

CHRONIC DISEASE

Global burden of non-communicable diseases attributable to dietary risks in 1990–2019

Jie Qiao¹  | Xiling Lin¹ | Yiwen Wu² | Xin Huang¹ | Xiaowen Pan¹ | Jingya Xu¹ | JunYun Wu¹ | Yuezhong Ren¹ | Peng-Fei Shan¹ 

¹Department of Endocrinology and Metabolism, The Second Affiliated Hospital of Zhejiang University School of Medicine, Hangzhou, China

²Department of Neurosurgery, Ningbo Hospital, Zhejiang University School of Medicine, Ningbo, China

Correspondence

Yue-zhong Ren and Pengfei Shan, Department of Endocrinology and Metabolism, the Second Affiliated Hospital of Zhejiang University School of Medicine, 88 Jiefang Road, Hangzhou, Zhejiang, 310009, China.
Email: renyuez@zju.edu.cn and pengfeishan@zju.edu.cn

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Abstract

Background: Dietary risks have raised attention worldwide during recent decades. The present burden-of-disease study aimed to evaluate the global dietary risks for non-communicable diseases (NCDs) from 1990 to 2019 and quantify their impact on mortality and disability-adjusted life-years (DALYs). Data from the 2019 Global Burden of Disease Study on deaths and DALYs from NCDs attributable to worldwide dietary risks were obtained and underwent deep analysis by year, age, gender, location, leading risks and leading causes, and their associations were examined. The socio-demographic index (SDI) was used as an indicator of national socio-economic status, as well as the relationships between age-standardised rates of deaths or DALYs and socio-economic status.

Results: In 2019, 7.9 million deaths and 187.7 million DALYs were attributable to dietary risk factors. High intake of sodium and low intake of whole grains and fruits were leading dietary risks for deaths and DALYs worldwide. However, both indices showed a decreasing trend by year, an increase by age and a higher disease burden in males. The main distribution of dietary-related NCDs was located in highly populated countries. A negative association between the SDI and disease burden and a positive association between the SDI and male preponderance were found.

Conclusions: Dietary risk factors for NCDs increased significantly and varied across regions during 1990–2019. Therefore, greater efforts are needed to raise public awareness of interventions and improve dietary practices aiming to reduce the disease burden caused by suboptimal dietary intake, especially in developing countries and among males.

KEYWORDS

DALYs, dietary risks, disability-adjusted life-years, global burden of disease study, mortality, non-communicable diseases

INTRODUCTION

Dietary risks are thought of as low nutritional intake and poor dietary habits; however, they primarily include high sodium intake and low intake of whole grains and fruits.

In recent decades, death and disability-adjusted life-years (DALYs) attributable to suboptimal diets have increased significantly¹ As a comprehensive measurement of diseases, DALYs quantify health loss as a result of specific diseases and injuries.² Non-communicable diseases (NCDs)

Key points

1. An important inverse relationship between dietary risk factors and non-communicable diseases (NCDs) in 1990–2019 is identified.
2. Individuals in low- and middle-income countries, whom experience greater risk of NCDs and their risk factors.
3. Males had higher numbers of deaths and DALYs than females at a relatively young age.
4. Greater efforts are needed to raise public awareness of interventions and improve dietary practices to reduce the disease burden caused by suboptimal dietary intake, especially in developing countries and among males.

accounted for the greatest proportion of total deaths (74.4%) in 2019, increasing from 2009 to 2019 by 20.5%, representing 7.1 million additional deaths in 2019 versus 2009.³ NCDs (e.g., ischaemic heart disease, stroke, diabetes mellitus, colon and rectal cancer and hypertensive heart disease) are leading causes of global deaths and disability. They are common among persons of working age; thus, expenditures for NCDs exceed those with respect to treating other diseases. The high burden of NCDs has raised concerns about the financial burden of follow-up, particularly, in low- and middle-income countries.⁴

The present study examined the relationship between suboptimal dietary intake and NCDs with socio-demographic characteristics and year, aiming to evaluate the hazard more precisely. We aimed to assist in the effort to reduce the burden of NCDs and promote the implementation of the World Health Organization's Global Action Plan for the Prevention of NCDs 2013–2020.⁵ The main foci of this action plan are four NCDs: cardiovascular disease, cancer, chronic respiratory disease and diabetes, which contribute most to the morbidity and mortality of NCDs, as well as four behavioral risk factors, including tobacco use, unhealthy diet, physical inactivity and harmful use of alcohol.

METHODS

Data source

Suboptimal nutrition was found to be a risk factor for the development of NCDs in the 2019 Global Burden of Disease (GBD) Study. We quantified the burden of the NCDs attributable to dietary risks from 1990 to 2019. Data for the analyses obtained from the Global Health Data Exchange consisted of (i) the numbers of males and females and age-standardised rates (per 100,000 population) of deaths and DALYs, annually from 1990 to 2019; (ii) absolute numbers and unadjusted rates of global gender-age-specific deaths and DALYs in

2019; (iii) countries' and regions' deaths and DALYs numbers and age-standardised rates in 2019; (iv) global deaths and DALYs, including the number and age-standardised rate of each NCD attributable to dietary risks in 1990, 2010 and 2019; (v) global deaths and DALYs, including the number and age-standardised rate of each dietary risk, which led to NCDs in 1990, 2010 and 2019; and (vi) age-standardised rates of deaths and DALYs in the GBD super regions in 1990, 2010 and 2019. Ethics approval and informed consent were not required for this study because the data are accessible to the public.

Socio-economic status was measured using the socio-demographic index (SDI), comprising a composite indicator of development status that is strongly correlated with health outcomes. It consists of the geometric mean of 0 to 1 indices of total fertility rate under the age of 25 years, mean education for those aged 15 years and older, and lag distributed income per capita. As a composite, a location with an SDI of 0 would have a theoretical minimum level of development relevant to health, whereas a location with an SDI of 1 would have a theoretical maximum level.⁶ The SDI of 195 countries and territories in the 2019 GBD study were divided into five categories: high SDI (> 0.81), high-middle SDI (0.70–0.81), middle SDI (0.61–0.69), low-middle SDI (0.46–0.60) and low SDI (< 0.46).

Statistical analysis

Analysed data are expressed as a value with a 95% uncertainty interval (UI). Age-standardised rates of death and DALYs are expressed as a number per 100,000 population. The association of age-standardised rates of deaths and DALYs with SDI was analysed using linear regression. All statistical analyses (unless otherwise specified) were conducted with Prism, version 8 (GraphPad Software Inc.). $p < 0.05$ was considered statistically significant.

RESULTS

Global trends in NCDs attributable to dietary risks by year

Globally, 42.0 million (95% UI = 40.0–43.9) deaths were attributed to NCDs in 2019; among them, 7.9 million (95% UI = 6.5–9.8) accounted for 28.5% of all risk-related NCDs attributable to dietary risks, which had increased from 5.4 million (95% UI = 4.5–6.5) in 1990. The DALYs reached 187.7 million (95% UI = 156.0–255.4) in 2019, accounting for 25.2% of all DALYs of NCDs, which had increased from 132.0 million (95% UI = 111.3–156.8) in 1990 (Figure 1).

The death rate, which was standardised by age and population, decreased from 154.3 (95% UI = 113.3–166.3) in 1990 to 101.0 (95% UI = 82.0–124.3) per 100,000 population in 2019. Males showed a similar trend to females, but higher rates of death and DALYs, from 1990 to 2019. In 2019, the

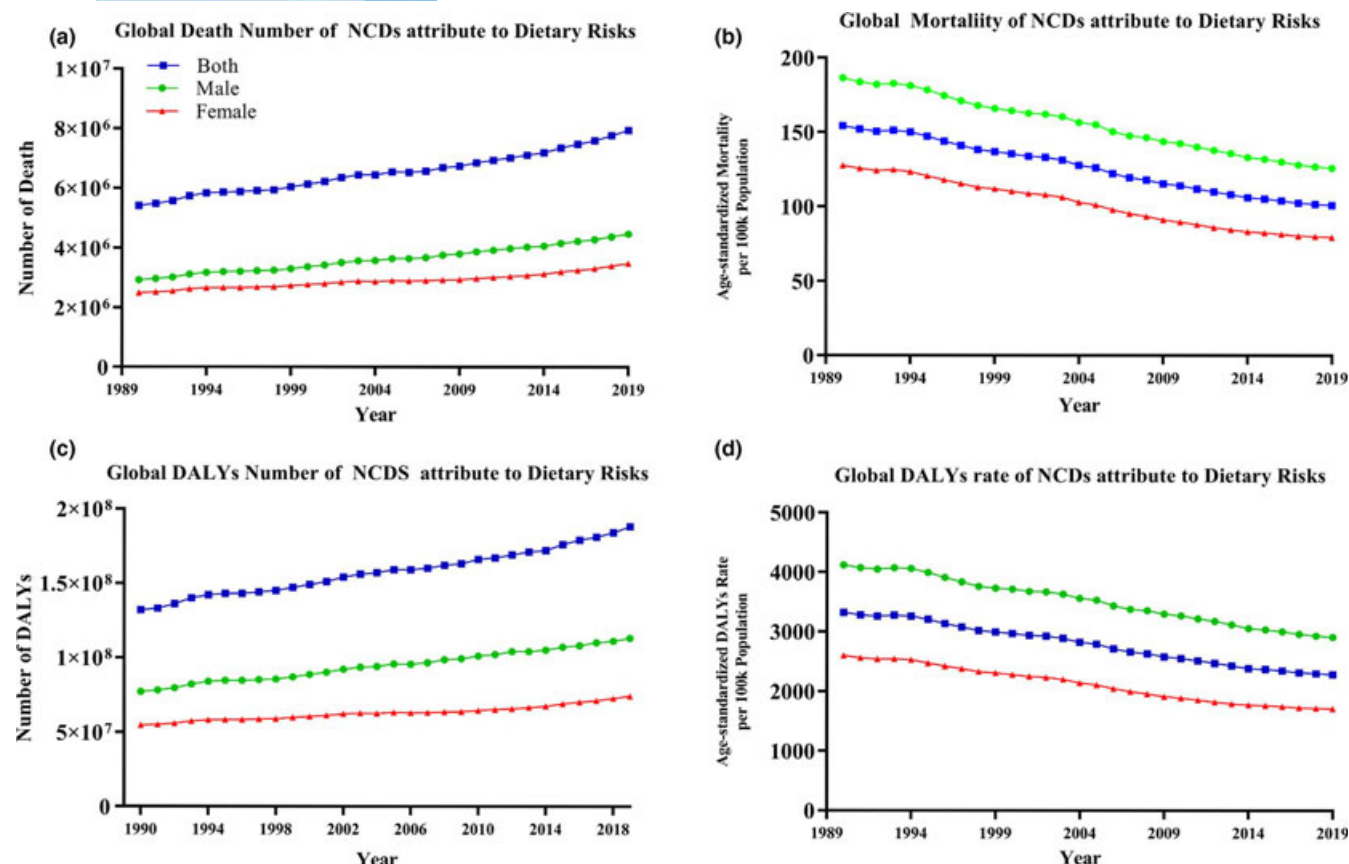


FIGURE 1 Global burden of non-communicable diseases (NCDs) attributable to dietary risks from 1990 to 2019. (a) death number (b) death rate (c) disability-adjusted life-years (DALYs) number (d) DALYs rate

mortality was 126 (95% UI = 102.7–154.5) among males and 80.0 (95% UI = 63.5–99.7) among females, and the DALY rate was 2911.5 (95% UI = 2402.2–3495.1) in males and 1709.6 (95% UI = 1395.6–2091.6) in females.

Global trends in NCDs attributable to dietary risks by gender and age

Global gender differences showed more severe consequences (i.e., higher death and DALY rates) in males from 1990 to 2019 (Figure 1). In 2019, 3.5 million (95% UI = 2.8–4.4) deaths were reported in women and 4.5 million (95% UI = 3.6–5.4) in men; the death rate per 100,000 population was 80.0 (95% UI = 63.5–99.7) in women and 126 (95% UI = 102.7–154.5) in men; the DALYs were 74.3 million (95% UI = 60.6–91.0) in women and 113.4 million (95% UI = 93.4–135.6) in men; and the DALY rate was 1710.0 (95% UI = 1396.1–2092.0) in women and 2911.5 (95% UI = 2402.2–3495.1) in men.

Trends in the numbers of deaths and DALYs attributable to dietary risks in both genders changed substantially with age (Figure 2), with males peaking at age 70–74 years with 567,603.0 (95% UI = 449,339.8–709,158.629.1) deaths and females peaking at age 80–84 years with 545,559.2 (95% UI = 428,615.7–697,221.4) deaths. The number of DALYs peaked for both genders at age 65–69 years with 23.9 million

(95% UI = 19.3–29.3), among females of a similar age at 9.3 million (95% UI = 7.4–11.6), and among males age 65–69 years at 15.0 million (95% UI = 12.1–18.2).

Before age 80 years, males had more deaths and DALYs, whereas females appeared to exceed those numbers after age 80 years; however, males in all age groups always had higher death and DALY rates. Deaths among those under 80 years accounted for 69.8% of all deaths and 88.9% of all DALYs in 2019. Males younger than 80 years bore a larger burden of deaths than females below age 80 years, as evidenced by their higher proportion of deaths (62.7% vs 37.2%) and DALYs (63.0% vs 37.0%). The adjusted death rates of both genders rose significantly with age, peaking at 4462.7 (95% UI = 3237.4–5833.8) per 100,000 population at ≥ 95 years, and the DALY rate peaking at 24,418.9 (95% UI = 31,914.7–18,051.9) at ≥ 95 years.

Global trends in NCDs attributable to dietary risks by super regions and locations

Dietary risk-related death and DALY rates from NCDs have increased over the past 28 years in most of the GBD study super regions, except in the high-income areas, Central Europe and the Caribbean region, which showed a decrease in 1990–2010 (Tables 1 and 2). The top three age-standardised

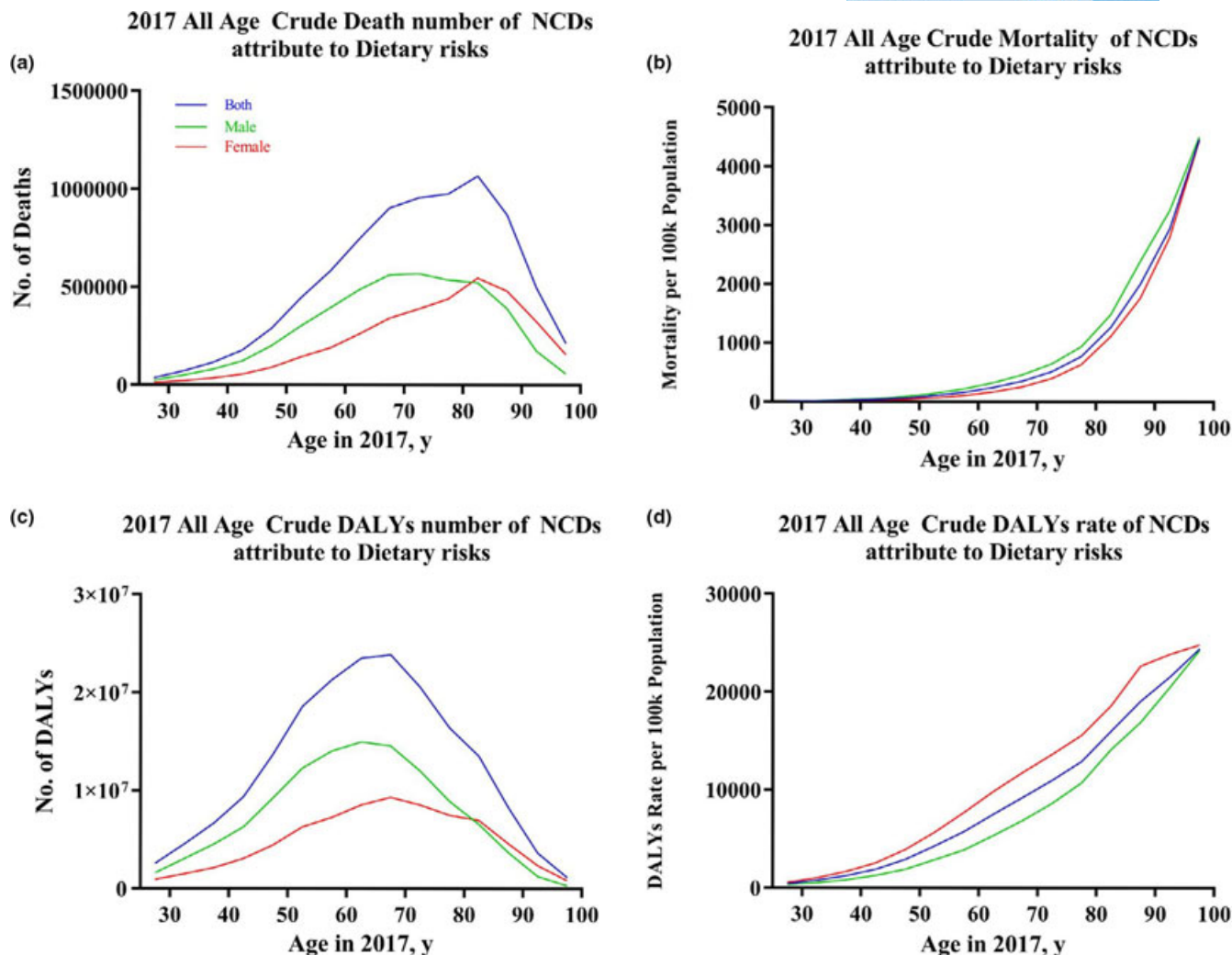


FIGURE 2 Global burden of non-communicable diseases (NCDs) attributable to dietary risks by age in 2019. (a) death numbers (b) death rate (c) DALYs number (d) DALYs rate. DALYs, disability-adjusted life-years

mortality rates in the super regions were located in Eastern Europe, Oceania and Central Asia, whereas the highest age-standardised DALY rates were located in Oceania, followed by Eastern Europe and Central Asia. The lowest mortality and DALY rates were observed in the high-income Asia Pacific region during 1990–2019. The disease burden was greater for men in most GBD super regions, compared to females, except in Oceania, Eastern Sub-Saharan Africa and Western Sub-Saharan Africa.

The distribution of deaths and DALYs from NCDs, attributable to dietary risks by countries in 2019, is described in a global heat map (Figure 3). The highest numbers of deaths and DALYs in the most populous nations were observed in China, with 2.0 million (1.5–2.6 million) deaths and 46.8 million (35.6–60.0 million) DALYs, followed by India (1.2 million deaths and 32.4 million DALYs) and the Russian Federation (0.4 million deaths and 8.5 million DALYs). The top three age-standardised death rates were found in Uzbekistan (483.6), the Solomon Islands (369.7) and Tajikistan (325.8). The top three countries with the

highest age-standardised DALY rates were the Solomon Islands (9795.9), Uzbekistan (8378.9) and Nauru (7715.1). The countries with the lowest death and DALY rates were Japan (31.7) and Israel (778.9).

Global trends in NCDs attributable to dietary risks by SDI

The age-standardised rates of dietary-related deaths were highest in high-middle SDI regions, with an age-standardised rate of 176.44 (95% UI = 162.6–188.8), whereas the highest DALY rate was observed in low-middle SDI regions with a DALY rate of 2794.2 (95% UI = 2310.0–3400.2) in 2019. Both rates were lowest in high SDI countries, with a death rate of 56.5 (95% UI = 46.6–68.9) and a DALY rate of 1308.1 (95% UI = 1113.8–1547.0) in 2019.

Linear regression showed that the age-standardised mortality of both genders combined was negatively associated with SDI ($r = -0.2598$, $p < 0.001$). The mortality was

TABLE 1 Age-standardised death rates (per 100,000 population) from non-communicable diseases attributable to dietary risks by Global Burden of Disease (GBD) super regions in 1990, 2010 and 2019

GBD 2017 super region	1990		2010		2017	
	Male	Female	Male	Female	Male	Female
	Mean	Mean	Mean	Mean	Mean	Mean
High-income						
High-income Asia Pacific	28.41	22.12	23.72	11.80	23.21	10.64
Western Europe	72.09	47.52	54.20	34.11	50.90	31.85
Australasia	70.72	52.83	53.98	40.44	51.13	38.25
High-income North America	84.45	66.34	82.29	58.36	79.40	58.37
Southern Latin America	75.05	53.76	87.81	58.11	82.34	56.25
Eastern Europe/Central Asia						
Central Europe	128.45	108.08	120.59	87.40	116.43	77.73
Eastern Europe	122.59	105.59	185.27	122.09	176.52	104.01
Central Asia	112.35	107.95	160.78	135.71	156.03	126.53
Latin America & Caribbean						
Tropical Latin America	78.59	72.74	78.80	72.12	79.27	69.53
Central Latin America	67.90	81.95	76.67	81.95	80.32	81.64
Andean Latin America	44.88	46.91	53.24	59.92	56.00	58.04
Caribbean	74.48	85.09	76.71	77.48	79.14	80.42
Southeast/East Asia & Oceania						
Southeast Asia	28.27	31.34	45.86	49.66	50.97	53.72
East Asia	29.49	28.79	37.06	35.12	43.22	38.78
Oceania	120.23	135.18	181.78	183.53	169.85	176.46
North Africa & Middle East						
North Africa & Middle East	102.58	126.57	108.81	112.57	111.28	105.73
South Asia						
South Asia	19.21	20.70	35.99	40.10	41.08	51.66
Sub-Saharan Africa						
Southern Sub-Saharan Africa	64.09	95.84	109.36	145.11	103.91	116.52
Eastern Sub-Saharan Africa	26.59	39.02	37.26	43.67	38.22	49.41
Central Sub-Saharan Africa	52.35	51.27	51.22	50.90	50.24	55.91
Western Sub-Saharan Africa	28.85	45.81	41.51	60.09	41.31	57.60

$y = -101.0 \times x + 185.4$. Similarly, the DALYs were negatively correlated with the SDI ($r = -0.3071$, $p < 0.001$) and the DALY rate was $y = -2626 \times x + 4305$. Gender differences were calculated as the difference in the values of the males minus values of the females. Male gender was positively correlated with mortality ($r = 0.1446$, $p = 0.039$, $y = 30.39 \times x + 24.58$) and a similar trend in the DALY rate ($r = 0.1455$, $p = 0.042$, $y = 801.0 \times x + 661.2$) was found (Figure 4a,b). The same results were found when we calculated the gender ratio as the males rate divided by the female rate, and the gender ratio was positively correlated with mortality ($r = 0.5761$, $p < 0.0001$, $y = 0.9911 \times x + 0.8555$), showing a similar trend in the DALY rate ($r = 0.5844$, $p < 0.001$, $y = 1.143 \times x + 0.8983$) (Figure 6c,d).

Leading causes of deaths and DALYs from NCDs attributable to dietary risks

Of the 23 NCDs attributable to dietary risks in the GBD data system, we analysed the top 15 causes (Figure 5). The top 10 causes of deaths or DALYs worldwide by NCDs attributable to dietary risks in 2019 were ischaemic heart disease, stroke, diabetes mellitus, colon and rectal cancer, hypertensive heart disease, chronic kidney disease, tracheal, bronchial and lung cancer, oesophageal cancer, stomach cancer, and breast cancer. The mortality of ischaemic heart disease ranked first in both males (78.7, 64.1, 92.1) and females (48.3, 39.0, 58.0). This was followed by stroke and colon and rectal cancer among males and stroke and diabetes mellitus among

TABLE 2 Age-standardised disability-adjusted life-years rates (per 100,000 population) from non-communicable diseases (NCDs) attributable to dietary risks by Global Burden of Disease (GBD) super regions in 1990, 2010 and 2019

GBD 2017 super region	1990		2010		2017	
	Male	Female	Male	Female	Male	Female
High-income						
High-income Asia Pacific	871.31	645.02	800.84	429.71	739.53	417.76
Western Europe	1909.00	1190.72	1502.04	1012.49	1418.04	995.91
Australasia	1922.86	1445.87	1562.10	1244.55	1557.16	1234.07
High-income North America	2476.10	1940.72	2573.01	1928.34	2608.61	1934.05
Southern Latin America	2144.09	1475.48	2406.27	1725.96	2295.52	1695.87
Eastern Europe/Central Asia						
Central Europe	3544.25	2688.78	3259.03	2220.21	2956.59	2044.57
Eastern Europe	3298.36	2665.21	4752.83	3012.38	4079.69	2615.02
Central Asia	3331.24	2902.48	4388.96	3506.48	4389.45	3323.16
Latin America & Caribbean						
Tropical Latin America	2392.87	2135.43	2400.90	2105.44	2363.55	2020.70
Central Latin America	2149.59	2453.11	2532.96	2464.81	2721.79	2491.06
Andean Latin America	1426.23	1508.51	1790.89	1857.47	1694.08	1819.08
Caribbean	2263.76	2544.95	2451.05	2464.74	2653.13	2549.48
Southeast/East Asia & Oceania						
Southeast Asia	933.32	1059.30	1740.39	1735.65	2034.52	1901.45
East Asia	840.38	798.02	1291.83	1005.84	1501.54	1106.54
Oceania	4124.45	4409.01	5875.24	6017.02	5757.12	5802.55
North Africa & Middle East						
North Africa & Middle East	2996.19	3669.89	3285.44	3344.26	3295.64	3203.39
South Asia						
South Asia	573.88	639.54	1293.53	1242.45	1616.75	1596.83
Sub-Saharan Africa						
Southern Sub-Saharan Africa	2108.25	2923.45	3117.55	3881.55	2813.43	3229.96
Eastern Sub-Saharan Africa	796.09	1074.63	1149.40	1282.09	1202.59	1470.09
Central Sub-Saharan Africa	1551.75	1455.85	1543.98	1552.37	1789.40	1755.65
Western Sub-Saharan Africa	903.03	1327.75	1311.74	1787.66	1341.35	1720.15

Colour from green to red represent the corresponding space value.

females. Males and females shared the top three causes of DALY rates: ischaemic heart disease, stroke and diabetes mellitus. The rankings of five diseases on the numbers of deaths, including diabetes mellitus, tracheal, bronchial and lung cancer, chronic kidney disease, breast cancer, and atrial fibrillation and flutter rose by 72.3%, 39.0%, 72.2%, 37.5 and

69.9%, respectively, from 1990 to 2010, and by 31.6%, 14.7%, 27.9%, 20.4% and 38.6%, respectively, from 2010 to 2019. However, the rankings on the numbers of deaths of colon and rectal cancer, stomach cancer, oesophageal cancer, rheumatic heart disease, and cardiomyopathy and myocarditis declined in 1990–2019, and deaths from rheumatic heart

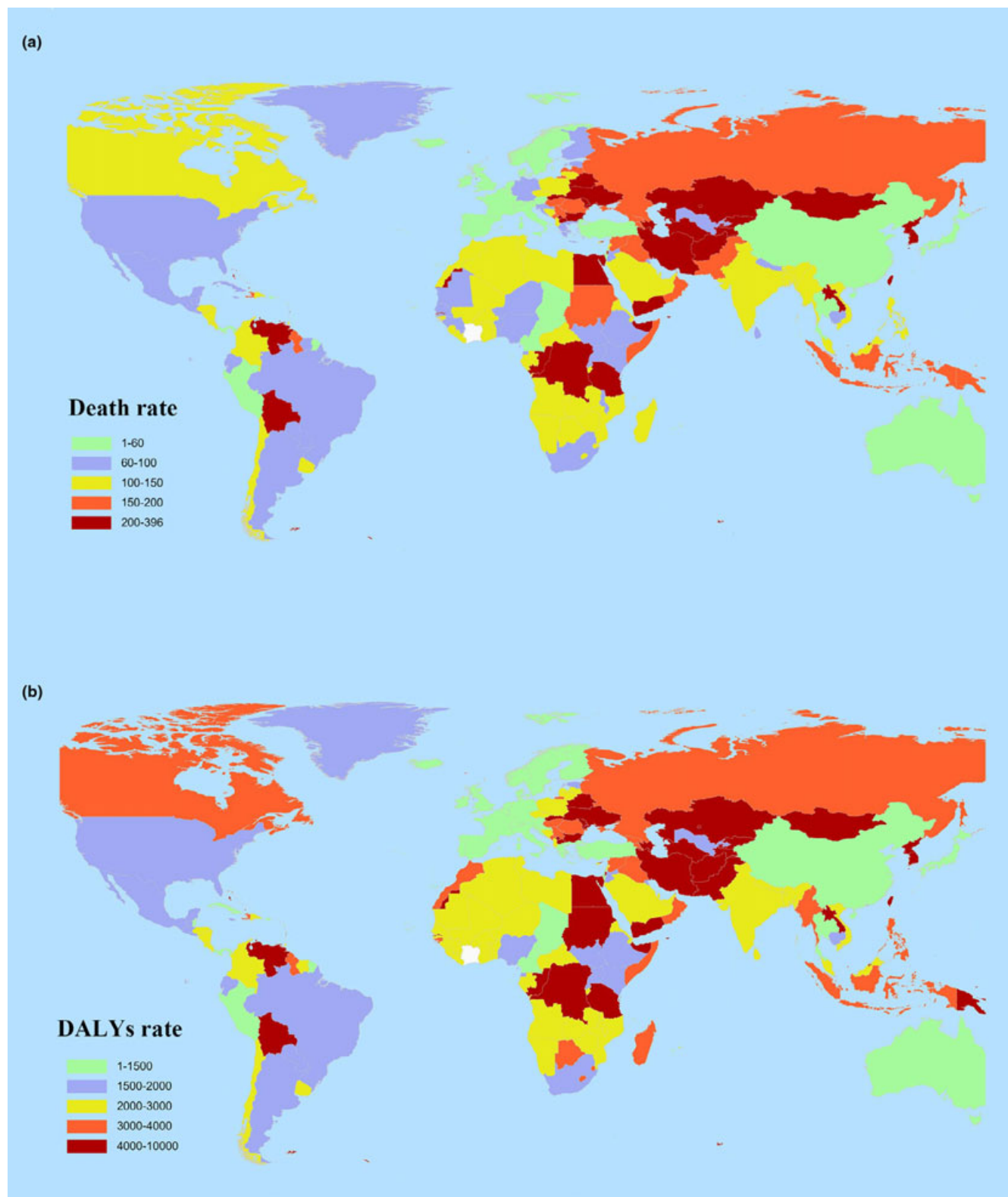


FIGURE 3 Global map of non-communicable disease burden attributable to dietary risks in 2019. (a) death rate (b) DALYs rate. DALYs, disability-adjusted life-years

disease showed a significant downward trend after 1990 (Figure 5a).

The five leading causes of death from ischaemic heart disease, stroke, colon and rectal cancer, diabetes mellitus,

and hypertensive heart disease increased by 27.6%, 16.2%, 63.5%, 72.3% and 3.5%, respectively, during 1990–2010. In 2010–2019, the five leading causes of death from ischaemic heart disease, stroke, diabetes mellitus, colon and rectal

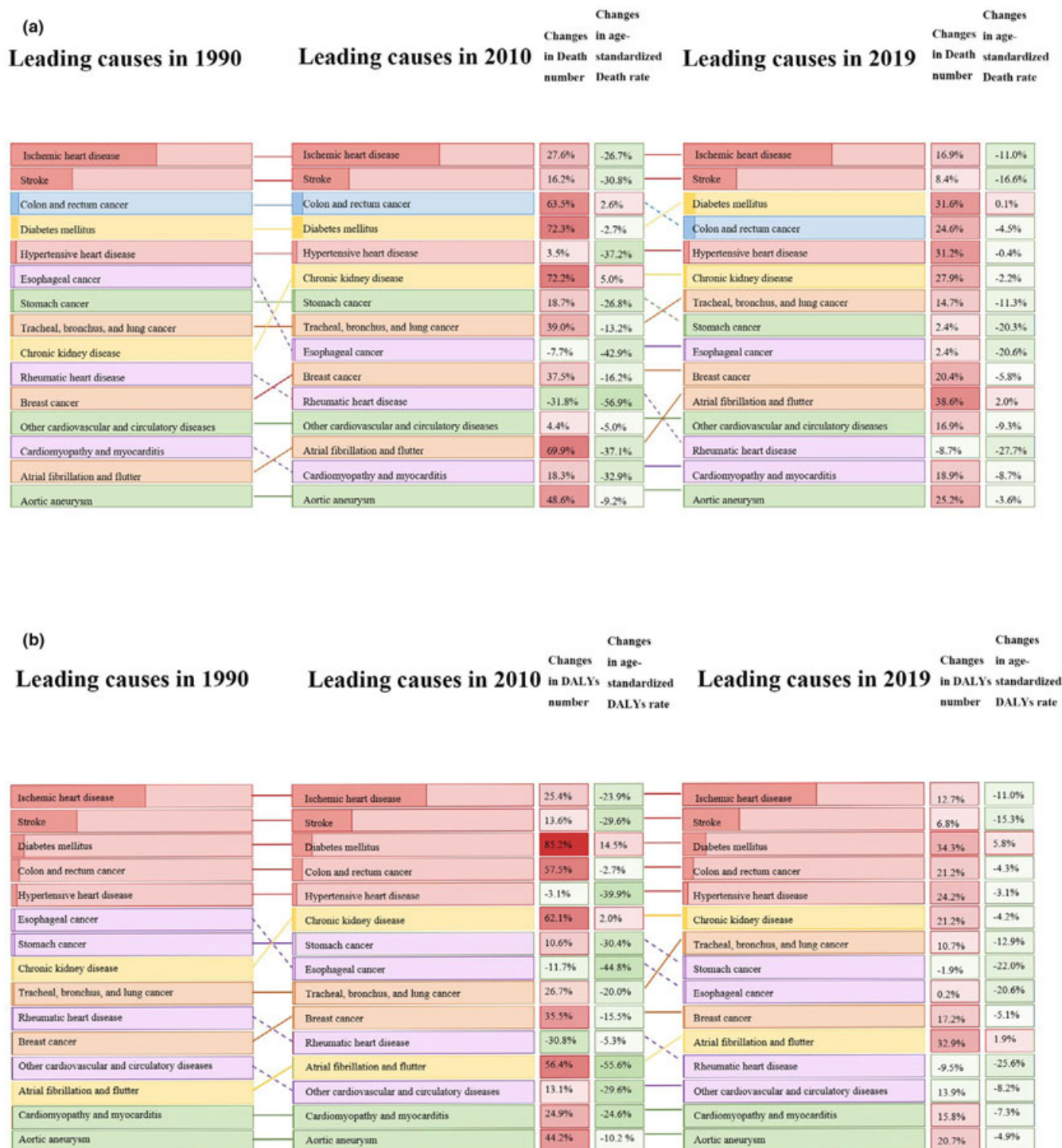


FIGURE 4 Leading causes of deaths and disability-adjusted life-years (DALYs) from non-communicable diseases attributable to dietary risks in 1990–2019. Here we describe the leading causes change in 1990, 2010 and 2019. In general, leading 5 causes of deaths and DALYs were unchanged in the past 29 years

cancer, and hypertensive heart disease increased by 16.9%, 8.4%, 31.6%, 24.6% and 31.2%, respectively (Figure 5a). The ranking of diabetes rose from fourth to third. A similar trend was found in the numbers of DALYs, with an 85.2% and 34.3% increase during the two periods, respectively. The top five causes of DALYs remained stable in the two periods (Figure 5b).

Leading risks of deaths and DALYs from NCDs attributable to dietary risks

The top five dietary risks for death or DALYs attributable to NCDs remained stable during the two periods. These risks during 1990–2019 included diets high in sodium, low in whole grains, low in legumes, low in fruits and high in

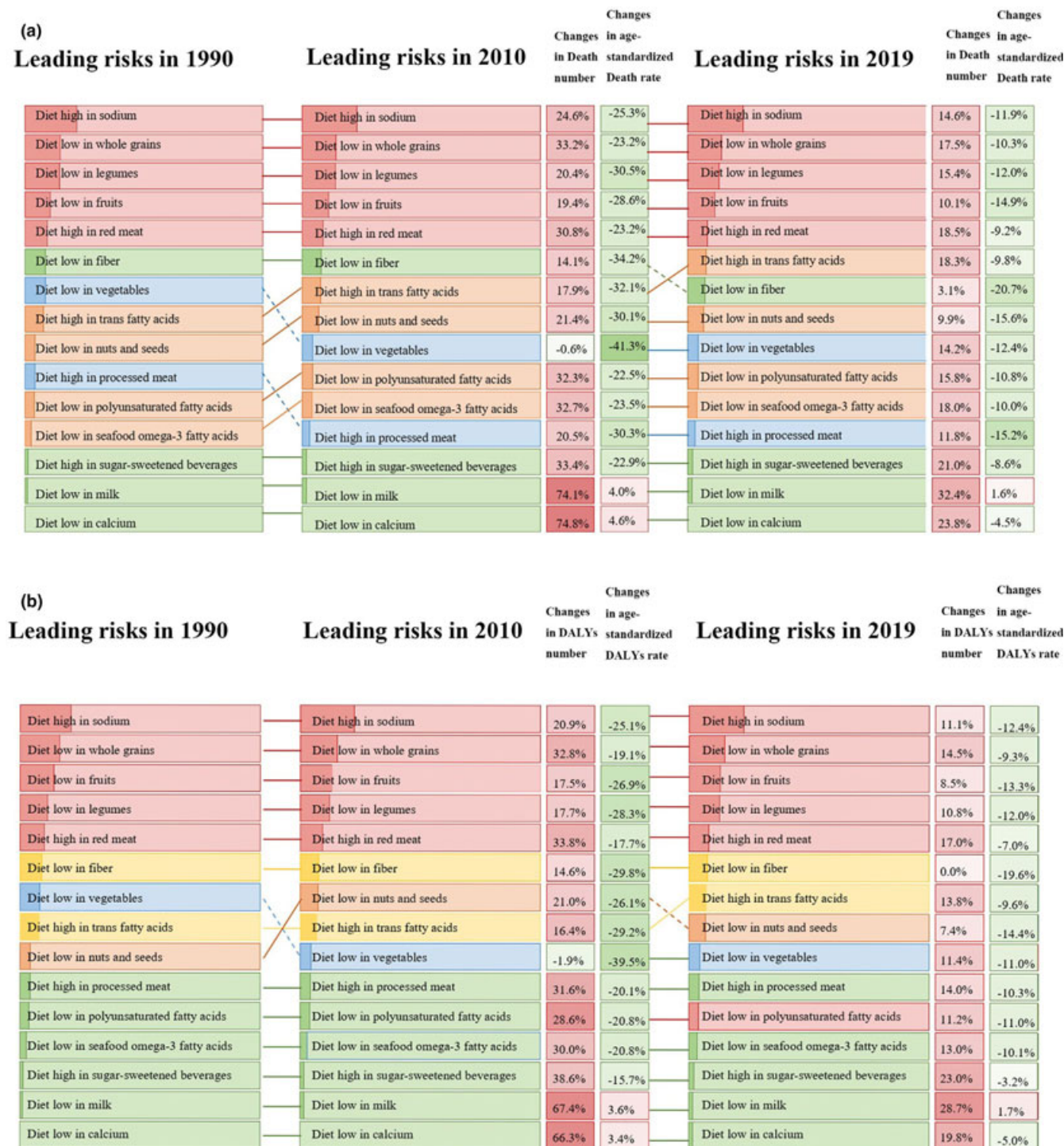


FIGURE 5 Leading causes of deaths and disability-adjusted life-years (DALYs) from non-communicable diseases attributable to dietary risks in 1990–2019. Here we describe the leading causes change in 1990, 2010 and 2019. In general, leading 5 causes of deaths and DALYs were unchanged in the past 29 years

red meat. Diets high in trans fats increased significantly during the two periods by 17.9% and 18.3%, respectively, from a ranking of eighth to sixth. The other three diet risks, including diets low in nuts and seeds, low in polyunsaturated fatty acids, and low in omega-3 fatty acids, moved up one place during the past 29 years. The rankings of diets low in nuts

and seeds moved from ninth to eighth, and the rankings of diets high in trans fats remained at eighth in 1990–2019, as measured by the DALYs (Figure 6b). However, diets low in vegetables and high in processed meat, showed large declines in rankings (Figure 6a), and diets low in vegetables declined by 39.5%, and the DALY rate declined by 11.0% (Figure 6b).

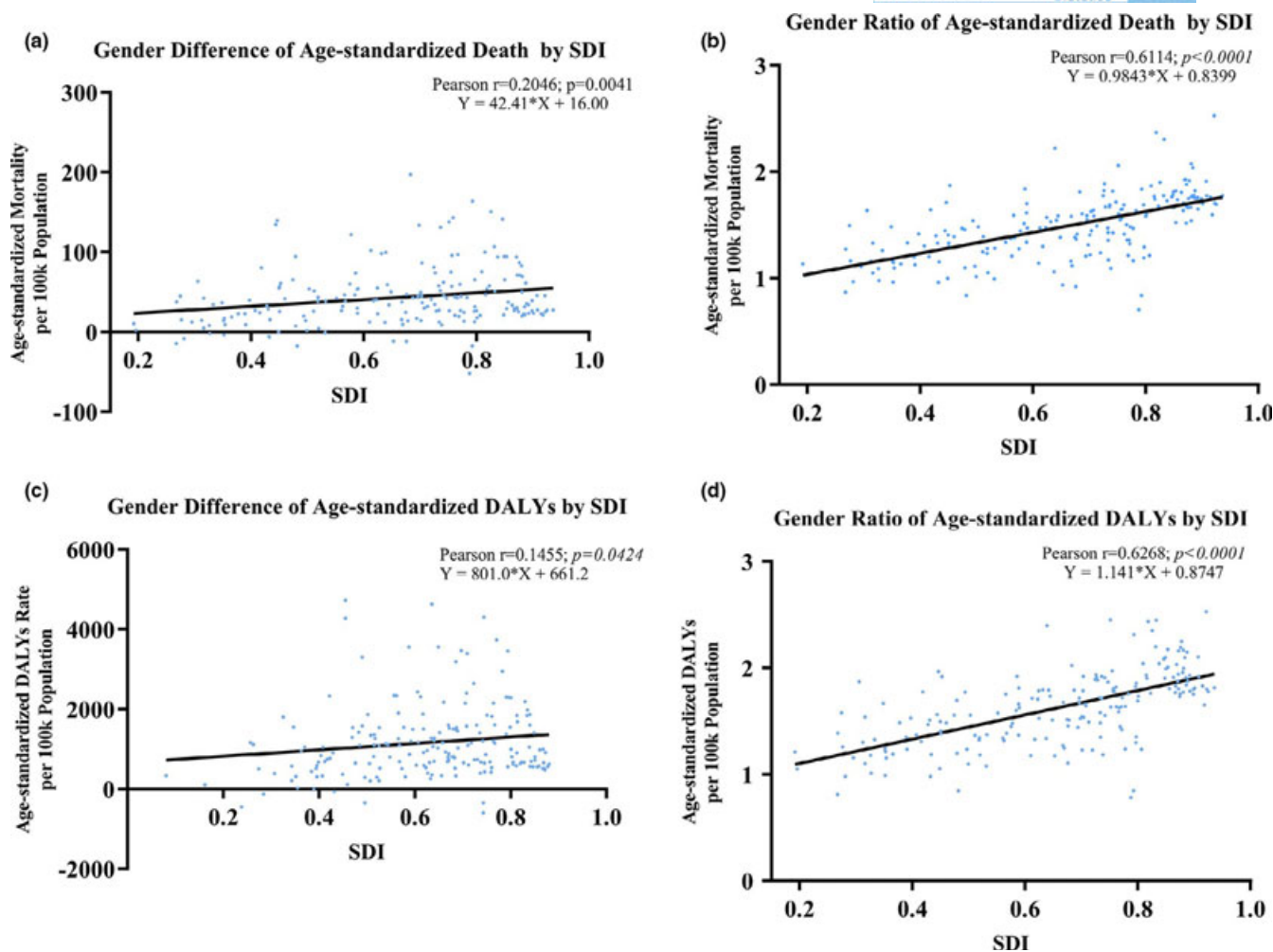


FIGURE 6 Burden of non-communicable diseases attributable to dietary risks by socio-demographic index (SDI) and gender in 2019. (a) showed the age-standardised mortality of both genders combined was negatively associated with SDI $y = -101.0 \times x + 185.4$ ($r = -0.2598$, $p < 0.001$). (b) showed the DALYs were negatively correlated with the SDI $y = -2626 \times x + 4305$ ($r = -0.3071$, $p < 0.001$). (c) and the gender ratio was positively correlated with mortality ($r = 0.5761$, $p < 0.0001$, $y = 0.9911 \times x + 0.8555$) (d) show a similar trend in the DALY rate ($r = 0.5844$, $p < 0.001$, $y = 1.143 \times x + 0.8983$). DALYs, disability-adjusted life-years

DISCUSSION

The results obtained in the present study support reports of trends in deaths and DALYs from NCDs attributable to dietary risks by age, sex and region in 204 countries from 1990 to 2019. Dietary risk-related NCDs accounted for an increase in all-cause deaths from 18.9% to 22.7%, as well as all-cause DALYs from 9.9% to 15.5%, over the past 29 years. We concluded that 7.9 million deaths and 187.7 million DALYs from NCDs worldwide in 2019 were related to dietary risks that increased 146.7% compared to the 1990 increase of 142.1%. Both mortality and DALY rates decreased significantly, after age was standardised to adjust for population and age structure, indicating an overall increase in the numbers of deaths and DALYs related to population growth and the ageing population. During the same period, the proportion of dietary risk-related deaths and DALYs remained stable; these trends might have been driven by decreases in background mortality. In 2019, dietary risk-related cardiovascular disease accounted for 85.5% of deaths and 80.8% of DALYs;

dietary risk-related cancers accounted for 7.6% of deaths and 7.4% of DALYs; and dietary risk-related diabetes accounted for 4.8% of deaths and 9.6% of DALYs.

Given the overall changes in the DALYs and deaths from dietary risks-related NCDs, the rates are controversial. We suspect that the increase in the numbers of deaths and DALYs might have resulted from population growth and an ageing population.

The analysis by age revealed a single-peak distribution of numbers of deaths or DALYs of both genders. The all-age adjusted mortality and DALY rates increased significantly with age, supporting age as the risk factor with the greatest impact. Gender disparities have fluctuated over the past 29 years. Males had a higher numbers of deaths and DALYs than females at a relatively young age, and females exceeded those numbers at age 80–84 years. After the data were adjusted, no gender differences were found in the overall rates across all ages. We speculate that the intersection might have been related to a significantly higher life expectancy of females.

The analysis by location showed that countries with the highest numbers of deaths or DALYs were China, India, the Russian Federation, the USA and Indonesia, which have larger populations. After the data were standardised by population and age structure, the countries with the highest death rates and DALYs were Uzbekistan and the Solomon Islands, respectively. The burden of dietary risk-related NCDs was negatively associated with the SDI. Except for the high SDI regions, all regions experienced significant increases in the numbers of deaths and DALYs. People in higher socio-economic groups were more likely to have healthier diets, characterised by a high intake of fruits and vegetables and low in intake of trans fats and processed foods.⁷ People in low- and middle-income countries had a large increase in NCDs and their risk factors, which were considered outcomes of urbanisation, nutritional transition (from a traditional diet to a classical western diet) and an ageing population.^{8,9} However, people in high-SDI regions consumed more fat, salt and processed foods.¹⁰ Thus, many factors have contributed to sharp increases in the dietary risk-related disease burden worldwide, which might not simply be associated with socio-economic level, but largely with personal determining factors.

Dietary habits depend on total monthly income, with low incomes more likely to result in poor eating and feeding habits and food insecurity. Low SDI regions have less access to healthy foods and high-quality medical care because of the high costs of fresh food and medical services, which are barriers to early education, screening, diagnosis and treatment of NCDs. High SDI regions have more access to fresh fruits and vegetables and medical education, increasing awareness of disease prevention and healthy lifestyles.

Gender-specific disparities were found at several levels in the present study. Males of different ages living in different SDI regions suffered more than females, as measured by deaths and DALYs from 1990 to 2019. These differences might be related to the higher mortality and DALY rates of cardiovascular disease and cancer among males under age 70 years.^{11,12} The age of the males with the highest number of deaths or DALYs was much younger than the age of the females, which may be attributed to the protective effects of oestrogen before menopause. Oestrogen has anti-oxidant and anti-apoptotic effects on cardiomyocytes in ischaemia.¹³ The high burden of NCDs in males may be attributed to the less attention paid to body mass index because high-caloric food intake and high consumption of alcohol are more likely found in males. This finding could have partially been a result of the greater exposure of males to potentially aggravating factors (e.g., less physical activity, more smoking and work-related stress).

Differences in deaths or DALYs rates by gender difference and ratio were positively associated with the SDI. However, in some relatively low-SDI regions, females had a greater burden of NCDs attributed to dietary risks, consistent with previous studies.^{14,15} In the present study, the death and DALY rates of females exceeded those of males in a few low SDI regions. The reasons may be related to less education and medical-care access and high body mass index in low-SDI

countries.¹⁶ Therefore, target measures are crucial for males and females from different socio-economic contexts. The leading causes of deaths or DALYs from NCDs attributable to dietary risks included ischaemic heart disease, stroke, diabetes mellitus, stomach cancer, colon and rectal cancer, and hypertensive heart disease, related to diets high in sodium sugar,^{16–20} saturated fats, trans fats, and low in omega-3 fatty acids and fibre.^{15–19} Diabetes-related deaths and mortality have increased over the past 29 years, as indicated by DALYs. The global health and financial burdens of diabetes have increased, and are expected to grow in the coming years, which indicates that diabetes is a public health threat worldwide. Implementation of cost-effective treatments, early diagnosis and prevention strategies for diabetes are strongly encouraged. Nevertheless, the DALY and mortality rates of rheumatic heart disease have declined, which is likely related to the high cure rate of rheumatism from the wide use of penicillin. However, the prevalence of dietary-related gastrointestinal cancer remains high, with a significant decline in the death and DALY rates. Another interesting phenomenon is the increase in the mortality and DALY rates of atrial fibrillation and flutter related to dietary risks since 1990; however, a PubMed search on this topic did not reveal a potential research direction.

Although sodium, sugar and fat have been considered as killers in public health, our analysis shows that the leading dietary risk factors for mortality and DALYs are diets high in sodium and low in whole grains, fruits, legumes, fibre, vegetables and omega-3 fatty acids, each one causing more than 2% of global deaths. We found that people in regions with high numbers of deaths and DALYs from NCDs (e.g., China) are more likely to have high-sodium intake. Dietary risk-related NCDs attributable to diets low in milk and calcium consumption are associated with rising DALYs. Hence, promoting and improving the intake of some dietary nutrients (i.e., calcium) and reducing the intake of others (i.e., sodium and fat) deserve attention.

In the present study, we conducted a comprehensive analysis of data from the GBD website on dietary risk-related NCDs during 1990–2019. To our knowledge, our study offers the most comprehensive, accurate and up-to-date information about the burdens of dietary risks by year, age, sex, SDI level and region. It also provides an overview of the leading causes of NCDs attributable to dietary risks.

Our study has limitations. First, as with other analyses of disease burden, our study has the same methodological limitations as the 2019 GBD study. Second, dietary risks might be just one of several high risks for NCDs because the GBD data have unavoidable confounding factors. We could not eliminate the confounding factors in dietary risk-related NCDs from other causes.

CONCLUSIONS

This evaluation of the burdens of NCDs attributable to dietary risks in the present study showed a continuous global

trend in the growth of dietary risk-related NCDs. The mortality and DALY rates showed a decreasing trend by year. However, age distribution and calendar year showed substantial differences between the male and female groups, with males in countries having lower SDIs showing a greater disease burden as a result of dietary risks. Thus, we recommend the implementation of cost-effective policies that promote optimal dietary intake as a preventive measure to avoid the occurrence of NCDs.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported. The reporting of this work is compliant with CONSORT1/STROBE2/PRISMA3 guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

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CONFLICT OF INTEREST

There are no conflicts of interest.

AUTHOR CONTRIBUTIONS

JQ analysed and interpreted all of the data from the dataset, and was a major contributor to the writing of the manuscript. XL completed the graphic drawings. YW, XH, XP, JX and JYW downloaded and sorted the data from the website. All authors read and approved the final version of the manuscript submitted for publication.

PEER REVIEW

The peer review history for this article is available at <https://publons.com/publon/10.1111/jhn.12904>.

DATA AVAILABILITY

The datasets generated and/or analysed during the current study are available at [http://www.healthdata.org/gbd/2019\[21\]](http://www.healthdata.org/gbd/2019[21]).

ORCID

Jie Qiao  <https://orcid.org/0000-0001-7601-7341>

Peng-Fei Shan  <https://orcid.org/0000-0002-6684-9395>

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