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Population health impacts of China's climate change policies[☆,☆☆,☆☆☆]

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ABSTRACT

Rapid and wide-ranging reductions in greenhouse gas emissions are required to meet the climate targets agreed upon at the 2015 Paris climate conference. There will be significant transition risks for health, livelihoods, and ecosystems associated with large-scale mitigation, but also opportunities. The aim of this study was to investigate the impacts, positive and negative, of climate policies on population health in China. We review the Intended Nationally Determined Contribution (INDC) that China took to the Paris meeting, link commitments in the INDC to national planning documents relevant to environment and health, and search the literature for Chinese publications on health trade-offs and synergies. Synergies are evident in the measures taken to reduce local air pollution in China: controls on coal burning have materially improved local air quality and benefited health. But there may be risks to health also, depending on how policies are implemented and what safeguards are provided. To date most assessments of the health impacts of climate policies in China have been modelling studies. We recommend work of this kind is complemented by observational research to identify unexpected impacts and vulnerabilities. It will become even more important to undertake this work as emission reductions accelerate to meet the Paris climate targets.

1. Introduction

The 2015 Paris Agreement under the UN Framework Convention on Climate Change (UNFCCC) acknowledged that climate change has already caused severe impacts and the risks of further damage are projected to increase over the next several decades depending on actions taken on mitigation and adaptation. Since the Paris meeting, the Intergovernmental Panel on Climate Change (IPCC) Special Report on Warming of 1.5 °C concluded that each unit of warming above the 1 °C the earth has warmed since preindustrial times brings additional risks to most human and natural systems(IPCC, 2018). The adaptation and mitigation goals that were agreed upon in Paris are ambitious. Governments pledged to limit average world-wide warming to well below 2 °C above pre-industrial temperature, and to progress efforts to hold warming to less than 1.5 °C. To keep warming to 1.5 °C above pre-industrial temperatures, carbon dioxide (CO_2) emissions need to decline about 45% by 2030 and reach net zero about 2050, with non-CO_2 emissions also showing deep reductions (IPCC, 2018). The global energy system must be transformed to achieve these targets. Governments recognized that the Intended Nationally Determined Contributions (INDCs) brought to Paris are first steps, necessary but not sufficient (UNEP, 2017. Nairobi, 2017) and so the Agreement includes review and reporting elements designed to act as a “ratchet mechanism” to extend and strengthen national actions (Obergassel et al., 2015).

The scale and speed of change set in motion by the Paris agreement will be disruptive and undoubtedly there will be “transition risks” associated with moving quickly to a low-carbon economy (Carney, 2016). However, there are also opportunities associated with radical change;

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in many cases climate policies may benefit health by reducing hospitalizations and premature deaths, as highlighted in the IPCC Special Report on Warming of 1.5 °C (1), the 5th Assessment Report of the IPCC (Woodward et al., 2014), and the second Lancet Commission on Climate Change (Watts et al., 2015). As climate and development agendas are brought together in the next few decades, it will be a challenge to identify "how current socio-technical provisioning systems can be shifted towards low-carbon, well-being enhancing forms" within the context of the Sustainable Development Goals (Lamb and Steinberger, 2017).

The aim of our paper is to understand the impacts, positive and negative, that the Chinese government response to climate change may have on population health in China. To do this we begin with the commitment that China took to the Paris meeting and the policy areas highlighted therein. We link the major themes in what is now the Nationally Determined Contribution (NDC) with targets set in national documents such as the 13th 5-year plan, and highlight specific policies relevant to China's climate targets. We also review the literature on transition risks (trade-offs) and benefits (synergies) in China. Policies adopted in China may have effects globally, either directly (for example, as a result of cross-boundary transport of air pollution (Carmichael et al., 2002)), or indirectly, due to knock-on effects overseas (such as perturbations in the global coal market due to Chinese energy policies (Paulus and Truby, 2011)).

2. Methods

We focus here on impacts in China and include outcomes that are closely related to health (such as effects on livelihoods and food security), but not broader, more diffuse effects of policy (e.g. impacts on economic growth and trade). We looked particularly for studies of specific policies that have been or shortly will be implemented. However we also refer to modelling studies that explore the outcomes of interventions that may be introduced in the future.

We searched for peer-reviewed studies that investigated the quantitative association between public health co-benefits and greenhouse gas (GHG) emissions reduction in China, using the electronic databases PubMed, Web of Science and ScienceDirect (Elsevier). We included Chinese and English language articles published between 1995 and 2018. The following Medical Subject Headings (MeSH terms) and key words were employed in our search: "benefit," "co-benefit," "ancillary effect," and "greenhouse gas," "carbon," "CO_2," "mitigation," "reduction," "cut," and "health."

The papers included here are all drawn from the English-language literature. We found few studies published in Chinese only that covered both ancillary benefits and climate change mitigation – most commonly the Chinese language literature focussed on the acute effects of local air pollution. The topic of public health co-benefits of GHG abatement is generally a new research field in China, and it may be that Chinese scholars tend to publish their best quality work in English to maximise the impact and enhance professional experience and career advancement.

3. Findings

3.1. A short summary of the international literature on health benefits of climate policy

Climate policies and technologies to reduce greenhouse gas emissions can benefit health in many ways. The pathways include reducing exposure to air pollutants, increasing physical activity, and reducing the incidence of diet-related disease. Power plants, other stationary sources, certain industrial processes, mobile sources, burning of carbon-containing fuels elsewhere, and agricultural activities all emit airborne particles and gases that are health-damaging, leading to premature deaths and excess hospitalizations. These processes are also sources of greenhouse gases, including carbon dioxide and methane (Smith et al., 2013). Consequently it is possible that climate policies may be "win win" interventions for health. For instance, switching from private cars to public transport is likely to reduce CO_2 emissions, local air pollution, congestion, and road accidents, and polices that promote walking and cycling may have additional positive effects on fitness, reducing the incidence of several chronic diseases (Rojas-Rueda et al., 2012).

The food system generates about a quarter of GHG emissions worldwide. Agriculture is the main source of methane and nitrous oxide emissions, while food processing, transport, and storage contributes to emissions of CO_2 and hydrofluorocarbons (HFCs). An emissions pricing scheme that encouraged consumption of food associated with relatively low levels of GHG emissions could be beneficial both in terms of climate change mitigation and health gains (e.g. due to a move from meat to plant-based foods in high-income countries). (Springmann et al., 2016).

A review of 42 studies quantifying the health benefits of mitigation related to air quality, transportation, and diet concluded that most studies reported substantial local health benefits (Chang et al., 2017). In many cases, the monetary value of the health benefits from, for example, avoided premature deaths and hospitalizations, was estimated to be greater than the costs of implementing the mitigation policies, with the health benefits accruing much sooner than the benefits of reducing greenhouse gas emissions. The authors concluded the literature demonstrates that "mitigation policies are very likely a 'win-win'," (Chang et al., 2017) because they cut air pollutants that harm population health in the short term and reduce greenhouse gas emissions that will add to the burden of climate-sensitive disease and injury later in the century. Including the magnitude of the health benefits when estimating the costs of mitigation policies would provide a more accurate view of costs and benefits to inform decisions about policy choices than assessments that focus only on climate effects. These findings are robust across a diversity of published methods and modelling choices employed in studies of the health benefits of carbon mitigation.

3.2. Chinese publications on health benefits of mitigation policies

Table 1 displays the articles identified in our search of the scientific literature: these focus particularly on the benefits of improved air quality that result from reducing the use of fossil fuels (Yang and Teng, 2018). In the energy sector, for example, the health benefits of six CO_2 abatement measures related to coal consumption in Shanxi, China were investigated in terms of how effectively each could reduce local air pollution (specifically levels of CO, PM_{10} and SO_2) and thereby bring about health gains. The study found that the use of improved technologies could substantially reduce CO_2 emissions and at the same time avoid many premature deaths (the estimated savings as measured in life-years lost ranged from 75,000–7,723,000) (Aunan et al., 2004). Under low-carbon energy scenarios in 2010 and 2020, a study from Shanghai reported that GHG mitigation measures such as improving energy efficiency, generating wind electricity, and expanding natural gas use could prevent 2804–8249 and 9870–23,100 deaths due to decreases in particulate matter (PM) with an average aerodynamic diameter of 10 μm or less (PM_{10}) in 2010 and 2020, respectively, compared with a Business as Usual (BAU) scenario (Chen et al., 2007).

Another study modelled the potential impact of urban climate change mitigation policies in the transport, building, and energy sectors in two Chinese cities (Xi'an and Suzhou) for the year 2020. Compared with BAU scenarios, all interventions reduced CO_2 emissions and were expected to improve health in the short-term (Sabel et al., 2016). Rive and Aunan estimated reductions in emissions and local air pollution from 11 energy-related Clean Development Mechanism (CDM) projects in seven Chinese regions, and calculated what the effects might be on health and agricultural production. They found that low-carbon energy measures that upgraded technologies, promoted fuel switching, and installed renewable energy could make substantial contributions to

Table 1
Summary of studies on health co-benefits of climate change mitigation in China (n = 12).

Author (date)	Study design	Involving sector (s)	Mitigation measures	Major findings	
				Benefits for climate	Health co-benefits
Wang & Smith, (1999)	Scenario model study	Energy in power, household sectors	Energy efficiency improvement and fuel substitution	Green House Gas (GHG) emissions 15% below Business As Usual scenario by 2020	A 4% reduction in projected mortality (about 560,000 postponed deaths)
Aunan et al. (2004)	Scenario model study	Industry, power, and rural households sectors	Six different abatement options that could reduce emissions of CO_2, PM_{10} and SO_2 related to use of coal	Six abatement measures CO_2 emission-reduction potential ranges from 0.3 to 12.8 million tons, with effects also On PM_{10} and SO_2 emissions	From 75,000–7,723,000 life years lost can be avoided (depending on particulate size) due to reduced PM emissions from the six mitigation measures which are expected to run over 90 years
Chen et al. (2007)	Scenario model study	Energy, industry, economy, and residential sectors	Energy efficiency improvement in Shanghai expanding natural gas use, and wind electricity generation	Energy efficiency improve 2% annually from 2000 to 2020, and various other low-carbon measures in natural gas use and wind electricity generation	Compared with the base case scenario, implementation of low-carbon measures could each year prevent 9870–23,100 premature deaths in Shanghai due to PM_{10} reduction
Markandya et al. (2009)	Scenario model study	Electricity generation	Shift technologies and fuels, decrease use of coal, use carbon capture and storage, increase nuclear energy and the share of renewable energy	CO_2 emissions in 2030 achieve the 2050 reduction targets (50% reduction compared with the emissions in 1990)	Compared with BAU, the health gains in Ch China would be about 500 life-years per million people in 2030, higher than the figure in EU (100), and lower than India (1500)
He et al. (2010)	Scenario model study	Energy policies related to household, industry, buildings, and transportation	Switch energy structure, improve energy efficiency, and control energy consumption	Emissions of CO_2 reduce by 1469 million metric tonnes (MT) compared with the 2030 projected BAU scenario	By 2030, 135,811 all causes mortality would be avoided compared with BAU scenario, and more than 100 billion US$ of health benefit can be gained
Rive and Aunan (2010)	Scenario model study	Energy	The Clean Development Mechanism (CDM) activities in China to 2012	Annual abatement from CDM projects would be 319 MT CO_2-eq/yr in 2010, and 560 MT CO_2-eq/yr in 2012	Monetized health benefit (avoided deaths) from PM reduction associated with CDM is 5359 million RMB per year in 2010
Rafaj et al. (2013)	Scenario model study	Energy, household, transportation, industry, and agriculture, etc.	Various mitigation measures involving industrial processes and energy activities for reducing the emissions of air pollutants and GHGs	For 2 °C climate mitigation policy scenario, global CO_2 emissions reduce by 80% in 2050 compared to the baseline emission level	By 2050, for the Mitigation scenario, loss in statistical life expectancy due to $PM_{2.5}$ is halved, and ozone-related premature deaths cut annually by 20,000 cases when compared with the baseline scenario
Sabel et al. (2016)	Scenario model study	Urban transport, building fabric and energy supply	Heat, powerplant fuel peat and oil changed to wood; biofuels for transport; 10% reduction in private car use and 50% growth in electric cars); building renovation, etc.	By 2020, all policies modelled reduced CO_2 emissions relative to the BAU scenario, with different extents	With the exception of using biomass for domestic heating, the GHG reduction policies were likely to improve health, especially in areas few such policies have been adopted before, although the benefits tended to be slight
He and Qiu (2016)	Scenario model study	Transportation	Alternative transport, increased kilometers travelled (KT) in public transport to replace 5%–40% of KT by private cars	The annual reduction of travel transport-related CO_2 emissions range from 15.65 billion tons to 125.18 billion tons per year, depending on the scenario	The number of deaths prevented from air pollution-related disease per year range from about 569,000 to 4,516,000
Peng et al. (2017)	Scenario model study	Power, transport, residential, and industry sectors	20% increase in air pollution controls, 80% replacement of small coal power plants, 10%	CO_2 emissions reduction range from 0 to 440 Mt, for different sectors	Air-pollution-related deaths reduced 13,000–27,000, for various measures in the four sectors

(*continued on next page*)

Table 1 (*continued*)

Author (date)	Study design	Involving sector (s)	Mitigation measures	Major findings	
				Benefits for climate	Health co-benefits
			improvement in energy efficiency, replacement of vehicles with high emissions, and replacement of 20% of coal-based stoves		
Li et al. (2018)	Scenario model study	Energy	CO_2 intensity reduction, and CO_2 price,	CO_2 intensity reduces 3%, 4% or 5% per year between 2015 and 2030	Relative to BAU scenario in 2030, ~36,000, 94,000 and 160,000 premature mortalities due to $PM_{2.5}$ reductions could be prevented
Peng et al. (2018)	Scenario model study	Power, transport, and residential	Decarbonization of the electricity supply, electrification of demand in transportation and residential heating/cooking sectors	Compare with BAU in 2030, a half decarbonized power supply switch for electrification of transport and residential sectors reduces 14–16% carbon emissions	Relative to BAU, the mitigation measures could prevent 55,000–69,000 deaths annually, due to improved air quality

Abbreviations: BAU, business as usual; CDM, Clean Development Mechanism; EU, European Union; GHGs, greenhouse gas; KT, kilometers travelled; MT, metric tonnes; PM, particulate matter; PM_{10}, particulate matter with an average aerodynamic diameter of 10 mm or less; $PM_{2.5}$, particulate matter with aerodynamic diameter 2.5 µm or less; SO_2, sulfur dioxide.

better air quality, and the monetized health and agricultural benefits achieved by lower PM and NOx emissions amounted to roughly 12 billion RMB per year in 2010 (Rive and Aunan, 2010).

Cutting GHG emissions to 15% below BAU by 2020 through energy efficiency improvement and fuel substitution in China in the household and power generation sectors could reduce mortality by 4% relative to the BAU scenario, according to Wang et al. (Wang and Smith, 1999 Aug 4) Another study found that if aggressive energy policies were implemented nationally in China, by 2030 roughly 1.5 million tonnes of CO_2 emissions per year could be avoided, air pollutant concentrations cut by up to a third, and almost 136,000 deaths (per year) from all causes could be avoided, leading annually to more than US$100 billion of health benefits (He et al., 2010).

In electricity generation, low carbon strategies such as alternative technologies and fuels, greater use of nuclear power and renewable energy, and coal burning linked with carbon capture and storage technology could improve public health. For instance, Markandya and colleagues estimated that mitigation measures that reduced GHG emissions in China by 50% by 2030 could save 500 life-years per million people per year. The economic value of these health gains could, according to their calculations, offset greatly the costs of the climate interventions (Markandya et al., 2009).

In the transport system, a study conducted to investigate the effects of changes in residents' travel demand concluded that shifting 5–40% of private car kilometers to alternative transport could reduce CO_2 emissions in 2050 by 15.65–125.18 billion tonnes compared with BAU, and avoid between 570,000 and 4.5 million deaths by 2050 due to reductions in air pollutants (Ling-Yun and Qiu, 2016). A 2018 study from Peng et al. evaluated the co-benefits of various end-use electrification scenarios in the transport and residential sectors relative to BAU in 2030 (Peng et al., 2018). A power supply in which use of coal to generate electricity for transport and the residential sector was cut by 50% could reduce overall CO_2 emissions by 14–16%, improve air quality, and prevent 55,000–69,000 deaths annually.

Assuming international coordination in climate change mitigation action and taking current air pollution control legislation into account, Rafaj et al. estimated that a climate policy scenario consistent with no more than 2 °C global warming could roughly halve life expectancy lost due to exposures to $PM_{2.5}$ pollution, and ozone-related premature deaths could be reduced annually by 20,000 cases (Rafaj et al., 2013).

Consistent with China's pledge to reach peak CO_2 emissions by 2030, Li et al. modelled three policy scenarios that target CO_2 intensity reductions of 3%, 4% or 5% per year between 2015 and 2030 (Li et al., 2018). The results projected that relative to a No Policy scenario in 2030, the 3%, 4%, and 5% policies could prevent ~36,000, 94,000, and 160,000 premature deaths due to improved air quality. For the 4% Policy scenario, the health benefits were estimated to be 3.7 times larger than policy costs using international estimates of the statistical value of a life. When Chinese national valuations were applied, the benefit cost ratio was greatly reduced, demonstrating the sensitivity of cost-benefit analyses to assumptions about the monetary value of health gains. Using a 2015 base case, Peng and colleagues evaluated the potential benefits of mitigation strategies in the power, industry, transport, and residential sectors. They estimated that low carbon scenarios in each sector could reduce local air pollution sufficiently in each case to save between 13,000 and 27,000 deaths annually (Peng et al., 2017).

3.3. Climate change policy in China

The commitment China took to the Paris conference in 2015 was essentially two-fold: to reduce the CO_2 emissions intensity of the economy by roughly two-thirds by 2030 (compared with 2005) and to restrain the growth in absolute emissions so that levels peak around 2030. The country is on track to achieve the carbon intensity target, and there are signs that CO_2 emissions may plateau well before 2030 (Elzen den et al., 2019). The NDC highlighted four areas in which China would

Table 2
Major elements of the Intended Nationally Determined Contribution (INDC) that China took to the 2015 Paris conference, related targets in the national 5-year plan, and illustrative policies.

INDC – major concentrations	INDC-related targets	13th 5-year plan – related targets	Policies relevant to these targets
1. Greater use of low carbon energy systems	1.Carbon dioxide emissions peak around 2030, as soon as possible 2.CO_2 emissions per unit of GDP lower by 60%–65% in 2030 compared to 2005 3.Strategic emerging industries increase by 15% of GDP by 2020	1.Supporting the optimization of regional carbon emissions rate to reach the peak first, and strive to achieve the peak in some heavy-duty industries around 2020 2.By 2020, CO_2 emissions per unit of GDP will decrease by 18% from 2015 3.By 2020, carbon dioxide emissions per unit of industrial added value will decrease by 22% from 2015 4.Production of difluorochloromethane will reduce by 35% of the baseline level (2010) by 2020 5.By 2020, the ratio of added value of strategic emerging industries to GDP will reach 15%, and the value add of service industries will reach 56% of GDP	1. Household coal ban 2.Requirement to use high quality coal only 3.Reduce production capacity of high-energy-consuming industries
2. Increased energy efficiency	1.By 2030, non-fossil energy accounts for about 20% of primary energy consumption (1) By 2020, natural gas accounts for more than 10% of primary energy consumption (2) By 2020, coal-bed methane (CBM) production is expected to reach 30 billion cubic meters (3) By 2020, wind power capacity will reach 200 million kilowatts (4) By 2020, photovoltaic installations will reach 100 million kilowatts (5) By 2020, the use of geothermal energy will reach 50 million tons of coal equivalent 2.The average coal-fired power generation of newly-built coal-fired generating units should be reduced to about 300 g per kWh of coal equivalent.	1.By 2020, non-fossil energy will account for 15% of total energy consumption (1) By 2020，The share of natural gas in total energy consumption increased by about 10%. (2) By 2020，Wind power installed capacity reaches 200 million kilowatts (3) By 2020, photovoltaic installed capacity will reach 100 million kilowatts (4) By 2020, strive to achieve 340 million kilowatts of conventional hydropower installed capacity (5) By 2020, nuclear power capacity will reach 58 million kilowatts (6) By 2020, the proportion of electricity in terminal energy consumption will increase to over 27%	1.Promote rural biogas transformation and upgrading 2. Replace inefficient incandescent lighting throughout China with high efficiency lighting products (the Green Lights Program)
3. Climate-smart urbanisation	1.By 2020, green building accounts for 50% of new buildings in urban areas 2.Public transportation in large and medium cities accounts for 30% of motorized travel	1.By 2020, the proportion of green buildings in new towns will reach 50% 2.By 2020, the CO_2 emissions from the transportation turnover of operating trucks, passenger buses, and operating vessels will decrease by 8%, 2.6%, and 7%, respectively, compared with 2015 3.By 2020, carbon dioxide emissions from passenger transport in urban passenger transport units will be 12.5% lower than in 2015. 4.By 2020, the production capacity of pure electric vehicles and plug-in hybrid vehicles will reach 2 million, and the cumulative production and sales volume will exceed 5 million. 5.Advocate “135″ green low-carbon travel mode (walking within 1 km, cycling within 3 km, public transportation within 5 km)	1.Promote shared bicycles 2.Extend central heating
4. Boost carbon sinks	1.By 2030, the forest stock volume will increase by about 4.5 billion cubic meters from 2005	1.By 2020, forest coverage rate will reach 23.04%, and the forest stock volume will rise to 16.5 billion cubic meters 2.Actively increase grassland carbon sinks, and by 2020, the comprehensive vegetation coverage of grasslands will reach 56%	1.Develop wetlands and marine carbon sink 2.Promote carbon emissions trading

take climate action: greater use of low carbon energy systems, increased energy efficiency, urbanisation policies, and increased carbon sinks. Table 2 links the NDC goals with related targets in the 13th China national 5-year plan (Haacke, 2015; Aglietta and Bai, 2016), and lists examples of policies relevant to the targets.

China is moving to reduce emissions on many fronts, but has relied mostly on direct interventions by the central government to deter or close down high-polluting industries, to identify and promote low carbon technology, and to drive greater efficiencies in energy use (Jotzo et al., 2018). Economic policy instruments are also being applied, including what will be the largest carbon emissions trading system in the world once it is fully operational in the 2020s, by which time it is expected to cover the sources of about half the country's CO_2 emissions (Jotzo et al., 2018).

The broader policy environment is relevant. One of the three primary goals of Healthy China (2030), the blueprint for advancement released by the Central Committee of the Communist Party and the State Council in October 2016, is to connect health with socio-economic development. In other words, the government acknowledges that material progress in China should not occur at the expense of health and well-being. The 2018 Tsinghua-Lancet Commission on Healthy Cities in China concluded similarly - “the drive to develop healthy cities in China and create the world's first eco-civilization is set in the context of an unprecedented global push for sustainable development”. (Yang et al., 2018).

Climate policies such as those included in Table 2 may reduce health risks and ease local environmental pollution, but neither is necessarily the case. This is illustrated by China's attempt to move from coal to gas as a primary energy source. In general, such a shift reduces both local air pollution and greenhouse emissions. But depending on how the gas is produced, which sectors make the change, and the region of the country in which the change occurs, the health benefits may be reduced considerably. For example, China plans to supplement natural gas supplies with large quantities of shale gas and synthetic natural gas (SNG) produced from coal. In most circumstances, coal-based SNG returns similar benefits in local air quality (and hence health gains for the local population), but does not achieve the same level of greenhouse gas mitigation as natural gas. Moreover the water-intensive production of SNG is an important consideration, especially in the north-west and other parts of the country that already experience significant water scarcity (Qin et al., 2018). If the shift from coal to gas occurs principally in the power sector, the health gains are less than if deployment is focussed on residential energy use, because end-of-pipe control technology is already widely applied in coal-fired power stations to reduce the release of particulate pollution.

3.4. Case studies

We use three case studies to explore in greater detail the ways in which China's climate policies may influence population health. The case studies were chosen to illustrate the variety of policies relevant to both climate change and health.

4. Reducing air pollution from coal burning

Coal is the main energy source behind China's unprecedented economic development, but burning coal releases large quantities of health-damaging air pollutants and CO_2 (Shan et al.) and is responsible for short-lived climate pollutants, such as black carbon (Chen et al., 2009). In its 2013 ″Action Plan for Air Pollution Prevention and Control", the China State Council called for 'a medium and long-term national coal consumption cap target" and set targets for key regions with high levels of air pollution (i.e., Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta), requiring them to cap and reduce coal consumption by 2017 (State Council, 2013). The subsequent Energy Development 13th Five Year Plan, published in early 2017, set a limit on national coal consumption (4.1 million metric tons) by 2020, while increasing the share of non-fossil energy consumption. The Plan anticipates an aggressive reduction in coal's share of China's energy mix to below 58% by 2020, compared with 64% in 2015 (The 13th Five-Year Plan for the Development of the Coal Industry (2016–2020), 2013). Initial coal reduction strategies focused on improving the efficiency of coal-fired power plants, improving energy efficiency in industrial and construction sectors, investing in wind and solar power, and increasing uptake of carbon capture and storage technologies. These efforts appear to have slowed coal consumption (Tang et al., 2018), and improved air quality in regions targeted by these policies (Cai et al., 2017).

Until recently, less attention was paid to phasing out household coal burning, a practice among over a third of Chinese homes, than power generation. In late 2016, the Beijing government announced a policy to mitigate air pollution from household and small-industry coal burning by designating "coal restricted areas" (Diao, 2017). By 2020, over 3700 villages in Beijing must transition away from coal heaters and there are plans to extend this policy to other northern provinces. To motivate the Beijing transition, the government simultaneously instituted a subsidy for electric- or natural gas-powered heat pumps (Beijing City Government, 2016). Emerging evidence from early roll-out of these policies indicates successful elimination of coal use in wealthier districts, with benefits measured by indoor temperatures and levels of indoor air pollution. In a less affluent region, the policy had partial effectiveness (Barrington-Leigh, under review). It is plain that household coal policies could make an important contribution to restricting GHG global emissions, but the short-term health gains will not be evenly shared if clean household heating is introduced in some areas and not others.

5. Reducing flooding and improving livelihoods through the sloping land conversion (SLC) program

Afforestation and other improvements in land use are important components of China's emissions reduction portfolio. Terrestrial ecosystems sequestered 190–260 million tons of carbon between 1980 and 2000, absorbing 28–37% of CO_2 emissions during this period from the burning of fossil fuels in China (Piao et al., 2009). At the time it was instituted (1999), the Sloping Land Conversion Program (SLCP, also known as 'Grain for Green') was the largest re-forestation program in the developing world (Bennett, 2008). It was initiated in response to severe droughts and flooding that left over 13 million people homeless and caused more than 3500 deaths in north-east China in the 1990s. Farming on sleep slopes and deforestation were thought at least partially responsible for these events.

The SLCP restoration program was implemented across 25 provinces, aiming to increase vegetative cover by converting sloped ($>15°$) and degraded cropland to forest and grassland (Yin et al., 2014). It was also intended to stimulate rural economic development and poverty reduction by offering grain and cash subsidies to farmers in exchange for retiring part of their land from cultivation (Bennett, 2008). By 2010 SLCP converted an estimated 24.4 million hectares of degraded cropland and barren land into forest or grassland, with participation from over 24 million households (State Forestry Administration, 2011).

Impacts of SLCP on socio-economic development and population health are difficult to isolate given the diversity of local conditions across targeted policy areas and rapid socio-demographic changes in rural China over the same time period. In western Shaanxi, SLCP had an overall positive impact on household net income; however, the effect differed depending on household composition, socioeconomic status, and geographic location (Liang et al., 2012). Studies conducted in flood-prone and highly-populated regions of northern and southwestern China concluded the SLCP contributed to the control of surface runoff and soil erosion, thus reducing flood risk at local scales (Liu et al., 2008; Rodríguez et al., 2016). However, the evidence is not strong that SLCP increased the transfer of labor towards non-farming activities (Li et al., 2011), which may imply agricultural intensification of remaining cultivated fields where over-application of chemical fertilizers is common, with accompanying risks to human populations and local ecosystems (Mueller et al., 2012).

6. Promoting healthier cities through active transport

China's transportation systems have undergone massive change in recent decades. Between 2007 and 2017, the total length of public roadways grew by 1.2 million kilometers and private vehicle ownership increased by over five fold (Total length of public roads in China from 2007 to 2017 (in million kilometers)). Increased motorization has led to longer commute times, traffic congestion, air pollution, and increases in road traffic accidents and injuries. Greenhouse gas emissions from transport have risen steeply and are expected to account for about 13% of total national emissions by 2035 (Li et al., 2018). To a large extent travel by motor vehicle has replaced active forms of transportation such as walking and cycling, and has contributed to a decline in total physical activity. Between 1991 and 2006, average weekly physical activity (in metabolic equivalent (MET)-hours) decreased by a third among Chinese adults, and the proportion of adults who walked or cycled for more than 30 min per day fell from 46-51% to 28–33% (Ng et al., 2009). In 1986, 63% of trips in Beijing were made by bicycle; in 2014 the proportion was 11% (Jiang et al., 2017). These changes contribute to the country's rising prevalence of obesity (Du et al., 2013) and growth in non-communicable diseases such as diabetes and cardiovascular disease (Yang et al., 2010). In 2007, the economic cost of ill-health due to lack of physical activity in China was estimated to be almost USD7 billion (Zhang and Chaaban, 2013). Acquisition of a motorized vehicle was associated with weight gain in men in a longitudinal study in eight provinces of China between 1989 and 1997; in the same period men and women who acquired a non-motorized vehicle (mostly a bicycle) lost weight (Bell et al., 2002).

Urban transportation policy in China is largely focused on supporting economic growth while reducing traffic congestion and local air pollution. Most major Chinese cities have constructed extensive rail transit systems to meet growing travel demand and to limit use of motor vehicles, and many more mass transit systems are planned (Jiang et al., 2017). In general, travel by public transport requires more physical activity than the same journey by car (Morabia et al., 2011) and larger increases in activity occur with active transit modes (walking and cycling) (Sahlqvist et al., 2012). Around the time of the Beijing Olympics in 2008, a number of municipal governments subsidized public bike sharing programs to encourage non-motorized transport (Shaheen et al., 2011). Recently the number of electric bikes has increased rapidly and these are now a common urban transport mode (National Bureau of Statistics of China, 2018). Most are electric scooter style unlike the machines sold in other countries and, while they reduce motorized transport, there are limited benefits for physical activity. More recently, dockless bike-sharing programs have become very popular and these are now the third largest mode of public transit. The two largest Chinese bike-sharing companies (Ofo and Mobike) have more than 14 million bikes in operation in over 170 Chinese cities. These bike programs may have avoided carbon and $PM_{2.5}$ emissions due to reduced car use (The Mobike White Paper: Bike-share in the City, 2018; Qiu and He, 2018), but have also raised concerns about traffic safety and parking.

Many Chinese cities have removed separated bicycle lanes and unobstructed sidewalks to make way for road expansion. Road crash fatality rates are high by international standards. About a quarter of the road deaths are pedestrians and cyclists and the number of deaths among e-bike riders is increasing (Jiang et al., 2017). As in other countries, commonly reported barriers to active transport include safety, air pollution, lack of secure parking for bicycles, and inadequate lighting at night (Yang and Zacharias, 2015). While commuting distances have lengthened in recent decades, short trips are still common: a survey carried out in 2013 found that a third of Beijing commuters travelled less than 5 km (Yang and Zacharias, 2015). The Healthy China 2030 plan includes the proportion of the population exercising regularly as one of its markers of progress. Steps taken in Chinese cities to promote walking and cycling in place of trips by motor vehicle will help meet the Healthy China 2030 targets. Such improvements would also reduce pollution, limit motor vehicle use, and contribute to mitigation of climate change.

6.1. Future research

Most assessments of the health impacts of climate policies in China have been modelling studies that calculate the outcomes expected under different scenarios. It would be helpful if work of this kind was complemented more strongly by observational research, particularly real-time empirical studies (i.e., 'accountability studies') that assess the real-world effects of these policies or regulatory actions on environmental pollution, health, and welfare. Accountability studies are the closest epidemiologic equivalent to controlled experimental studies, and thus can provide evidence for causal relationships. This would enable planners to identify effects not included in the modelling and to identify vulnerable groups that may require extra support during transitions. An example of the value of such work is provided by an international study of the effect of bicycle share schemes on car use (Fishman et al., 2014). In theory, increasing the number of trips made by bicycle both improves health (as a result of increased physical activity) and reduces greenhouse emissions (because bike trips substitute for motor vehicles). A six city study found that in practice the impact of bike share schemes on car use varied greatly from one place to another, and in one city (London) it appeared there was actually no net gain. These differences related to background rates of public transport (in London most of the bike trips replaced bus or metro journeys) and the heavy use of vehicles in some cities to support the bike share scheme.

We note that it may be challenging to differentiate single policy-specific changes in pollution, wellbeing, or health from other time-varying policies or changes that influence them, especially in China which is rapidly changing and where policies are often implemented in tandem. However, given the explicit targets included in the China NDC, the variety of policies flagged in the Five Year Plan, and the multiple settings in which these policies will be implemented, it seems likely there will be many opportunities to monitor and learn from climate interventions that may have impacts on health. These opportunities might occur at city scale (for instance low-carbon transport policies) or at the level of provinces or regions (energy policies, for example). The large number of settings also provides an opportunity to learn from innovation, as different communities take different approaches to implement a variety of mitigation technologies. Evaluating the costs and benefits of any differences in effectiveness, along with the factors that promoted success, can help guide actions in other communities in China and around the world. In all cases, it is desirable to not only track health outcomes over time in the population directly affected, but to include as well longitudinal measures for a suitable comparison group that did not receive the intervention. This is important because secular changes in population health in China are occurring very rapidly (Yang et al., 2010).

7. Conclusion

China's task is to limit greenhouse gas emissions during a period of transformative economic growth. Many countries are striving to reduce emissions in ways that protect the health and well-being of their populations. What distinguishes the situation in China is the scale of change, the global significance of national trends (for instance, China leads the world in both coal consumption and installation of solar power), and the pace and reach of mitigation policies. The measures taken so far to restrict emissions could potentially bring gains to public health – this is most evident in the controls on coal burning, which have materially improved local air quality. In some instances, there are also risks, depending on how policies are implemented and the safeguards provided. An example is restrictions on the use of coal without provision of alternative sources of heating.

China is one of only half a dozen G20 countries that is presently on track to achieve their 2030 NDC targets, but even so the commitments tabled in 2015 fall short of the emission cuts required to meet the Paris climate targets (Rogelj et al., 2016). Indeed if current NDCs are implemented world-wide, the average global temperature is projected to increase by around 3 °C by 2100, with further warming occurring in the next century (UNEP, 2018). This means future climate policies everywhere will need to be much more ambitious, with much greater investment than in the past, making it more important than ever that trade-offs and synergies for human health are well-understood.

References

Aglietta, M., Bai, G., 2016 Sep. China's 13th five-year plan. Cent. Etudes Prospect. Inf. Int. 1–16.

Aunan, K., Fang, J., Vennemo, H., Oye, K., Seip, H.M., 2004 Jan 1. Co-benefits of climate policy—lessons learned from a study in Shanxi, China. Energy Policy 32, 567–581.

Beijing City Government, 2016 Jan. 13th Five-Year Energy Development Plan.

Bell, A.C., Ge, K.Y., Popkin, B.M., 2002 Apr. The road to obesity or the path to prevention: motorized transportation and obesity in China. Obes. Res. 10 (4), 277–283.

Bennett, M.T., 2008 May 1. China's sloping land conversion program: institutional innovation or business as usual? Ecological Economics. Elsevier 65 (4), 699–711.

Cai, S., Wang, Y., Zhao, B., Wang, S., Chang, X., Hao, J., 2017 Feb 15. The impact of the "air pollution prevention and control action plan" on PM2.5 concentrations in jing-jin-ji region during 2012-2020. Sci. Total Environ. 580, 197–209.

Carmichael, Gregory R., Streets, David G., Calori, Giuseppe, Amann, Markus, Jacobson, Mark Z., James Hansen, A., et al., 2002 Sep. 20. Changing trends in sulfur emissions

in Asia: implications for acid deposition, air pollution, and climate. Environmental science & technology. American Chemical Society 36 (22), 4707–4713.
Carney, M., 2016 Sep. 26. Resolving the Climate Paradox. Berlin. pp. 1–13.
Chang, K.M., Hess, J.J., Balbus, J.M., Buonocore, J., Cleveland, D.A., Grabow, M.L., et al., 2017 Jan 1. Ancillary health effects of climate mitigation scenarios as drivers of policy uptake: a review of air quality, transportation and diet co-benefits modeling studies. Environ. Res. Lett. 12, 113001.
Chen, C., Chen, B., Wang, B., Huang, C., Zhao, J., Dai, Y., et al., 2007 Feb 1. Low-carbon energy policy and ambient air pollution in Shanghai, China: a health-based economic assessment. Sci. Total Environ. 373 (1), 13–21.
Chen, Y., Zhi, G., Feng, Y., Liu, D., Zhang, G., Li, J., et al., 2009 Nov 10. Measurements of black and organic carbon emission factors for household coal combustion in China: implication for emission reduction. Environ Sci Technol. American Chemical Society 43, 9495–9500.
National Bureau of Statistics of China, 2018 Jan. China Statistical Yearbook. China Statistics Press, Beijing.
Diao, J., 2017 Mar 11. Beijing Moves Suburbs from Coal to Electric Heat. Beijing Today.
Du, H., Bennett, D., Li, L., Whitlock, G., Guo, Y., Collins, R., et al., 2013 Mar 1. Physical activity and sedentary leisure time and their associations with BMI, waist circumference, and percentage body fat in 0.5 million adults: the China Kadoorie Biobank study. Am J Clin Nutr. Oxford University Press 97 (3), 487–496.
Elzen den, M., Kuramochi, T., Höhne, N., Cantzler, J., Esmeijer, K., Fekete, H., et al., 2019 Mar 1. Are the G20 economies making enough progress to meet their NDC targets? Energy Policy 126, 238–250 Elsevier Ltd.
UNEP, 2018 Nov 22. Emissions Gap Report 2018. pp. 1–112.
Fishman, E., Washington, S., Haworth, N., 2014 Aug 1. Bike share's impact on car use: evidence from the United States, Great Britain, and Australia. Transport. Res. Part D. Elsevier Ltd 31 (C), 13–20.
Haacke, O., 2015 Feb 12. Understanding China's 13th five-year plan. China business review. [Internet], Available from: http://www.chinabusinessreview.com/understanding-chinas-13th-five-year-plan/.
He, K., Lei, Y., Pan, X., Zhang, Y., Zhang, Q., Chen, D., 2010 Nov 1. Co-benefits from energy policies in China. Energy 35 (11), 4265–4272 Elsevier Ltd.
IPCC, 2018 Oct. [Internet] In: Masson-Delmotte, V., Zhai, P., Roberts, D., Skea, J., Shukla, P.R., Pirani, A. (Eds.), IPCC, 2018: Summary for Policymakers, pp. 32. Geneva, Switzerland, Available from: https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_High_Res.pdf.
Jiang, Y., Gu, P., Chen, F., Chen, Y., Zegras, P.C., 2017. Measuring Transit-Oriented Development in Quantity and Quality: A Case of 24 Cities with Urban Rail Systems in China. Transportation Research Board th Annual Meeting.
Jotzo, F., Karplus, V., Grubb, M., Loschel, A., Neuhoff, K., 2018 Apr 3. China's emissions trading takes steps towards big ambitions. Nat. Clim. Change 8 (4), 265–267.
Lamb, W.F., Steinberger, J.K., 2017 Nov 1. Human well-being and climate change mitigation. WIREs Clim Chang. Wiley-Blackwell 8 (6), e485.
Li, J., Feldman, M.W., Li, S., Daily, G.C., 2011 May 10. Rural household income and inequality under the sloping land conversion program in Western China. Proc Natl Acad Sci USA. National Academy of Sciences 108 (19), 7721–7726.
Li, M., Zhang, Da, Li, C.-T., Mulvaney, K.M., Selin, N.E., Karplus, V.J., 2018 May. Air quality co-benefits of carbon pricing in China. Nature Climate Change. 8, 398–403.
Liang, Y., Li, S., Feldman, M.W., Daily, G.C., 2012 Mar 1. Does household composition matter? The impact of the Grain for Green Program on rural livelihoods in China. Ecol. Econ. 75, 152–160.
Ling-Yun, H.E., Qiu, L.-Y., 2016 Jan 1. Transport demand, harmful emissions, environment and health co-benefits in China. Energy Policy 97, 267–275.
Liu, J., Li, S., Ouyang, Z., Tam, C., Chen, X., 2008 Jul 15. Ecological and socioeconomic effects of China's policies for ecosystem services. PNAS. National Academy of Sciences 105 (28), 9477–9482.
Markandya, A., Armstrong, B.G., Hales, S., Chiabai, A., Criqui, P., Mima, S., et al., 2009 Dec 12. Public health benefits of strategies to reduce greenhouse-gas emissions: low-carbon electricity generation. Lancet 374 (9706) 2006–15.
Morabia, A., Mirer, F.E., Amstislavski, T.M., Eisl, H.M., Werbe-Fuentes, J., Gorczynski, J., et al., 2010 Sep 20. Potential health impact of switching from car to public transportation when commuting to work. Am J Public Health 100, 2388–2391.
Mueller, N.D., Gerber, J.S., Johnston, M., Ray, D.K., Ramankutty, N., Foley, J.A., 2012 Oct 1. Closing yield gaps through nutrient and water management. Nature. Nature Publishing Group 490 (7419), 254–257.
Ng, S.W., Norton, E.C., Popkin, B.M., 2009 Apr 1. Why have physical activity levels declined among Chinese adults? Findings from the 1991-2006 China health and nutrition surveys. Soc. Sci. Med. 68 (7), 1305–1314.
Obergassel, W., Arens, C., Hermwille, L., Kreibich, N., 2015. Phoenix from the Ashes: an Analysis of the Paris Agreement to the United Nations Framework Convention on Climate Change. part 1. .
Paulus, M., Truby, J., 2011. Coal lumps vs. electrons: how do Chinese bulk energy transport decisions affect the global steam coal market? Energy Econ. 33, 1127–1137.
Peng, W., Yang, J., Wagner, F., Mauzerall, D.L., 2017 Nov 15. Substantial air quality and climate co-benefits achievable now with sectoral mitigation strategies in China. Sci. Total Environ. 598, 1076–1084.
Peng, W., Yang, J., Lu, X., Mauzerall, D.L., 2018 Jan 1. Potential co-benefits of electrification for air quality, health, and CO2 mitigation in 2030 China. Appl. Energy 218, 511–519.
Piao, S., Fang, J., Ciais, P., Peylin, P., Huang, Y., Sitch, S., et al., 2009 Apr 23. The carbon balance of terrestrial ecosystems in China. Nature. Nature Publishing Group 458 (7241), 1009–1013.
Qin, Y., Höglund-Isaksson, L., Byers, E., Feng, K., Wagner, F., Peng, W., et al., 2018 Sep 1. Air quality–carbon–water synergies and trade-offs in China's natural gas industry. Nature Sustainability. Nature Publishing Group 1 (9), 505–511.
Qiu, L.-Y., He, L.-Y., 2018 Apr. Bike sharing and the economy, the environment, and health-related externalities. Sustainability 10 (4) 1145–10.
Rafaj, P., Schöpp, W., Russ, P., Heyes, C., Amann, M., 2013 Jan 1. Co-benefits of post-2012 global climate mitigation policies. Mitig Adapt Strateg Glob Change. Springer Netherlands 18 (6), 801–824.
Rive, N., Aunan, K., 2010 Jan 1. Quantifying the air quality cobenefits of the clean development mechanism in China. Environ. Sci. Technol. 44, 4368–4375.
Rodríguez, L.G., Hogarth, N.J., Zhou, W., Xie, C., Zhang, K., Putzel, L., 2016 Sep. 8. China's conversion of cropland to forest program: a systematic review of the environmental and socioeconomic effects. Environmental Evidence. BioMed Central 1–22.
Rogelj, J., Fransen, T., Fekete, H., Winkler, H., Schaeffer, R., Sha, F., et al., 2016 Jun 29. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. Nature. Nature Publishing Group 534 (7609), 631–639.
Rojas-Rueda, D., de Nazelle, A., Teixidó, O., Nieuwenhuijsen, M.J., 2012 Nov. Replacing car trips by increasing bike and public transport in the greater Barcelona metropolitan area: a health impact assessment study. Environ. Int. 49, 100–109.
Sabel, C.E., Hiscock, R., Asikainen, A., Bi, J., Depledge, M., van den Elshout, S., et al., 2016 Mar 8. Public health impacts of city policies to reduce climate change: findings from the URGENCHE EU-China project. Environ Health. BioMed Central 15 (Suppl. 1), 25.
Sahlqvist, S., Song, Y., Ogilvie, D., 2012 Sep. Is active travel associated with greater physical activity? The contribution of commuting and non-commuting active travel to total physical activity in adults. Prev. Med. 55 (3), 206–211.
Shaheen, S.A., Zhang, H., Martin, E., Guzman, S., 2011 Jan 1. China's hangzhou public bicycle: understanding early adoption and behavioral response to bikesharing. Transportation research record. SAGE PublicationsSage CA: Los Angeles, CA 2247 (1), 33–41.
Shan, Y.Guan, D.Zheng, H.Ou, J.Li, Y.Meng, J.et al., China CO2 emission accounts 1997-2015. Scientific Data. [Internet]. 5. Available from: https://doi.org/10.1038/sdata.2017.201.
Smith, K.R., Frumkin, H., Balakrishnan, K., Butler, C.D., Chafe, Z.A., Fairlie, I., et al., 2013 Mar 18. Energy and human health. Annu. Rev. Public Health 34 (1), 159–188.
Springmann, M., Mason-D'Croz, D., Robinson, S., Wiebe, K., Godfray, H.C.J., Rayner, M., et al., 2016 Nov 7. Mitigation potential and global health impacts from emissions pricing of food commodities. Nat. Clim. Change 7 (1), 69–74.
State Forestry Administration, 2011 Jan. China Forestry Development Report. China Forestry Publisher House, Beijing.
Tang, X., Jin, Y., McLellan, B.C., Wang, J., Li, S., 2018. China's coal consumption declining—impermanent or permanent? Resour. Conserv. Recycl. 129, 307–313 Feb 1.
National Development Reform Commission National Energy Administration, 2013 Jan. The 13th Five-Year Plan for the Development of the Coal Industry (2016-2020).
UNEP, 2017 Nov. The Emissions Gap Report 2017. Nairobi. pp. 1–116.
[Internet]. Shanghai The Mobike White Paper: Bike-Share in the City. Available from: https://mobike.com/sg/blog/post/mobikewhitepaper.
State Council, 2013 Jan. The Notice on the action plan of the air pollution prevention and control from the state Council. [Internet] Available from: http://www.gov.cn/zwgk/2013-09/12/content_2486773.htm.
Ministry of Transport of China, Total length of public roads in China from 2007 to 2017 (in million kilometers). [Internet]. Available from: https://www.statista.com/statistics/276051/total-length-of-public-roads-in-china/.
Wang, X., Smith, Kirk R., 1999 Aug 4. Secondary benefits of greenhouse gas Control: health impacts in China. Environmental science & technology. American Chemical Society 33 (18), 3056–3061.
Watts, N., Adger, W.N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., 2015. Health and climate change: policy responses to protect public health. Lancet 386, 1861–1914.
Woodward, A., Smith, K.R., Campbell-Lendrum, D., Chadee, D.D., Honda, Y., Liu, Q., et al., 2014 Apr 5. Climate change and health: on the latest IPCC report. Lancet 383 (9924), 1185–1189.
Yang, X., Teng, F., 2018 Feb 1. The air quality co-benefit of coal control strategy in China. Resources, Conservation and Recycling. Elsevier 129, 373–382.
Yang, M., Zacharias, J., 2015 Aug 17. Potential for revival of the bicycle in Beijing. International Journal of Sustainable Transportation. Taylor & Francis, vol. 10 (6), 517–527.
Yang, G., Wang, Y., Zeng, Y., Gao, G.F., Liang, X., lancet, M.Z.T., et al., 2010. Rapid health transition in China, 1990–2010: findings from the global burden of disease study. Lancet 381, 1987–2015.
Yang, J., Siri, J.G., Remais, J.V., Cheng, Q., Zhang, H., Chan, K.K.Y., et al., 2018 Apr 12. The Lancet commissions the tsinghua–lancet commission on healthy cities in China: unlocking the power of cities for a healthy China. The Lancet. Elsevier Ltd 1–44.
Yin, R., Zhao, M., Yao, S., 2014. Designing and implementing payments for ecosystem services programs: what lessons can be learned from China's experience of restoring degraded cropland? Environ. Sci. Technol. 48 (1), 19–20.
Zhang, J., Chaaban, J., 2013 Jan. The economic cost of physical inactivity in China. Prev. Med. 56 (1), 75–78.