review process.



Adapted from: Rauch A, Negrini S, Cieza A. Toward strengthening rehabilitation in health systems: methods used to develop a WHO package of rehabilitation interventions. Archives of physical medicine and rehabilitation. 2019.

Some countries, such as Cambodia, Kenya, Mali and Morocco, have recently taken significant steps towards implementing UHC, including eye care, despite significant resource constraints. For example, Cambodia has already established their priority eye care interventions within the context of their essential package of health services (Box 5.7). Despite this, it remains that a considerable number of countries globally do not include eye care services as part of UHC – of 29 countries (59% low-income or low- to middle-income) that completed the WHO ECSAT between 2014 and 2016, more than 20% reported that health insurance schemes did not cover any eye care services; several other countries reported that eye care services were only minimally covered.

Box 5.7 The inclusion of eye care in health sector strategic plans: a case study from Cambodia

In Cambodia, the MoH has adopted a robust process to inform eye care service planning. Since 2008, eye care has been routinely included as a priority in the Cambodian national health strategic plans. In 2015, the MoH commenced development of the current health plan (2016–2020). The planning process included projecting the estimated costs of activities and targets within the strategic plan, in order to inform priority setting and resource mobilisation. As part of this activity, costs associated with providing eye care services were estimated.

This process required defining the resources, or inputs, associated with eye care, estimating the average cost for priority interventions, and projecting the total number of these priority interventions that needed to be provided each year, as well as the costs associated with running the overall programme, including activities such as monitoring and evaluation. This process enabled the MoH to assess the resources needed to meet national targets for eye care which informed the development of the national eye care plan (National Strategic Plan for Blindness Prevention and Control 2016–2020).

The national plan includes comprehensive objectives that cover many aspects of strengthening health systems, such as workforce requirements. It also provides a high degree of detail, specifying activities, outputs, time frames, responsible agencies, targets, indicators and associated costs.

In summary, the provision of good quality eye care, in accordance with population needs, reduces health inequalities; however, reliable information about population needs are essential. UHC requires that each country expands priority eye care services; that more people are covered; and that the costs of eye care will not expose individuals to catastrophic out-of-pocket expenses. WHO is currently developing a package of eye care interventions that, in combination with other tools – in particular, the OneHealth Tool – will support countries in meeting these challenges.

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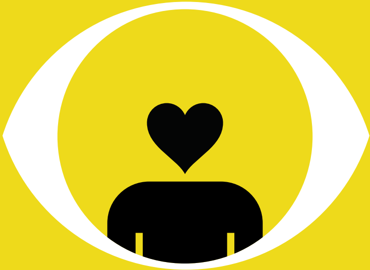
Chapter 6

Integrated people-centred eye care



Integrated people-centred eye care provides a continuum of health interventions that address the full spectrum of eye conditions, according to people's needs and throughout their life course.

The implementation of integrated people-centred eye care requires four strategies:

1. Empowering and engaging people and communities;
2. Reorienting the model of care;
3. Coordinating services within and across sectors; and
4. Creating an enabling environment

Building on WHO's existing Framework on integrated people-centred health services *(1)*, IPEC is defined as services that are managed and delivered so that people receive a continuum of health interventions covering promotion, prevention, treatment and rehabilitation, to address the full spectrum of eye conditions according to their needs, coordinated across the different levels and sites of care within and beyond the health sector, and that recognizes people as participants and beneficiaries of these services, throughout their life course.

Achieving IPEC requires four strategies

WHO's commitment to the Framework on integrated people-centred health services has been adapted to eye care because, as described in Chapter 4, the challenges facing health services that motivated their development, are characteristic of the eye care sector: eye care services are inequitably distributed, of unequal quality and poorly integrated across related health programmes and sectors; and these services are often provided by an uncoordinated and, at times, unregulated workforce. Furthermore, there is a lack of integration of eye care related information in HIS. IPEC has the potential to overcome these challenges and to facilitate approaches to service delivery that respond to emerging health challenges in the eye care sector, including unhealthy lifestyles, ageing populations, and the need to address a range of noncommunicable eye conditions.

Achieving IPEC by adapting the Framework of integrated people-centred health services to eye care, requires the following four strategies:

1. Empowering and engaging people and communities;
2. Reorienting the model of care;
3. Coordinating services within and across sectors; and
4. Creating an enabling environment

This chapter provides high-level guidance on these four strategies for the eye care sector. It is acknowledged that countries may have different starting points when implementing these strategies, depending on the maturity of their health system, resources available, and local needs.

Empowering and engaging people and communities

As identified in the Framework for integrated, people-centred health services, empowering and engaging individuals, families, communities and care-givers to become effective users of health services requires the provision of opportunities, skills and resources, and advocating for a reformed health system to enhance health care experience and outcomes. Underserved and marginalized populations must be reached in order to guarantee universal access to quality services that are co-produced according to their specific preferences and needs. In order to tailor these requirements to address eye care, countries must build targeted policy options and interventions.

Health literacy is an essential component of empowering individuals and their families; it is crucial for the effectiveness of many eye care interventions and, more generally, for compliance *(2-4)*. The vast majority of cases of vision impairment caused by common eye conditions, such as diabetic retinopathy and glaucoma, are avoidable with early detection and timely intervention *(5-7)*. However, a large proportion of individuals remain undiagnosed because these conditions are often asymptomatic in their early stages; awareness of the importance of regular eye examinations among high-risk populations (such as the elderly and those with diabetes) is largely lacking. In some situations, inadequate knowledge of the availability of services, along with a tendency for individuals to consider reduced vision as part of the normal ageing process, can also lead to poor outcomes *(8)*. Furthermore, even when individuals are aware having an eye condition, poor eye health literacy can limit adherence to medications and routine assessment *(3, 4, 9)*.

The eye care sector needs to increase its efforts to provide sound, and effective education.

The eye care sector needs to increase its efforts to provide sound, and effective education. Strategies for engagement and empowerment can occur at the individual or specific population group level. One of the examples of effective community empowerment in the field of eye care is the community-directed treatment with ivermectin as a preventive intervention for onchocerciasis (Box 6.1).

Box 6.1 Community-directed treatment with ivermectin (CDTI) for the prevention of onchocerciasis

Onchocerciasis is transmitted by blackflies and can lead to vision impairment and blindness. Ivermectin is an effective and safe medicine for the mass treatment of onchocerciasis. Mobile teams of health workers faced a range of challenges with initial methods of ivermectin distribution including low coverage, minimal community involvement, and high costs to the health system. In 1995, the African Programme for Onchocerciasis Control (APOC) was established. APOC's strategy of community-directed treatment with ivermectin (CDTI) was formally adopted in 1997 after a multicountry study demonstrated that community-directed treatment was a feasible, effective and sustainable approach *(10)*.

CDTI focuses on empowering communities to take responsibility for ivermectin delivery – i.e. putting the community in charge of deciding how, when and by whom ivermectin distribution should take place. This strategy has resulted in substantial achievements for onchocerciasis control in Africa:

- Over 142 million people received treatment for onchocerciasis by the end of 2017. In the same year, fourteen countries reported having achieved 100% geographical coverage.
- Over 17 million disability-adjusted life years (DALYs) have been averted *(11)*.
- By 2005, the prevalence of infection had declined to about 73% of its level prior to CDTI and was estimated to decline to 14% of the pre-CDTI level by 2015.

Outreach eye care services have been shown effective in increasing service coverage in hard-to-reach communities

Eye care literacy must target raising awareness of the availability of vision rehabilitation. Many individuals with severe vision impairment and blindness that cannot be treated may live in situations of dependency because they or, their family and community, are unaware that rehabilitation services can be provided to achieve independence. If these services are unavailable, health literacy can engage people to advocate for them.

Information technology has introduced new solutions to overcome the challenge of timely information exchange and health education, the eye care sector must take advantage of this technology. For example, routine mobile text messages have been shown to increase the rate of attendance at eye care facilities *(12)*. The use of electronic health records, and ensuring that patients have easy access to their records, are additional ways of strengthening communication between eye care patients and providers *(13-15)*.

Outreach eye care services have been shown effective in increasing service coverage in hard-to-reach communities, enabling greater responsiveness to local community needs *(16, 17)*. When implementing eye care programmes, it is important to ensure that they are an integral part of the health sector service delivery system, both for sustainability and because new avenues of delivery of eye care interventions can then be explored. For example, eye care interventions, such as screening, can be integrated into the delivery systems of existing health interventions, such as for vaccines.

To simplify access to care for underserved populations, rapid technological change also has potential. As described in Chapter 4, telehealth is employed effectively in the field of eye care. Telehealth supports people in rural and remote settings who are otherwise underserved *(18, 19)*, and facilitates care coordination between care providers (Box 6.2).

To simplify access to care for underserved populations, rapid technological change has potential.

Box 6.2 Engaging rural and remote communities through telehealth: a case example from Lions Outback Vision, Australia

Teleophthalmology, particularly real-time video consultations, holds great potential to improve the accessibility of services in countries where geography, population and workforce distribution make it difficult to provide specialist eye services outside of major cities. Ophthalmology is particularly suited to telemedicine due to its high reliance on imaging for the diagnosis and management of ocular disease.

Overview of the service

Since 2011, Lions Outback Vision (LOV) – part of the Lions Eye Institute – has provided a state-wide teleophthalmology service, linking patients in rural and remote communities of Western Australia to consultant ophthalmologists based in the state capital city, Perth. The distance from Perth to the furthest community in the service is over 3000 km. Referrals to the service originate from optometrists working within regional communities, with rural hospital emergency departments and general practitioners often referring patients for optometric review. The service provides a combination of "store-and-forward" and "real-time" telemedicine links, with results of ophthalmic investigations being sent to the treating ophthalmologist prior to a real-time video consultation. Patients who require ophthalmological clinical assessment or surgical management are provided with an appointment at an upcoming LOV outreach visit.

Following advocacy and a demonstrated evidence base, government health insurance rebates were introduced for optometrists and general practitioners to support telehealth in 2015. There are minimal additional infrastructure costs, given that ubiquitous platforms such as Skype or FaceTime are used for video-consultations. Currently, 94% of all optometrists in the regions visited by LOV actively participate in the telehealth service. The provision of both an online booking system and availability for "on call" urgent assessment reduces barriers for uptake.

Key outcomes

Following implementation of the LOV telehealth service, the non-attendance rate at outreach service visits has decreased from approximately 50% to 3%. Patients also demonstrated very high satisfaction with the telehealth service.

The provision of video consultations that include patient consent, and booking, for surgery has resulted in several key outcomes. Firstly, it has eliminated the "wait for the waiting list", where patients can wait for up to one year for a public service outpatient appointment prior to being placed on the waiting list for surgery. In addition, the efficiency and impact of outreach ophthalmology services has improved significantly – a higher proportion of primary eye care is being appropriately managed by optometry with less duplication of services, and a marked increase in surgical management by LOV ophthalmologists.

Reorienting the model of care

Reorienting the model of care involves ensuring that efficient and effective health-care services are designed and provided by means of innovative models of care that prioritize primary and community care services and the co-production of health. The Framework on integrated people-centred health services defines service priorities based on life-course needs, and building a strong PHC. Strong PHC, with integrated eye care, is important since eye care involves both the delivery of interventions aimed at the individual through primary care (e.g. diabetic retinopathy screening) and population-based interventions, such as the provision of vitamin A supplementation.

Strengthening eye care in PHC requires adequate funding, appropriate workforce training, a sustainable workforce.

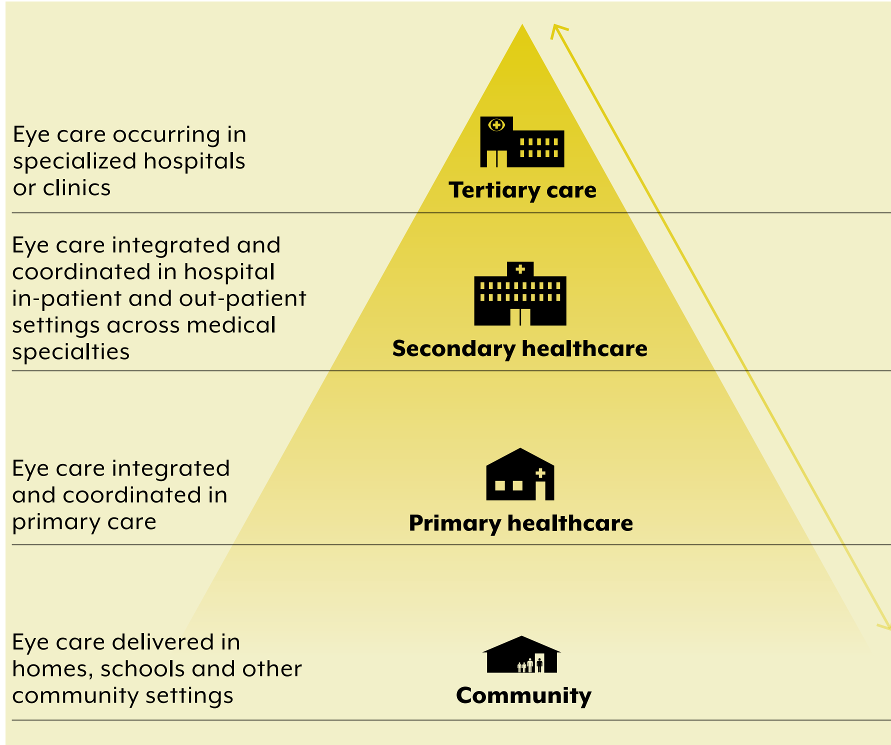
During this century, building or strengthening PHC, and integrating eye care, is vital for a number of reasons. First, PHC makes it possible for health systems to adapt and respond to changing population demographics and lifestyle changes and the increasing number of people with eye conditions and vision impairment. Secondly, PHC promotes access to services across the continuum of care, while facilitating the use of health promotive and preventive services that are often more cost-effective than treatment services. Finally, PHC is critical to sustainably addressing other key components of UHC such as (i) reducing household expenditure by emphasizing population-level services that prevent eye conditions and promote early detection and timely referral; and (ii) reaching remote and disadvantaged populations through a focus on community-based services that are provided as close as feasible to people's homes *(20)*.

Strengthening eye care in PHC requires adequate funding, appropriate workforce training, a sustainable workforce *(20)*, coordination with other services and sectors, and effectively-planned referral systems. When sufficiently resourced, PHC can meet a large number of people's eye care needs throughout their life course, and can raise awareness of the importance of maintaining eye health and eye disease prevention behaviours, such as facial cleanliness to prevent active trachoma. Services for diabetic retinopathy *(21)*; refractive services for adults; case-finding of common eye conditions, such as cataract; and the diagnosis and management of some common eye conditions that do not typically cause vision impairment, such as conjunctivitis, can also be provided within PHC. In situations where more specialized services are required – for example after the detection of cataracts or diabetic retinopathy – primary care can facilitate referrals and coordination across providers and care settings. Given that many of the eye conditions that can be effectively managed at the primary care level are often conditions for which people seek eye care in secondary and tertiary eye care settings *(22-26)*, building both a strong primary care and a community delivered eye care can increase the efficiency of eye care services. Of note, building eye care that is integrated into primary care does not place any less importance on secondary and tertiary levels. To address population eye care needs, all levels of care (Fig. 6.1) with integrated and effective referral pathways are needed.

There is no single path countries can follow to achieve a strong primary care that includes eye care. That path may include the integration of primary eye care services within PHC centres, achieved through enhanced supervision and the training of existing staff (Box 6.3), or the adoption of standalone primary eye care services, either in fixed facilities or through mobile units. While technical guidance is not yet available on how to move forward in building a strong primary care specific to the eye care sector, the documents, *A vision for primary health care in the 21st century (20)* and the WHO Technical Series on *Safer Primary Care (27)* offer useful resources.

There is no single path countries can follow to achieve a strong primary care that includes eye care.

Figure 6.1 Integrated eye care at all service delivery levels



Box 6.3 Integration of eye care into primary care through training of existing staff: a case example from Tajikistan

Primary care doctors (*Family doctors*) in Tajikistan undergo a professional training programme based on the national training curriculum. Until recently this curriculum did not include eye and ear care and, as a result, these services were not provided at the primary care level throughout the country. In 2018, with technical and financial support from WHO, a new hearing and vision module was included in the national training curriculum for primary care doctors and nurses. During this period WHO also led awareness raising efforts directly with health workers, to increase acceptance and adherence to the content of the training materials.

At present, forty-eight trainers of primary care doctors and nurses have been trained to educate and demonstrate on how to provide essential ear and eye care. Basic equipment, such as ophthalmoscopes, is also being provided to the trainers (primary care facilities). As a result of these efforts, primary care doctors and nurses within Tajikistan have already identified at least a thousand people with previously undiagnosed ear and eye conditions that require treatment. In 2019, WHO will continue to monitor the results of this intervention; in addition, WHO will fundraise to further strengthen the capacity of eye and ear care at the tertiary level through additional trainings and the provision of sector specific surgical and other diagnostic equipment.

Coordinating services within and across sectors

Without good continuity and coordination of eye care, patients are at risk of suboptimal outcomes

The coordination of services focuses on improving the delivery of care by aligning and harmonizing processes and information; it does not necessarily require merging structures, services, or workflows. The Framework on integrated people-centred health services identifies three strategic approaches: coordinating individuals; coordinating health programmes and providers; and coordinating across sectors. All are fundamental to achieving IPEC.

Coordination of care for the individual involves a range of strategies including case management, team-based care, and efficient referral systems. These strategies contribute to the experience of continuity of care, whereby the process of care is experienced as discrete, coherent and interconnected, and in line with individual needs and preferences. Without good continuity and coordination of eye care, patients are at risk of experiencing fragmented, poorly-integrated care from multiple providers, often with suboptimal outcomes and high levels of dissatisfaction due to failures of communication, inadequate sharing of clinical information and duplication of investigations *(28)*. Crucial to the ongoing success of care coordination is smooth information flow, available to all care providers *(28)*. There are recent examples of the successful implementation of well-coordinated and efficient referral networks in the field of eye care *(29)*.

Coordinating care for the individual presupposes the coordination of all related programmes and providers, and involves bridging information gaps across levels of care as well as ensuring continuity in administration and funding. Additionally, coordinating care may require developing networks of health service delivery at the regional or district levels, integrating existing vertical programmes into the health systems (as described later in Box 6.7), and providing financial and other incentives.

Coordination also encompasses the creation of linkages between eye care and other health programmes, such as neonatal care, noncommunicable diseases, rehabilitation and occupational health and safety. Successful eye care interventions are being delivered through other health services such as retinopathy of prematurity screening through neonatal care *(30)* (Box 6.4).

Box 6.4 Addressing retinopathy of prematurity in neonatal care: a case study from Argentina

By the end of the 1990s, retinopathy of prematurity was estimated to be the cause of at least 50% of vision impairment in children *(31)*. In response, the MoH established a multidisciplinary working group to address the problem. Starting in 2004, training was provided to over 70 neonatal care units in preventing, diagnosing and treating the disease. In 2007, national legislation mandated formal integration and continuation of these services, and ongoing funding was subsequently made available through the MoH. An important feature of the changes was the commitment to ongoing collection of data to monitor progress and identify areas for improvement.

Since the programme was established, a 38% reduction has been observed in the number of children with the disease, and a 65% reduction in those who acquired vision impairment as a result *(30)*.

Since health care requires multiple actors, both within and outside of the health sector, coordination of care crosses all sectors, including social services, finance, education, labour, and the private sector. Coordination is primarily a governance and leadership issue, necessitating strong leadership from MoH to coordinate intersectional action. The provision of vision rehabilitation services, for example, requires intersectional partnerships with the social sector so that during the rehabilitation process, the social and labour sectors can offer other support for inclusion and social participation. Coordination with the education sector for the inclusion of programmes for the early identification of eye conditions could also be a solution. To this end, there are a range of guidelines for school based eye care services in different regions and countries. There are also examples of eye care interventions, such as refractive error screening, provided through the education sector *(32)* (Box 6.5).

Given the growing demands for eye care services, effective options for public–private partnerships need to be explored as a means of providing affordable eye care. Examples already exist of such partnerships that have contributed to providing access to eye care services to vulnerable communities, including those for the provision of spectacles (Box 6.6) and interventions for trachoma control in low-resource settings *(39, 40)*.

Box 6.5 School eye health programme in Baltimore: a case study from the USA

School-based vison screening often provides the first indication of a possible vision impairment or eye condition in children *(33)*. In the United States of America it has been found that many children who fail a screening do not access recommended follow-up care *(34, 35)*. In response, there has been an increased focus on delivering follow-up eye care through schools, particularly in lower socioeconomic neighborhoods *(36-38)*.

In the city of Baltimore, a public–private partnership is underway to deliver school-based eye care to children between the ages of around 4–14 years. The Baltimore City Health Department partnered with Johns Hopkins University Wilmer Eye Institute and School of Education, Baltimore City Public Schools, Vision To Learn and the private sector to create *Vision for Baltimore*, a city-wide programme providing school-based eye care. Johns Hopkins has been conducting a study alongside the programme to monitor the impact of the intervention on academic performance.

Since the project was first established in 2016, more than 35 000 children in public schools have undergone screening, with approximately 12 000 failing the screening test. Of the 6000 children whose parents permitted a follow-up eye examination, approximately 80% were prescribed spectacles.

Key lessons learnt to date include the importance of building an alliance between health workers and educators to build a school-based model. Partners involved in the project are now exploring ways to increase the number of families that give permission for the eye examination, as well as how to promote the wearing and retention of spectacles.

Box 6.6 Public–private partnerships for the provision of spectacles in Pakistan, Sri Lanka and South Africa

Public–private partnerships in eye care can be beneficial, especially where provision of public services is weak, under-resourced, or inefficient. Examples from Pakistan, Sri Lanka and South Africa demonstrate the positive outcomes of the collaboration between the MoH and local NGOs or INGOs for the population in need of refractive services and spectacle provision.

In Pakistan, for example, the Layton Rahmatulla Benevolent Trust (LRBT) Hospital, the largest NGO and eye care provider in the country – in collaboration with the Government of Pakistan and the Brien Holden Vision Institute – is currently establishing optical stores in secondary and tertiary hospitals. Optical stores are embedded in the LRBT hospital system. When patients are prescribed spectacles by optometrists or ophthalmologists, they can purchase them from the optical stores located next to the hospital pharmacies. Since October 2016, LRBT has provided spectacles to 18 619 individuals, of whom 68% are women and girls, mostly from low- to middle-income communities.

In Sri Lanka, The Brien Holden Vision Institute, in partnership with Ministry of Health & Nutrition, established four vision centres and optical shops to provide refractive and optical services to semi-urban and rural communities. Vision centres have been established in communities where public eye care facilities were not available and work in close coordination with the health department. Patients who need surgical services or are diagnosed with complex eye health anomalies are referred to secondary and tertiary eye care facilities in public or private sectors. To date, 94 782 people (57% women and girls) have been provided with spectacles by optometrists at the vision centres.

In the KwaZulu-Natal and Gauteng provinces of South Africa, The Brien Holden Vision Institute, has been providing a spectacle delivery service in collaboration with Department of Health since 2007. Since the start of the collaboration, over 165 000 spectacles have been dispensed, 26 000 of them at no cost.

Besides the provision of spectacles to those in need, these partnerships have also contributed to the increased awareness of the need for marginalized communities to have access to eye care and for local management and monitoring support for the optical services.

However, several challenges remain in spectacle supply in these countries. Availability of qualified and skilled human resources (optometrists and optical technicians) is a significant challenge, as there is no standard training programme available in many countries. The sector remains unregulated, and local legislation and relevant authorities are insufficient. The informal sector has contributed to the growth of optical street vendors, and online eyewear sellers place pressure on the smaller optical chains and independent vision centres/optical shops.

Creating an enabling environment

The first step is the integration of eye care into health system planning

The three previous strategies described, will only become operational if enabling environments are in place. WHO has conceptualized an enabling environment as six building blocks of a health system. Of these six blocks, one – the delivery of eye care services – is the focus of IPEC. Although the remaining five – leadership and governance; information; health workforce; health financing; and medicines and health technologies (including assistive products) are all relevant to realizing IPEC, given the specific challenges faced by the eye care sector outlined in Chapter 4, this section will elaborate on leadership and governance, health workforce and information only.

Leadership and governance

Good governance involves transparent leadership that is inclusive, participatory and makes the best use of available resources and information to ensure the best possible results. It is sustained by mutual accountability among those who make and implement policy, managers, providers and the users themselves. The responsibilities of governance in health care involves developing a strategic plan, then managing accountability and overseeing the plan's implementation. In most countries, the strategic plan is a national health plan that sets out the core values of the health system; the health outcome targets to be achieved; a concrete action plan for achieving these targets; and a time frame for doing so. In order to carry out strategic planning, leadership is needed to create a coalition of stakeholders – across sectors of government and civil society – to collect information on inputs, service access, coverage and health outcomes, and to create regulations and formal standards of practice *(41)*.

The importance of strategic planning in the health sector cannot be overstated. Unfortunately, as discussed in Chapter 4, for most countries, eye care is often omitted in national health strategic plans, or only briefly mentioned *(42)*. To realize IPEC in countries, however, the inclusion of eye care in national health strategic plans is of utmost importance for ensuring that issues of eye care service provision are systematically addressed and fully integrated. The first step is the integration of eye care into health system planning, in terms of overall targets and a concrete plan of how to achieve these targets. Secondly, at an operational level, integration will contribute to eye care interventions being included across all service delivery platforms and other health areas. Finally, integration increases the likelihood of eye care being considered within broader human resources, assistive products and health technology procurement and infrastructure plans.

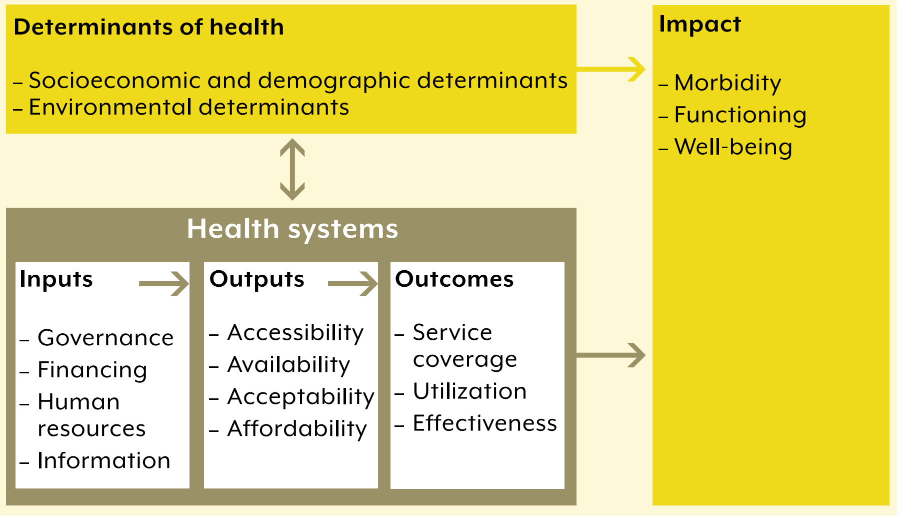
Even in situations where a health system is not the main provider or financer of specific eye care services, the role of governance will remain important. Regulatory frameworks for the engagement of state, private and non-state actors in the eye care sector need to be in place to reduce risking the development and sustainability of equitable eye care services. When a strong regulatory framework exists and is enforced, privatization, commercialization and marketization have the potential to increase universal access to eye care services. Market forces alone, however, will not automatically lead to equitable and universal access. For this reason, equitable access to eye care must remain a constant goal and supported by a strong regulatory framework *(43)*.

Information

Key components of the information building block include the development of a health information and surveillance system; the use of standardized tools and instruments; and the collation and publication of national and international health statistics. These components make possible the generation and strategic use of information and research on health and health systems.

A well-functioning HIS ensures the production, analysis, dissemination and use of reliable and timely health information by health policy, management and clinical decision-makers on a regular basis. As presented in Fig. 6.2, a HIS covers three domains: health determinants; health systems capacity and performance (inputs, outputs and outcomes); and health status (impact). To collect information from these three domains, a HIS must generate population and facility-based data from censuses, civil registration data, population surveys, individual records, and service and resource records by means of standardized tools and instruments. The system also needs to have the capacity to synthesize information in the form of sensitive, valid and reliable indicators and the ability to promote the knowledge that arises from those indicators. An example of a development of a well-integrated HIS in the field of eye care is described in Box 6.7.

Fig. 6.2 Domains of measurement of health information systems



Adapted from Framework and standards for country health information systems, second edition. Geneva: World Health Organization, 2012.

Box 6.7 Integrating vertical programmes into the health system and development of well-integrated health information system: a case study from Oman

In the 1970s, active trachoma was endemic in Oman with an estimated prevalence of 70–80% among the Omani population of all ages. To address this public health issue, the MoH of Oman, with assistance from WHO, started a vertical “trachoma control programme” with a focus on the treatment of trachoma in schools. The programme resulted in a substantial decline in the incidence of the disease to 7% by 1983. Due to its success, the MoH expanded the programme and included two additional vertical components, namely the screening of school children, and community screening in endemic regions.

In 1991, the programme was further expanded, renamed the “Eye health care programme” and was integrated into the national health care plan of Oman, focusing on six priority eye conditions: cataract, trachoma, glaucoma, corneal diseases, diabetic retinopathy and refractive error. A national eye care committee was established to plan the implementation and evaluation of activities relating to eye care in Oman. Eye care services were provided through school health services and the MoH PHC institutions to provide comprehensive eye care.

At the end of the 1990s, the national health care plan prioritized eye care under the “specific disease control programmes” targeting certain priority health problems. All health-care providers were trained in the prevention and management of eye conditions, as well as the recording and evaluating of eye care activities. Eye care services were expanded to cover all service levels of the health system, including community, primary, secondary and tertiary levels. In 2014, a national eye strategy with an action plan for 2016–2020 was developed by the MoH in collaboration with WHO and the Eastern Mediterranean Regional office of the International Agency for the Prevention of Blindness in accordance with the WHO Global Action Plan 2014–2019 towards universal eye health.

The centralized HIS is an important part of the eye care services in Oman. Oman initially started an “Eye health care monthly reporting system” in all health institutions under the MoH and the school eye care. The aim was to collect monthly data on all vision screenings of preschool-aged children at primary health care institutions, as well as referrals to secondary or tertiary level institutions, and statistical data on the eye care of both outpatients and inpatients from secondary and tertiary centres. As an example, primary eye care institutions would report new cases of cataract, whereas secondary and tertiary institutions with ophthalmic units would collect information on, and report monthly, all new cataract cases – which were linked with visual status and ICD 10 codes – and all cataract cases managed. With regards refractive error, secondary and tertiary centres would report all new cases as per the ICD codes, whereas cases of refractive error detected at school screenings would be recorded and reported to the regional school refractionist as early as possible so that further prompt action could be taken.

In 2008, a National Electronic Health Information Management System (the Al Shifa 3+ system) was launched in Oman. Al-Shifa is being used across all levels of health-care units with the MoH acting as the reporting body. The system was designed to meet the needs of all levels of management, including data capturing and entering and the delivery of essential information needed by the middle management for the day-to-day operations of the health-care facility. The system also acts as a data warehousing and business intelligence suite which provides national level health-care statistics on key performance indicators on different eye conditions (e.g. cataract, refractive error, childhood blindness, diabetic retinopathy, etc.) accumulated from all facilities. These statistics enable the central level administration to analyse the overall functioning of health-care centres across the sultanate, and prepare the national annual report which serves to address gaps in the eye care programme, plan future activities, and strengthen the eye care programme.

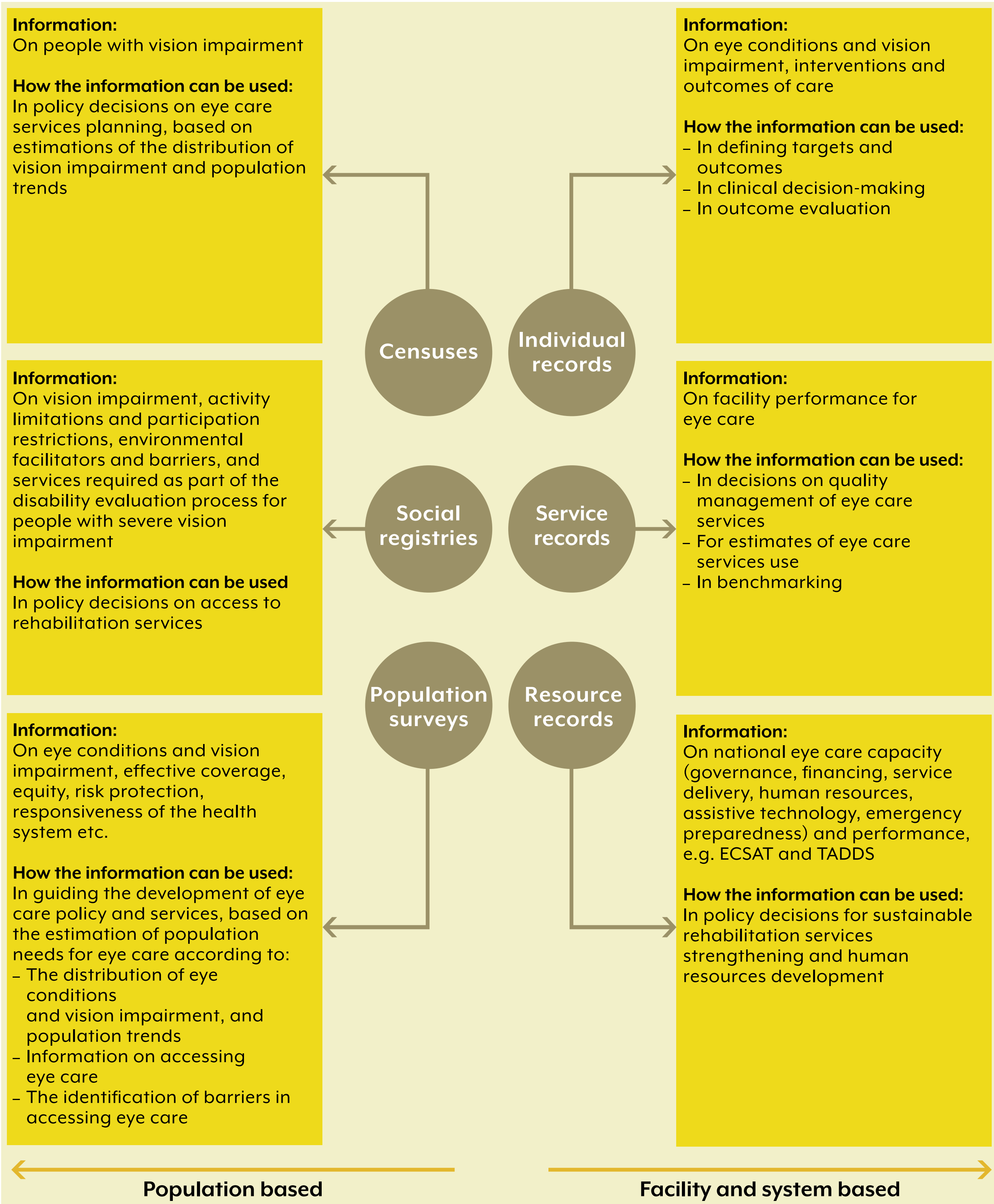
In addition to the data collected from the health information management system, Oman uses other sources of information on eye conditions and vision impairment. These include national population-based surveys, such as the National Blindness Survey and National Glaucoma Survey, MoH annual statistical reports, and various national studies on eye care.

Implications

Since the introduction of the eye care services in Oman, the prevalence of trachoma among the Omani population has declined from almost 80% in 1970s, to a level where, in 2012, Oman became the first country to be internationally certified as trachoma free. In addition, the rate of blindness among those aged 40 years and older declined by approximately 30% between 1996 and 2010. There has been a marked increase in the number of ophthalmologists in the country, and eye units are now provided with modern technology and computerized case record systems. Through strengthening the referral system, especially at the primary care level, all patients with diabetes are now referred to ophthalmic units for screening for diabetic retinopathy. The eye care programme at primary, secondary and tertiary care units have been strengthened by analysing the institutional, as well as regional, reports on eye care activity through the health information management system.

Applied to eye care, and with the objective of moving towards IPEC, a HIS should collect information about i) the determinants of eye conditions; ii) the capacity of the health system to provide eye care services as well as its performance, and in particular, how well existing eye services address population needs in an equitable manner; and iii) the numbers of individuals with eye conditions and vision impairment, and their level of functioning and well-being. As illustrated in Fig. 6.3, to achieve these goals, tools and instruments need to be in place to collect population, facility and system-based data. These data generate information about eye care, as well as facilitating research on eye conditions and vision impairment, including research on health systems and eye care. Fig. 6.3 also shows the information generated by each of the sources and how the information can be used.

Figure 6.3 Data sources and information for decision-making and strengthening eye care



Adapted from Framework and standards for country health information systems, second edition. Geneva: World Health Organization, 2012.

As discussed in Chapter 4, the eye care sector can build on its many successes, including the frequent implementation of population-based surveys to generate prevalence estimates of certain eye conditions and vision impairment and the use of standardized tools, such as ECSAT and tool for assessment of diabetes and diabetic retinopathy (TADDS). Nevertheless, as discussed earlier, the eye care sector needs to ensure that the data generated in population surveys will support eye care service planning and provide information on the numbers of people of all ages with vision impairment whose needs have been met, as well as those whose needs have not yet been met. This ensures that comparable information is collected and reported on important service coverage indicators.

The eye care sector needs to ensure that surveys will provide information on the numbers of people of all ages with vision impairment whose needs have been met, as well as those whose needs have not yet been met.

Monitoring the implementation of IPEC also requires strategic, systematic planning to identify which information should be generated from what data sources (population-, facility- or system-based). Relevant indicators need to be developed. The eye care sector will only be able to report on interventions covering health promotion, prevention, treatment and rehabilitation; population needs; coordination of services; and the perspectives of eye care users, when comprehensive population-based facility and systems based data are collected. Information from these sources is required for the realization of IPEC.

Workforce

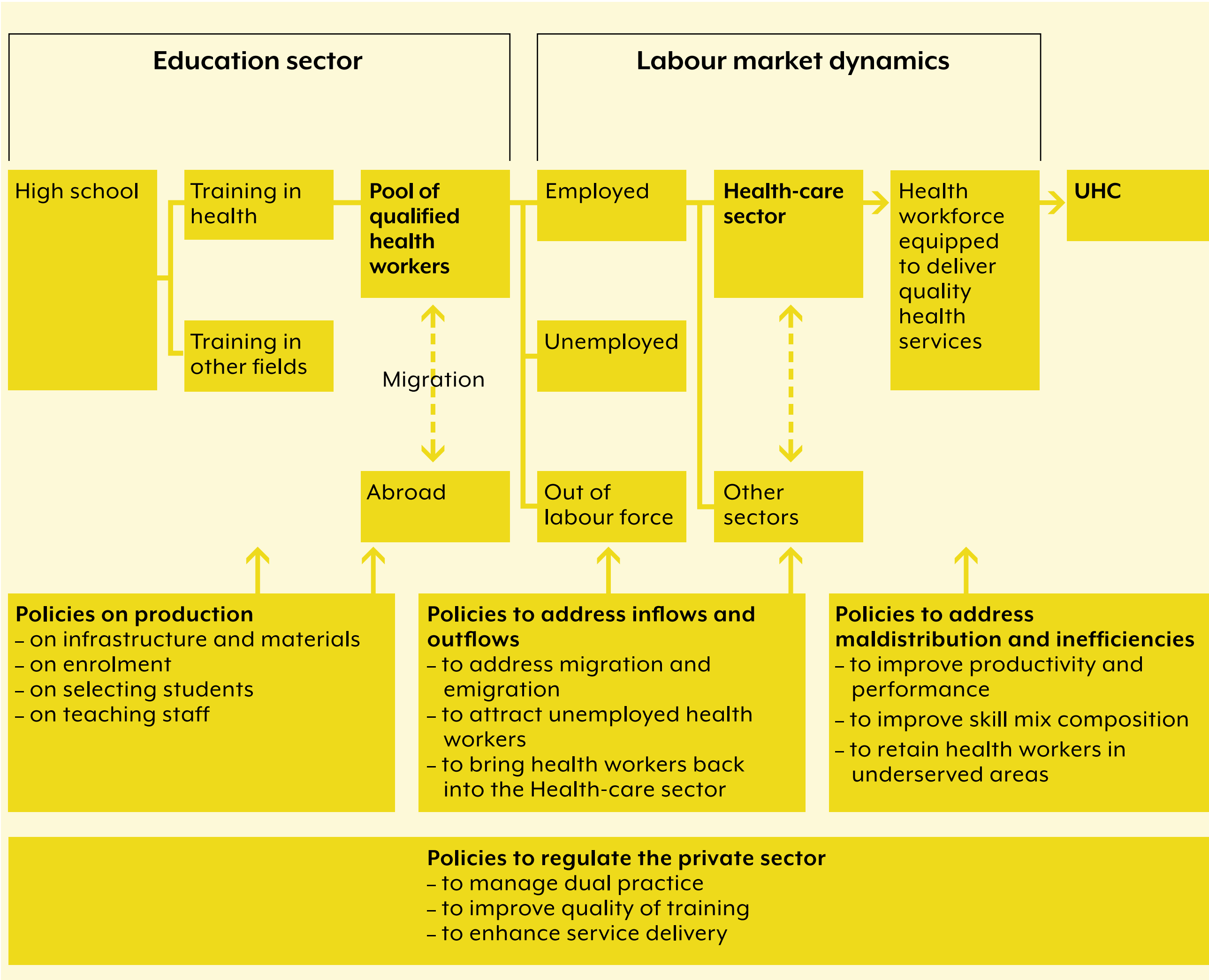
The realization of IPEC largely depends on the availability, accessibility, acceptability and quality of a health workforce and the services they provide. As outlined in Chapter 2, there are, however, human resource challenges that include general shortages, maldistribution of workers, attrition, imbalances in skill composition and, at times, inadequate regulation *(44-48)*.

Until recently, the number of eye care workers per million population has been used as a guide in workforce planning. While this approach is relatively simple, it does not consider other determining factors, such as population structure, epidemiology, regulations and standards, the location of the current workforce and public demand *(49)*. It assumes that eye care is delivered by a pre-defined set of health workers only, such as ophthalmologists, optometrists or opticians, while in reality, eye care is delivered by multiple specialized and non-specialized actors, particularly at primary level. To address the challenges described in Chapter 4, and to realize IPEC in the context of UHC, the eye care sector, starting with professional organizations, will need to work closely with relevant policy-makers in countries responsible for developing policies to optimize the supply of health workers. IPEC will require comprehensive planning of the eye care workforce, inclusive of all health workers involved at the entry point of health care (primary care) and based on an in-depth analysis of the health labour market in general. The challenges of the health labour market are diverse, extending beyond the basic question of the density of health workers involved in eye care, to include, for example, inequity in the distribution of health workers, migration, and retention of workers. Some challenges are associated with policies and governance on health workforce; others, such as quality, availability and data use, relate to HIS. To tackle these challenges, WHO developed the global strategy for human resources for health: workforce 2030 *(50)*.

IPEC depends on the availability, accessibility, acceptability and quality of a health workforce and the services they provide.

The health labour market Framework presented in Fig. 6.4 provides an overview of the main forces influencing the dynamics of the health labour market that would impact on equitable access to quality health services and UHC *(49)*. Driving forces comprise multiple sectors, including those of education and labour. The education sector needs to ensure that sufficient health workers are trained with appropriate knowledge and skills; the labour sector needs to ensure that working in the areas of health is attractive, and that financial incentives and working conditions assure an appropriate distribution of health workers. Policies on education and labour strongly influence these factors. Realizing these factors requires the coordination of a broad range of stakeholders; MoH, education, public service, and economy and finance, and professional organizations will work together to guarantee the availability of health workers involved in eye care.

Figure 6.4 Health labour market framework and policy levers for achieving universal health coverage *(51)*



Adapted from: Framework and standards for country health information systems, second edition. Geneva: World Health Organization, 2012.

Countries need comprehensive assessments on the availability of health workers with skills in eye care.

To better understand the challenges facing the eye care health workforce, countries need comprehensive assessments on the availability of health workers with skills in eye care which requires investment in HIS. At the WHA in May 2016, and as part of the global strategy on human resources for health, Member States were urged to progressively implement the National Health Workforce Accounts (NHWA) *(52)*. WHO has developed overall guidance and a series of NHWA tools to improve, over time, the availability, quality and use of data through monitoring standardized indicators on health workforce. With improved data through NHWA, health labour market analysis can be conducted, and can facilitate the understanding of eye care workforce dynamics which involves the assessment of the supply and demand of health workers involved in eye care.

In general terms, the supply – i.e. the number of qualified health workers willing to work for the eye care sector – is determined by wages, working conditions, safety conditions and career opportunities. The demand for health workers is determined by the needs of the population and the demand for eye care services. There are, however, many dynamic factors that need to be considered when planning the eye care workforce. For instance, supply depends on the extent to which the private and public institutions are willing and able to pay for health workers involved in eye care to be employed in primary care centres, clinics, hospitals or other parts of the health system. Institutions also compete with each other on wage rates, budgets, provider payment practices, labour regulations and hiring rules. The eye care sector similarly competes with other health areas in attracting health workers.

It is vital to ensure that the eye care sector orients eye care workforce planning towards the primary care setting.

Health systems involved in eye care cannot deliver adequate services without addressing the role of the private sector in all aspects of workforce planning, from education to the labour market. These policies include regulations on staff training, service quality and dual practice, to ensure equitable access to quality health services for the entire population. Although, in many countries, it is difficult to determine the exact proportion of eye care delivered in the private sector, and of health workers engaged in dual practice, both are known to be high. However, there is little evidence as to whether this has positive or negative consequences for the availability of health workers involved in eye care or the quality of services. This lack of evidence should stimulate not only the development of policies specifically designed to regulate the private sector, but also health policy and system research in the field of workforce in the eye care sector.

When implementing IPEC, it is vital to ensure that the eye care sector orients eye care workforce planning towards the primary care setting. This not only requires ensuring that primary care personnel have the competencies required to provide eye care interventions – particularly those for early identification and referral to specialized eye care when required – but also for the development of policies to facilitate the coordination of health workers providing services at primary care level.

Realizing IPEC also requires a competency-based care approach to workforce planning. Competencies refer to the specific tasks an individual must be able to perform to a specified standard to qualify as a professional. Competences are needed for different interventions, and health workers with appropriate competences and skills will be required at each service delivery level. There are already examples where the eye care sector is moving towards competency-based planning approaches (Box 6.8). The WHO Regional Office for Africa has recently developed core competencies for the eye care workforce in the African Region to improve the distribution of skills in the eye team *(53)*.

Box 6.8 Competency-based eye care: an example from Fiji and Papua New Guinea

Small island developing states can find it challenging to develop and maintain cadres of specialist health-care workers. In the Pacific, The Fred Hollows Foundation, New Zealand developed a training programme to build eye care competencies for nurses and doctors.

The Pacific Eye Institute (PEI) was established in 2006 offering a Post-Graduate Diploma in Eye Care for nurses, and a Master of Medicine in Ophthalmology for doctors. The diploma for nurses has been specifically designed to ensure nurses have the competencies to respond to population eye care needs in the region, such as refraction and health promotion. In recognition of the increasing prevalence of diabetes in the region, a competency on screening, grading of images for diabetic retinopathy and referrals has recently been added to the curriculum.

The diploma is now offered in Fiji and Papua New Guinea, and around 150 nurses from 11 countries have completed the qualification, which is recognized by many governments in the region.

Innovative workforce approaches, such as shifting activities between health workers through role delegation, will be needed to address inefficiencies and enhance equity in the eye care service delivery *(54)*. Role delegation has the potential to expand the number of mid-level health-care workers that can safely provide clinical tasks, or key components of tasks, that would otherwise be restricted to higher level cadres such as ophthalmologists. Such a shift would require action on the continuous professional education and on educational accreditation mechanisms. If policies allowing the effective use of defined skills and competencies of the health workforce are enforced, a more rational distribution of tasks and responsibilities among health workers involved in eye care can be created to improve access and cost-effectiveness *(46)*. Some countries have already enabled mid-level health workers to deliver a range of eye care services, using these cadres, either alone, or as part of teams within communities and health care facilities at different levels of the health system *(55)*.

Finally, strengthening eye care delivery according to population needs through a strengthened eye care workforce can yield dual positive economic benefits: (i) it reduces the impact of eye conditions and vision impairment on populations and, thus, productivity can be increased; and (ii) it creates jobs, directly and indirectly, in the health workforce with skills to address eye care needs. The UN High-Level Commission on Health Employment and Economic Growth reported in 2016 that the health sector is one of the sectors with highest potential to economic growth *(56)*. Health workforce financing should therefore be seen as an investment and not as a cost.

Putting into effect IPEC and securing UHC will not be possible unless the inefficiencies of the eye care workforce are eliminated, adequate funding secured, and the productivity and performance of health workers improved. Health workforce policies are needed to address worker shortages and maldistribution. Such policies need to be tailored to individual country context and population eye care needs.

To achieve the goal of integrating eye care into UHC, the *World report on vision* proposes the adoption of IPEC – the integrated, people-centred approach to eye care service delivery. IPEC has the potential to address many of the key challenges to the effective delivery of eye care services described in the report: services that are fragmented, of unequal quality, and not effectively provided at the primary care level; an uncoordinated and, at times, unregulated workforce that leads to shortages and maldistribution; and poor integration of eye care information into HIS. IPEC promotes equity in the provision of services according to population needs, and is therefore crucial to progress in achieving the targets of the SDGs and UHC. Chapter 6 reviews the four strategies for achieving IPEC: empowering and engaging people and communities; reorienting the model of care towards primary care; coordinating services within and across sectors; and creating an enabling environment through enhanced governance and leadership, a sufficient and well-trained workforce, and improved HIS.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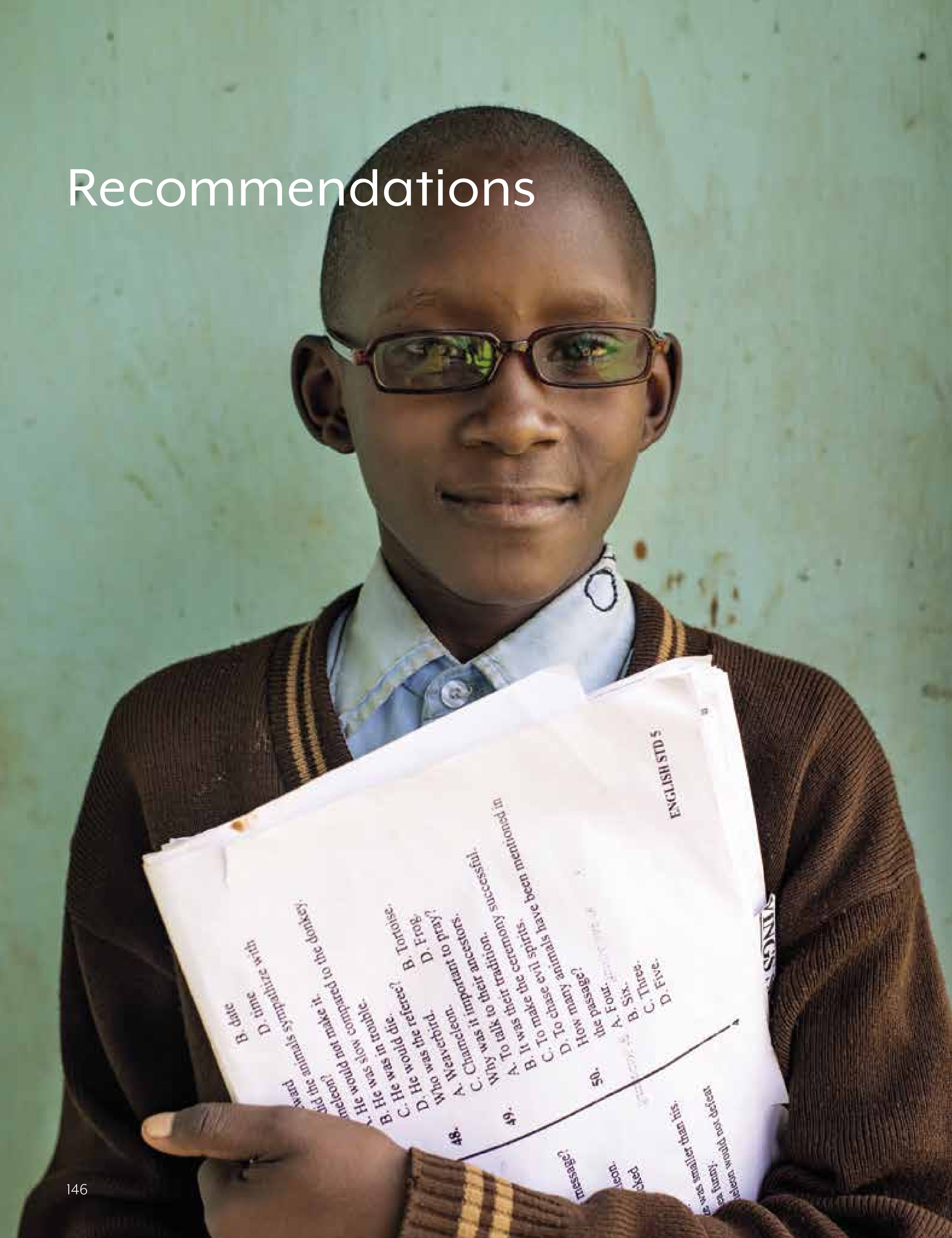
Recommendations



Making IPEC a reality

Globally, at least 2.2 billion people have a vision impairment, of whom at least 1 billion have a vision impairment that could have been prevented or has yet to be addressed. Population ageing, coupled with lifestyle changes, is leading to a dramatic increase in the number of people with eye conditions and vision impairment. In addition to urgently addressing this increasing coverage gap, health systems must sustain care for those whose needs are already being met. The extent of these met and unmet needs is currently unknown. However, sufficient evidence is available to act now; every country can take action, irrespective of the maturity of their health system or level of development.

Fortunately, eye care is an area of health care with highly cost-effective interventions for health promotion, prevention, treatment and rehabilitation to address the full range of needs associated with eye conditions and vision impairment across the life course. The benefits for the individual and society are significant. Addressing eye care needs also contributes intrinsically to progress towards UHC and the SDGs.

The *World report on vision* shows the substantial progress made during the past 30 years, thanks to concerted global advocacy and actions. Nevertheless, unmet needs remain: inequalities in coverage exist, and ensuring quality is a challenge. In the report, IPEC is proposed as an approach that ensures the delivery of eye care in adherence to universal health coverage.

To realize integrated people-centred eye care, each country or region needs to assess its current situation and context before mapping out specific next steps. Five global priority areas and recommended actions are identified:

1. Make eye care an integral part of universal health coverage

In order to eliminate inequalities in access to, and provision of, eye care services across the population, it is essential to plan these services carefully and according to the best available information about population needs, while ensuring quality. Until recently, the eye care sector has concentrated on reporting unmet needs. Effective planning of quality eye care services as part of UHC also requires information about ongoing and met needs and ensuring that the cost of priority eye care interventions does not expose the user to catastrophic expenditures.

Recommended actions are:

- Collecting and reporting information on the met and unmet eye care needs of the national population.
- Developing a package of eye care interventions to respond to population needs for strategic inclusion into the budgeting of UHC.
- Improving access with financial risk protection for priority eye care interventions, especially for low-income groups and other disadvantaged groups.
- Defining the desired outcomes of eye care interventions, for quality assurance, and reporting effective coverage.
- Defining input, output and outcome indicators to monitor the quality of eye care at the national level, and to make comparisons across countries.
- Ensuring that individuals with vision impairment or blindness that cannot be treated have access to high-quality vision rehabilitation to optimize functioning.

2. Implement IPEC in health systems

IPEC has the potential to overcome the challenges facing countries in providing access to priority eye care services – such as shortages of trained workforce, fragmented services and, at times, suboptimal quality outcomes – and in ensuring equitable access for all people. A health systems perspective is required, and recognition of the necessity to integrate services and respond to people's needs and preferences.

Recommended actions are:

- Integrating eye care into national health strategic plans.
- Strengthening eye care in PHC to improve access, and to adapt and respond to rapidly changing population needs, including the projected growth in the number of people with noncommunicable eye conditions.
- Increasing effective coverage of refractive error and effective coverage of cataract surgery – the leading causes of addressable vision impairment and blindness.
- Managing and delivering eye care services so that people receive a continuum of interventions addressing promotion, prevention, treatment, and rehabilitation across service delivery levels and sites.
- Reinforcing the coordination of eye care services in relevant programmes (e.g. diabetes, maternal child health, ageing); and sectors (e.g. social, education and labour).
- Ensuring that eye care workforce planning is an integral part of health workforce planning.
- Ensuring that health information systems include comprehensive information about eye care to identify needs; to effectively plan service delivery; and to monitor progress towards implementing IPEC and its impact at the population level.

3. Promote high-quality research

To sustain implementation of IPEC, high-quality implementation and health systems research is required, thus complementing existing evidence for effective eye care interventions. Moreover, studies analysing the costs and benefits of implementing the package of eye care interventions at the individual and societal level will be necessary. Eye care has a high potential of benefiting from technological advances; research is required to ensure such advances impact on clinical care and people's lives.

Recommended actions are:

- Supporting the creation of a global research agenda that includes health systems and policy research, and technological innovation for eye care that facilitate the development of a national research agenda.
- Promoting collaboration between researchers and ministries of health to ensure research is relevant to the national setting and to the implementation of IPEC.
- Creating or enhancing existing funding schemes for implementation and health systems research for eye care.
- Promoting return on investment studies to provide evidence on how investing in eye care secures health, social and economic return.
- Strengthening implementation research for scaling-up technological advances and task-sharing to ensure they rapidly benefit people with eye conditions and vision impairment.
- Encouraging governmental and private foundations in their support of research on innovative treatments and diagnostics both to eliminate blindness from eye conditions, and to eliminate eye conditions.

4. Monitor trends and evaluate progress

It is important to monitor the progress made towards implementing IPEC and its impact at the population level. This requires comprehensive information from health information systems on eye care and epidemiological data on eye conditions and vision impairment. Indicators and benchmarking are also required to evaluate progress toward implementation.

Recommended actions are:

- Strengthening national capacity to collect, analyse and use data on the burden and trends of eye conditions and vision impairment.
- Conducting periodic population surveys that include measurement of vision impairment, as defined in this report, and integrate variables relevant to eye care in general health surveys, ensuring that effective coverage of cataract surgery and refractive errors can be reported.
- Supporting the creation of a global indicators menu for eye conditions and vision impairment that facilitates the selection of national indicators and promotes cross-country comparisons.
- Defining how to, and periodically conducting, evaluations of the progress made towards implementation of IPEC.

5. Raise awareness and engage and empower people and communities

The public and individual communities – specifically underserved populations, such as women, migrants, indigenous peoples, and persons with certain kinds of disability – need to be made aware of the importance of early identification of eye conditions; the need to prevent and address vision impairment; and how they can be empowered to gain access to eye care services.

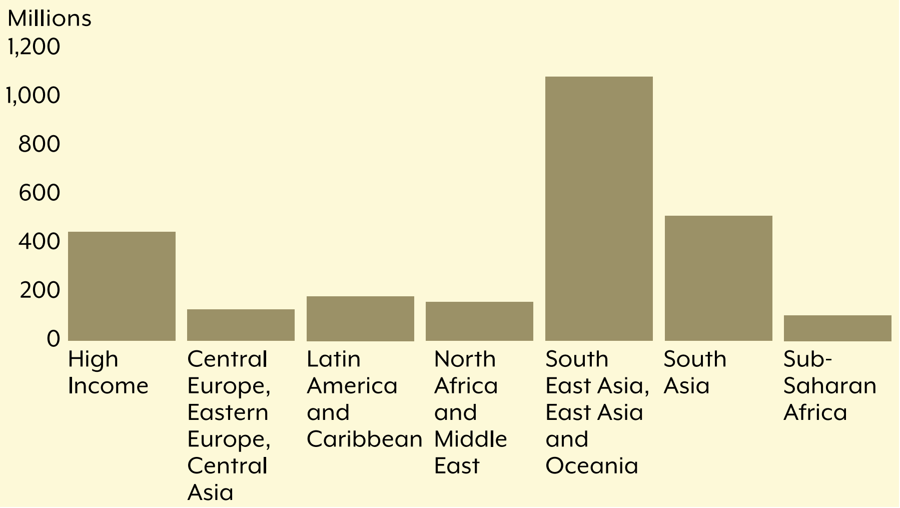
Recommended actions are:

- Raising awareness about the availability of effective interventions that address all eye care needs across the life course.
- Conducting public health campaigns that emphasize the importance of eye care.
- Engaging and empowering the public, specifically underserved populations, to be aware of their eye care needs and demand and seek eye care services.
- Engaging the education and labour sectors as partners in raising awareness about the importance of identifying eye conditions and accessing eye care services among students and employees.
- Raising awareness of the societal obligation to fulfil the rights of individuals with vision impairment and blindness that cannot be treated, to participate in society on an equal basis with others.

Annexes

Annex I: Regional comparisons of the numbers of people with selected eye conditions

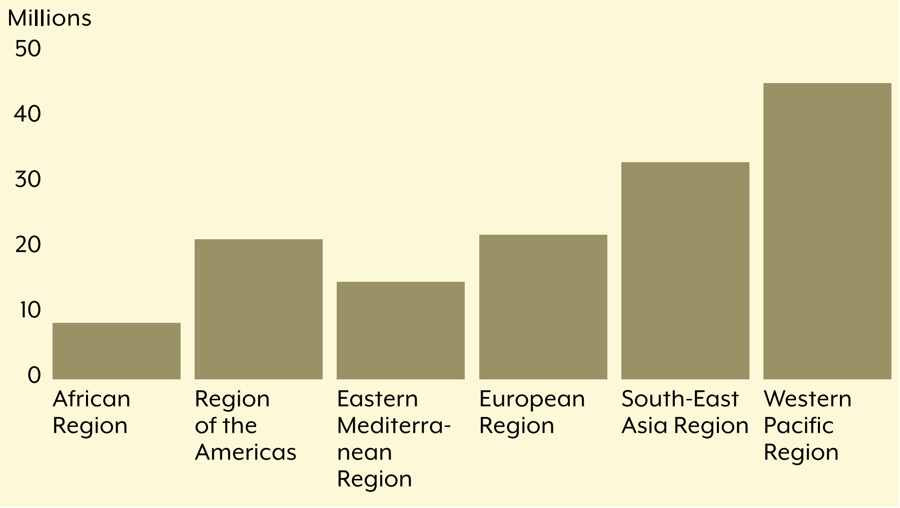
Fig. A1.1 Regional comparison of the total number of people with myopia*



* By Global Burden of Disease regions

Adapted from: Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. Ophthalmology. 2016;123(5):1036–42.

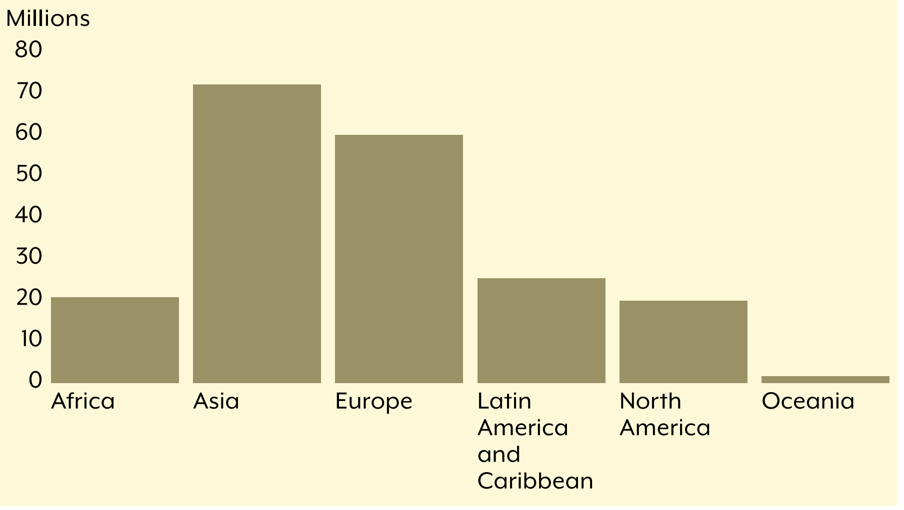
Fig. A1.2 Regional comparison of the total number of people with diabetic retinopathy*



* By WHO regions

Adapted from: World Health Organization. Global report on diabetes. 2016 and Yau J, Rogers S, Kawasaki R, Lamoureux E, Kowalski J, Bek T, et al. Global prevalence and major risk factors of diabetic retinopathy. Diabetes Care. 2012;35:556-64.

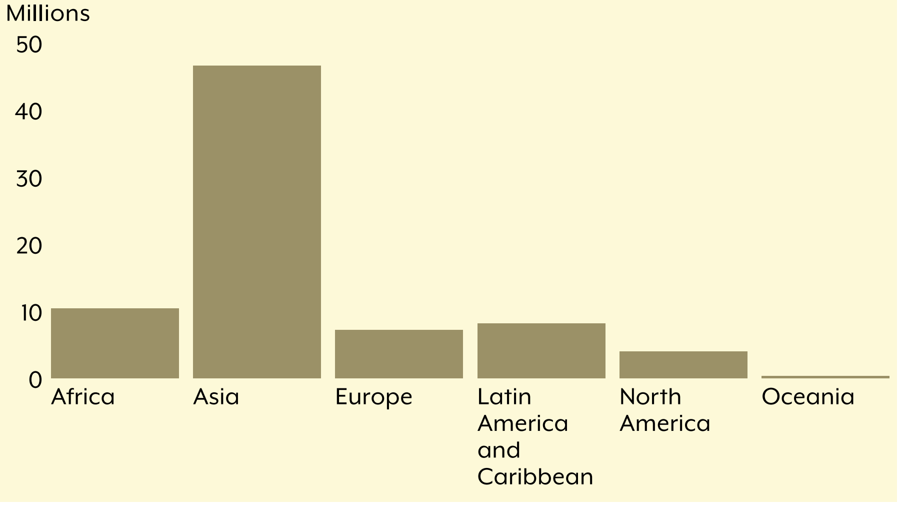
Fig. A1.3 Regional comparison of the total number of people with age-related macular degeneration*



* By United Nations' classification of macro-geographic continental regions

Adapted from: Wong WL, Su X, Li X, Cheung CM, Klein R, Cheng CY, et al. Global prevalence of age-related macular degeneration and disease burden projection for 2020 and 2040: a systematic review and meta-analysis. The Lancet Global Health. 2014;2(2):e106–16

Fig. A1.4 Regional comparison of the total number of people with glaucoma*



* By United Nations' classification of macro-geographic continental regions

Adapted from: Tham YC, Li X, Wong TY, Quigley HA, Aung T, Cheng CY. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. Ophthalmology. 2014;121(11):2081–90

Annex II: List of countries included in the regional comparisons of selected eye conditions and vision impairment presented in Chapter 2 and Annex 1 of this report

1. Distribution of glaucoma and age-related macular degeneration (United Nations' classification of macro-geographic continental regions)

Asia

Afghanistan; Armenia; Azerbaijan; Bahrain; Bangladesh; Bhutan; Brunei Darussalam; Cambodia; China; China, Hong Kong Special Administrative Region; China, Macao Special Administrative Region; Cyprus; Democratic People's Republic of Korea; Georgia; India; Indonesia; Iran (Islamic Republic of); Iraq; Israel; Japan; Jordan; Kazakhstan; Kyrgyzstan; Kuwait; Lao People's Democratic Republic; Lebanon; Malaysia; Maldives; Mongolia; Myanmar; Nepal; Oman; Pakistan; Philippines; Qatar; Republic of Korea; Saudi Arabia; Singapore; Sri Lanka; State of Palestine; Syrian Arab Republic; Tajikistan; Thailand; Timor-Leste; Turkey; Turkmenistan; United Arab Emirates; Uzbekistan; Viet Nam; Yemen.

Africa

Algeria; Angola; Benin; Botswana; British Indian Ocean Territory; Burkina Faso; Burundi; Cabo Verde; Cameroon; Central African Republic; Chad; Comoros; Congo; Côte d'Ivoire; Democratic Republic of the Congo; Djibouti; Egypt; Equatorial Guinea; Eritrea; Eswatini; Ethiopia; French Southern Territories; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Kenya; Lesotho; Liberia; Libya; Madagascar; Malawi; Mali; Mauritania; Mauritius; Mayotte; Morocco; Mozambique; Namibia; Niger; Nigeria; Réunion; Rwanda; Saint Helena; Sao Tome and Principe; Senegal; Seychelles; Sierra Leone; Somalia; South Africa; South Sudan; Sudan; Togo; Tunisia; Uganda; United Republic of Tanzania; Western Sahara; Zambia; Zimbabwe.

Europe

Åland Islands; Albania; Andorra; Austria; Belarus; Belgium; Bosnia and Herzegovina; Bulgaria; Croatia; Czechia; Denmark; Estonia; Faroe Islands; Finland; France; Germany; Gibraltar; Guernsey; Greece; Hungary; Holy See; Iceland; Ireland; Isle of Man; Italy; Jersey; Latvia; Liechtenstein; Lithuania; Luxembourg; Malta; Monaco; Montenegro; Netherlands; North Macedonia; Norway; Poland; Portugal; Republic of Moldova; Romania; Russian Federation; San Marino; Sark; Serbia; Slovakia; Slovenia; Spain; Svalbard and Jan Mayen Islands; Sweden; Switzerland; Ukraine; United Kingdom of Great Britain and Northern Ireland.

Oceania

American Samoa; Australia; Christmas Island; Cocos (Keeling) Islands; Cook Islands; Fiji; French Polynesia; Guam; Heard Island and McDonald Islands; Kiribati, Marshall Islands; Micronesia (Federated States of); Nauru; New Caledonia; New Zealand; Niue; Norfolk Island; Papua New

Guinea; Solomon Islands; Northern Mariana Islands; Palau; Pitcairn; Samoa; Tokelau; Tonga; Tuvalu; United States Minor Outlying Islands; Vanuatu; Wallis and Futuna Islands.

Latin America and the Caribbean
Anguilla; Antigua and Barbuda; Argentina; Aruba; Bahamas; Barbados; Belize; Bolivia (Plurinational State of); Bonaire, Bouvet Island; Brazil; Chile; Colombia; Costa Rica; British Virgin Islands; Cayman Islands; Cuba; Curaçao; Dominica; Dominican Republic; Ecuador; El Salvador; Falkland Islands (Malvinas); French Guiana; Grenada; Guatemala; Guadeloupe; Guyana; Haiti; Honduras; Jamaica; Martinique; Mexico; Montserrat; Nicaragua; Panama; Paraguay; Peru; Puerto Rico; Saint Barthélemy; Saint Kitts and Nevis; Saint Lucia; Saint Martin (French Part); Saint Vincent and the Grenadines; Sint Eustatius and Saba; Sint Maarten (Dutch part); South Georgia and the South Sandwich Islands; Suriname; Trinidad and Tobago; Turks and Caicos Islands; United States Virgin Islands; Uruguay; Venezuela (Bolivarian Republic of).

Northern America
Bermuda; Canada; Greenland; Saint Pierre and Miquelon; United States of America.

2. Distribution of trachoma; vitamin A deficiency; diabetic retinopathy (WHO regions)

African Region
Algeria; Angola; Benin; Botswana; Burkina Faso; Burundi; Cameroon; Cabo Verde, Central African Republic; Chad; Comoros; Côte d'Ivoire; Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Eswatini; Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritania; Mauritius; Mozambique; Namibia; Niger; Nigeria; Democratic Republic of the Congo; Rwanda; Sao Tome and Principe; Senegal; Seychelles; Sierra Leone; South Africa; Togo; Uganda; United Republic of Tanzania; Zambia; Zimbabwe.

Region of the Americas
Antigua and Barbuda; Argentina; Bahamas; Barbados; Belize; Bolivia (Plurinational State of); Brazil; Canada; Chile; Colombia; Costa Rica; Cuba; Dominica; Dominican Republic; Ecuador; El Salvador; Grenada; Guatemala; Guyana; Haiti; Honduras; Jamaica; Mexico; Nicaragua; Panama; Paraguay; Peru; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Suriname; Trinidad and Tobago; United States of America; Uruguay; Venezuela (Bolivarian Republic of).

South-East Asia Region
Bangladesh; Bhutan; Democratic People's Republic of Korea; India; Indonesia; Maldives; Myanmar; Nepal; Sri Lanka; Thailand; Timor-Leste.

European Region
Albania; Andorra; Armenia; Austria; Azerbaijan; Belarus; Belgium; Bosnia and Herzegovina; Bulgaria; Croatia; Cyprus; Czechia; Denmark; Estonia; Finland; France; Georgia; Germany; Greece; Hungary; Iceland; Ireland; Israel; Italy; Kazakhstan; Kyrgyzstan; Latvia; Lithuania; Luxembourg; Malta; Monaco; Montenegro; Netherlands; North Macedonia; Norway; Poland; Portugal; Republic of Moldova; Romania; Russian Federation; San Marino; Serbia; Slovakia; Slovenia; Spain; Sweden; Switzerland; Tajikistan; Turkey; Turkmenistan; Ukraine; United Kingdom of Great Britain and Northern Ireland; Uzbekistan.

Eastern Mediterranean Region
Afghanistan; Bahrain; Djibouti; Egypt; Iran (Islamic Republic of); Iraq; Jordan; Kuwait; Lebanon; Libya; Morocco; Oman; Pakistan; Qatar; Saudi Arabia; Somalia; Sudan; Syrian Arab Republic; Tunisia; United Arab Emirates; Yemen.

Western Pacific Region
Australia; Brunei Darussalam; Cambodia; China; Cook Islands; Fiji; Japan; Kiribati; Lao People's Democratic Republic; Malaysia; Marshall Islands; Micronesia (Federated States of); Mongolia; Nauru; New Zealand; Niue; Palau; Papua New Guinea; Philippines; Republic of Korea; Samoa; Singapore; Solomon Islands; Taiwan; Tonga; Tuvalu; Vanuatu; Viet Nam.

3. Distribution of myopia; near vision impairment; moderate to severe vision impairment or blindness (Global Burden of Disease regions)

Central Asia
Armenia; Azerbaijan; Georgia; Kazakhstan; Kyrgyzstan; Mongolia; Tajikistan; Turkmenistan; Uzbekistan.

Central Europe
Albania; Bulgaria; Bosnia and Herzegovina; Croatia; Czechia; Hungary; Montenegro; North Macedonia; Poland; Romania; Serbia; Slovakia; Slovenia.

Eastern Europe
Belarus; Estonia; Latvia; Lithuania; Republic of Moldova; Russian Federation; Ukraine.

Australasia
Australia; New Zealand.

High-income Asia Pacific
Brunei Darussalam; Japan; Republic of Korea; Singapore.

High-income North America
Canada; United States of America.

Southern Latin America
Argentina; Chile; Uruguay.

Western Europe
Andorra; Austria; Belgium; Cyprus; Denmark; Finland; France; Germany; Greece; Greenland; Iceland; Ireland; Israel; Italy; Luxembourg; Malta; Netherlands; Norway; Portugal; Spain; Sweden; Switzerland; United Kingdom of Great Britain and Northern Ireland.

Andean Latin America
Bolivia (Plurinational State of); Ecuador; Peru.

Caribbean
Antigua and Barbuda; Bahamas; Barbados; Belize; Bermuda; Cuba; Dominica; Dominican Republic; Grenada; Guyana; Haiti; Jamaica; Puerto Rico; Saint Lucia; Saint Vincent and the Grenadines; Suriname; Trinidad and Tobago.

Central Latin America
Colombia; Costa Rica; El Salvador; Guatemala; Honduras; Mexico; Nicaragua; Panama; Venezuela (Bolivarian Republic of).

Tropical Latin America
Brazil; Paraguay.

North Africa and Middle East
Afghanistan; Algeria; Bahrain; Egypt; Iran (Islamic Republic of), Iraq; Jordan; Kuwait; Lebanon; Libya; Morocco; Oman; Qatar; Saudi Arabia; State of Palestine; Sudan; Syrian Arab Republic; Tunisia; Turkey; United Arab Emirates; Yemen.

South Asia
Bangladesh; Bhutan; India; Nepal; Pakistan.

Central sub-Saharan Africa
Angola; Central African Republic; Congo; Democratic Republic of the Congo; Equatorial Guinea; Gabon.

Eastern sub-Saharan Africa
Burundi; Comoros; Djibouti; Eritrea; Ethiopia, Kenya, Madagascar, Malawi, Mozambique; Rwanda; Somalia; South Sudan; Uganda; United Republic of Tanzania; Zambia.

Southern sub-Saharan Africa
Botswana; Eswatini; Lesotho; Namibia; South Africa; Zimbabwe.

Western sub-Saharan Africa
Benin; Burkina Faso; Cameroon; Cabo Verde; Chad; Côte d'Ivoire; Gambia; Ghana; Guinea; Guinea-Bissau; Liberia; Mali; Mauritania; Niger; Nigeria; Sao Tome and Principe; Senegal; Sierra Leone; Togo.

East Asia
China; Democratic People's Republic of Korea; Taiwan.

Southeast Asia
Cambodia; Indonesia; Lao People's Democratic Republic; Malaysia; Maldives; Mauritius; Myanmar; Philippines; Seychelles; Sri Lanka; Thailand; Timor-Leste; Viet Nam.

Oceania
American Samoa; Fiji; Guam; Kiribati; Marshall Islands; Micronesia (Federated States of); Papua New Guinea; Samoa; Solomon Islands; Tonga; Vanuatu.

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Page 1
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Page 9
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Page 22
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Page 40
WHO/NOOR/Sebastian Liste

Page 49
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Page 52
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