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The global disease burden attributable to a diet low in fibre in 204 countries and territories from 1990 to 2019

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Abstract

Objective: The relationship of a diet low in fibre with mortality has not been evaluated. This study aims to assess the burden of non-communicable chronic diseases (NCD) attributable to a diet low in fibre globally from 1990 to 2019.

Design: All data were from the Global Burden of Disease (GBD) Study 2019, in which the mortality, disability-adjusted life-years (DALY) and years lived with disability (YLD) were estimated with Bayesian geospatial regression using data at global, regional and country level acquired from an extensively systematic review.

Setting: All data sourced from the GBD Study 2019.

Participants: All age groups for both sexes.

Results: The age-standardised mortality rates (ASMR) declined in most GBD regions; however, in Southern sub-Saharan Africa, the ASMR increased from 4·07 (95 % uncertainty interval (UI) (2·08, 6·34)) to 4·60 (95 % UI (2·59, 6·90)), and in Central sub-Saharan Africa, the ASMR increased from 7·46 (95 % UI (3·64, 11·90)) to 9·34 (95 % UI (4·69, 15·25)). Uptrends were observed in the age-standardised YLD rates attributable to a diet low in fibre in a number of GBD regions. The burden caused by diabetes mellitus increased in Central Asia, Southern sub-Saharan Africa and Eastern Europe.

Conclusions: The burdens of disease attributable to a diet low in fibre in Southern sub-Saharan Africa and Central sub-Saharan Africa and the age-standardised YLD rates in a number of GBD regions increased from 1990 to 2019. Therefore, greater efforts are needed to reduce the disease burden caused by a diet low in fibre.

Keywords
Diet low in fibre
Global Burden of Disease
Disability-adjusted life-year
Years lived with disability

Non-communicable chronic diseases (NCD) account for a major proportion of the total disease burden worldwide. A suboptimal diet, one of the major risk factors for NCD, can be due to several poor dietary habits (e.g. consuming a diet low in fruits, wholegrains or fibre). The burden of disease attributable to a suboptimal diet has increased dramatically in recent decades[1,2]. A diet low in fibre is defined as a mean daily intake of fibre from all sources, including fruits, vegetables, grains, legumes and pulses, of less than 23·5 g/d[1]. Some studies have revealed that a diet low in fibre is closely associated with increased burdens of diseases such as diabetes mellitus, stroke, colon and rectum cancer (CRC), and ischemic heart disease (IHD)[3,4].

Dietary fibre, an edible part of plant food and fruits that is not digestible or absorbable, is considered beneficial to human health and an important component in a healthy

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diet. The Global Burden of Disease (GBD) Study showed that a diet low in fibre is closely associated with the burden of IHD and CRC[1]. Epidemiological evidence has shown that a 10 g/d increase in dietary fibre intake reduces the IHD risk by 15 % and the CRC risk by 13 %[5,6]. IHD is one of the leading NCD, and several studies have shown that the risk of IHD could be decreased by reducing blood pressure and serum cholesterol levels through the intake of plenty of dietary fibre[7,8]. Moreover, dietary fibre may reduce the disease burden imposed by CRC through several complex mechanisms, such as increasing the volume of faeces, decreasing the concentration of faecal carcinogens and reducing exposure of the colorectum to carcinogens by shortening the time required for faeces to pass through the intestine[9]. In addition, through bacterial fermentation, dietary fibre produces anticarcinogenic SCFA, which have a positive impact on CRC[9]. Dietary fibre may eliminate several environmental pathogens related to IHD and CRC by promoting the activity of several enzymes (e.g. glutathione S-transferase, cytochrome P450 and dihydrouracil dehydrogenase). Evidence from four studies showed that the relative risk for stroke was 0·74 in the highest quintile of dietary fibre group compared with the lowest quintile group[10–13]. Moreover, several prospective studies indicate that the intake of a high-fibre diet reduces the prevalence of diabetes. The underlying mechanisms are associated with reductions in postprandial glycemia and insulinemia and the enhancement of insulin sensitivity[14,15].

According to the GBD Study 2017, dietary risk factors contribute to 11 million (95 % uncertainty interval (UI) (10, 12)) deaths and 255 million (95 % UI (234, 274)) disability-adjusted life-years (DALY). Moreover, 11·8 % of all CRC deaths and 8·6 % of all IHD deaths worldwide are attributable to a diet low in fibre[3]. Increasing attention has been paid to diets low in fibre as an important dietary risk factor worldwide. However, the burden of NCD attributable to diets low in fibre has not been systematically estimated. In our study, we examined age-standardised mortality rates (ASMR), age-standardised rate of DALY (ASDR), and age-standardised years lived with disability (YLD) of IHD, stroke, CRC, and diabetes mellitus attributable to a diet low in fibre across 204 countries and territories from 1990 to 2019. Additionally, we calculated the estimated annual percentage change (EAPC) of ASMR to estimate its change trend from 1990 to 2019 with the linear regression model[16] and explored the relationship between sociodemographic index (SDI) and ASMR, and ASDR attributable to diets low in fibre using a Gaussian process regression[17]. The results would provide useful information to help develop effective health-promoting strategies (e.g. guidance through public policy and lifestyle advocacy in specific regions, community-based intervention strategies to change the dietary habits of specific populations, etc.) to reduce the disease burden related to a diet low in fibre in different regions in the future.

Materials and methods

Data source

A diet low in fibre is one of the risk factors in the dataset of the GBD Study 2019, a multinational collaborative research programme to estimate disease burdens in different regions and countries[18,19]. The GBD Study is updated annually, representing a persistent effort and providing an appropriate data source for consistent comparisons of disease burdens from 1990 to 2019 by age and sex in different locations. Moreover, standard epidemiological measures, such as incidence, prevalence, and death rates, and summary measures of health, such as DALY, YLD, and years of life lost prematurely (YLL), are provided in the GBD dataset. DALY, YLL and YLD are estimated from life tables, estimates of prevalence and disability weights. All data sources can be acquired via the GBD Compare website (http://ghdx.healthdata.org/gbd-results-tool), and all input data are identified via the Global Health Data Exchange website (https://ghdx.healthdata.org/). The study was performed in compliance with the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) guidelines for reporting health estimates[18]. Details of the general methodology used in the GBD Study have been extensively described elsewhere[20,21]. The comparative risk assessment, an important analytical method, was used to gather data and estimate each risk factor's relative contribution to disease burden[18,22]. Then the study used Cause of Death Ensemble model (CODEm), a type of Bayesian geospatial regression analysis, and 95 % UI to estimate the burden of disease attributable to four levels of eighty-seven environmental, occupational, metabolic and behavioural risk factors[19,23]. In brief, first, the GBD Study determined the relative risk value of the risk and outcome after the correlation was confirmed by referencing meta-analysis and literature. Second, the mean exposure level of the risk was estimated using Bayesian meta-regression model (DisMod-MR 2.1) and spatiotemporal Gaussian process regression model (ST-GPR) based on population-based survey or report. Third, the theoretical minimum risk exposure level (TMREL) and population-attributable fraction (PAF) were determined. The PAF was calculated using the special formula:

$$\mathrm{PAF}_{\mathrm{oasct}} = \frac{\int_{x=1}^{u} RR_{oas}(x)P_{asct}(x)dx - RR_{oas}(\mathrm{TMREL})}{\int_{x=l}^{u} RR_{oas}(x)P_{asct}(x)dx},$$

where $RR_{\mathrm{oas}}(x)$ was the relative risk as a function of exposure level (x) for diet low in fibre, cause (o), age group (a) and sex (s)[18]. Pasct (x) was the distribution of exposure of a diet low in fibre according to age group (a), sex (s), country (c) and year (t). The lowest level of observed exposure (l) and the highest level of observed exposure (u) were described in the denominator. Finally, the above values were used to estimate the disease burden attributable to a diet low in fibre. The study used misclassification correction, garbage code redistribution and noise reduction algorithms to minimise heterogeneity, bias, or confounding and improve comparability[1,18,19]. UI were calculated by 1000 draw-level estimates for each parameter and could reflect measurement errors in the presence of missing data[18].

Definitions of a diet low in fibre and associated outcomes

A diet low in fibre was defined as an average daily consumption of less than 23·5 g/d of fibre derived from all sources, including fruits, grains, vegetables, legumes and pulses[1]. Across the GBD surveys, the definition of a diet low in fibre was standardised, and the exposure level was adjusted for a 2000 kcal/d diet using a residual method[1]. Each outcome of a diet low in fibre was also standardised. According to the WHO definition, stroke contains three separate subcategories, including ischemic stroke, intracerebral hemorrhage and subarachnoid hemorrhage[24]. IHD was defined as I20 to I25, diabetes as E10–E14 and CRC as C18–C21 according to the International Statistical Classification of Diseases, Tenth Revision (ICD-10)[25].

Statistical analysis

In this study, ASMR, ASDR and the age-standardised YLD rates with 95 % UI were calculated to evaluate the burden of disease attributable to a diet low in fibre. We used age-standardised rates (ASR) (per 100 000 population) and EAPC with 95 % CI in the ASMR, ASDR and age-standardised YLD rate to reflect the changes in trends from 1990 to 2019. The ASR was calculated with the specific formula:

$$ASR = \frac{\sum_{i=1}^{A} aiwi}{\sum_{i=1}^{A} wi} \times 10,000,$$

where *ai* represents the specific age ratio and *wi* represents the number of persons (or weight)[26]. In the study, we applied EAPC, an indicator that assessed trends in ASR over time, to estimate the trend of ASMR attributable to diet low in fibre. The natural logarithm of ASR was assumed to conform to linear over time, then the ASR was input into the regression model: $\ln(\text{ASR}) = \alpha + \beta X + \epsilon$, where X is calendar year and ϵ is the error term. Then EAPC was calculated with the specific formula 100× (exp(β)-1), and the 95 % CI was obtained from the linear regression model[27]. In our study, the ASMR attributable to a diet low in fibre was considered to be on the increase if the lower boundary of 95 % CI was higher than zero. Conversely, if the upper boundary of 95 % CI was lower than zero, the ASMR was deemed to be decreasing. Otherwise, the ASMR was considered to be stable[26]. In addition, Gaussian process regression and Loess smoother models were used to explore the relation between SDI and ASMR, and ASDR is attributable to a diet low in fibre[1].

Results

Global disease burden attributable to a diet low in fibre

Although the death number, DALY and YLD increased globally, the ASMR, ASDR and age-standardised YLD rate attributable to a diet low in fibre decreased from 1990 to 2019. The ASMR declined from 14·84 (95 % UI (8·28, 21·43)) to 7·74 (95 % UI (4·37, 11·32)) for both sexes, with an EAPC of −2·39 (95 % CI (−2·54, −2·24)) in 1990–2019 (Table 1). The ASDR declined from 331·12 (95 % UI (192·52, 473·01)) to 186·89 (95 % UI (111·11, 268·42)) for both sexes, with an EAPC of −2·10 (95 % CI (−2·25, −1·94)) (see online Supplemental Table S1). The age-standardised YLD rate showed a downward trend similar to those for the ASMR and ASDR, declining from 24·95 (95 % UI (13·69, 37·72)) to 22·08 (95 % UI (11·72, 34·33)), with an EAPC of −0·45 (95 % CI (−0·49, −0·41)) from 1990–2019 (see online Supplemental Table S2).

Globally, the ASMR and ASDR in males were higher than those in females in both 1990 and 2019. The ASMR attributable to a diet low in fibre decreased from 17·16 (95 % UI (9·72, 24·71)) to 9·20 (95 % UI (5·29, 13·50)), with an EAPC of −2·24 (95 % CI (−2·38, −2·11)) in males and from 12·82 (95 % UI (7·24, 18·62)) to 6·44 (95 % UI (3·60, 9·36)), with an EAPC of −2·58 (95 % CI (−2·74, −2·42)) in females from 1990 to 2019 (Table 1). The ASDR decreased from 394·72 (95 % UI (225·41, 562·68)) to 228·85 (95 % UI (135·57, 330·26)) in males and from 271·65 (95 % UI (156·08, 388·80)) to 146·92 (95 % UI (86·56, 208·53)) for females from 1990 to 2019 (see online Supplemental Table S1). However, the age-standardised YLD rate attributable to a diet low in fibre in males was lower than that in females in both 1990 and 2019. The age-standardised YLD rate in males and females declined from 24·41 (95 % UI (13·68, 36·86)) to 22·05 (95 % UI (11·86, 34·07)), with an EAPC of −0·37 (95 % CI (−0·41, −0·33)), and from 25·45 (95 % UI (13·68, 39·00)) to 22·10 (95 % UI (11·63, 34·33)), with an EAPC of −0·52 (95 % CI (−0·57, −0·47)), respectively (see online Supplemental Table S2).

The burden of disease attributable to a diet low in fibre increased with age, and older people had the highest mortality rates (Fig. 1). The mortality rates attributable to a diet low in fibre in the 70–74, 75–79, 80–84, 85–89, 90–95 and 95 plus age groups showed downward trends from 1990 to 2019. The trends of IHD and stroke mortality rates attributable to a diet low in fibre were similar to the trend of the total burden of disease, while those of CRC and diabetes mellitus were stable from 1990 to 2019.

Disease burden attributable to a diet low in fibre in different sociodemographic index regions

All ASMR and ASDR attributable to a diet low in fibre showed a downward trend in different SDI regions from 1990 to 2019. The high-SDI region had the lowest ASMR,

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Table 1 The death cases and age-standardised mortality rates attributable to a diet low in fibre in 1990, 2019, and its temporal trends from 1990 to 2019 by sex, SDI and GBD regions

	1990				2019				1900–2019	
Characteristics	Death cases number × 10^3	95 % UI	ASMR	95 % UI	Death cases number × 10^3	95 % UI	ASMR	95 % UI	EAPC	95 % CI
Global	515·41	291·48, 749·52	14·84	8·28, 21·43	606·22	342·05, 887·47	7·74	4·37, 11·32	−2·39	−2·54, −2·24
Sex										
Male	268·19	151·96, 386·69	17·16	9·72, 24·71	325·00	187·10, 478·79	9·20	5·29, 13·50	−2·24	−2·38, −2·11
Female	247·21	138·95, 359·47	12·82	7·24, 18·62	281·22	157·29, 409·54	6·44	3·60, 9·36	−2·58	−2·74, −2·42
SDI quintile										
Low SDI	23·15	12·41, 35·07	11·30	6·05, 16·83	43·09	23·40, 63·35	9·16	4·99, 13·45	−0·85	−1·09, −0·61
Low-middle SDI	100·80	61·99, 140·18	19·09	11·83, 26·41	157·39	97·19, 226·57	12·67	7·81, 17·96	−1·45	−1·60, −1·31
Middle SDI	141·57	81·87, 202·97	16·33	9·42, 23·43	189·14	109·58, 275·89	8·57	4·95, 12·50	−2·14	−2·30, −1·97
High-middle SDI	119·57	62·13, 182·11	13·01	6·79, 19·83	117·10	60·07, 183·38	5·98	3·06, 9·37	−3·21	−3·64, −2·78
High SDI	130·01	69·58, 191·85	12·66	6·79, 18·62	99·13	54·15, 144·20	4·64	2·53, 6·76	−3·67	−3·82, −3·53
GBD regions										
Eastern Europe	37·29	17·89, 58·73	15·38	7·26, 24·43	42·44	20·25, 67·20	12·38	5·86, 19·67	−1·97	−2·85, −1·08
Australasia	3·15	1·59, 4·68	13·98	7·12, 20·75	2·19	1·19, 3·23	4·01	2·20, 5·87	−4·76	−4·95, −4·57
Central Latin America	5·17	2·82, 7·53	6·93	3·73, 10·09	10·20	5·51, 15·64	4·47	2·41, 6·87	−1·62	−1·79, −1·45
Tropical Latin America	13·63	7·62, 19·56	16·54	9·20, 23·83	13·61	7·64, 20·05	5·78	3·22, 8·54	−3·97	−4·23, −3·72
Southern Latin America	7·46	4·11, 10·71	17·70	9·69, 25·36	6·24	3·50, 8·99	7·39	4·14, 10·67	−2·81	−3·04, −2·58
Andean Latin America	2·30	1·23, 3·32	12·01	6·46, 17·56	3·14	1·85, 4·60	5·75	3·38, 8·42	−2·55	−2·75, −2·34
Caribbean	3·96	2·14, 5·83	16·15	8·68, 23·84	4·07	2·17, 6·12	7·88	4·18, 11·83	−2·67	−3·00, −2·34
High-income Asia Pacific	14·10	7·61, 20·83	8·03	4·38, 11·75	18·02	10·45, 25·96	3·39	2·01, 4·85	−2·87	−2·99, −2·74
East Asia	96·22	48·74, 153·21	13·55	7·03, 21·35	84·29	40·98, 140·36	4·77	2·34, 8·01	−3·23	−3·51, −2·95
Southeast Asia	69·64	46·67, 92·59	30·36	20·38, 40·25	120·27	75·60, 165·21	21·88	13·66, 30·06	−1·08	−1·18, −0·97
South Asia	91·43	53·56, 131·31	19·00	11·31, 26·93	151·63	89·02, 222·42	12·00	7·18, 17·45	−1·59	−1·86, −1·33
Central Asia	10·48	5·22, 15·83	24·88	12·39, 37·56	10·85	5·27, 16·93	18·60	8·78, 29·01	−2·03	−2·90, −1·15
Oceania	0·12	0·07, 0·19	4·48	2·58, 6·77	0·16	0·09, 0·25	2·67	1·58, 4·09	−1·79	−1·91, −1·67
North Africa and Middle East	14·51	7·07, 23·09	9·74	4·81, 15·47	23·96	12·31, 36·90	6·12	3·15, 9·50	−2·04	−2·21, −1·87
Eastern sub-Saharan Africa	3·65	1·87, 5·79	5·55	2·86, 8·78	5·51	3·09, 8·43	3·77	2·12, 5·78	−1·59	−1·70, −1·49
Southern sub-Saharan Africa	1·01	0·52, 1·57	4·07	2·08, 6·34	2·24	1·27, 3·37	4·60	2·59, 6·90	0·46	0·02, 0·91
Western sub-Saharan Africa	3·89	2·04, 6·16	5·43	2·87, 8·50	3·45	2·01, 5·11	2·30	1·36, 3·42	−3·27	−3·51, −3·04
Central sub-Saharan Africa	1·37	0·67, 2·21	7·46	3·64, 11·90	4·11	2·06, 6·71	9·34	4·69, 15·25	0·77	0·25, 1·30
Central Europe	20·71	10·03, 31·81	15·92	7·80, 24·56	17·52	8·80, 27·43	7·97	3·99, 12·53	−2·88	−3·20, −2·56
Western Europe	62·85	32·35, 93·46	10·82	5·55, 16·05	45·15	24·48, 66·58	4·18	2·23, 6·13	−3·59	−3·77, −3·41
High-income North America	52·49	27·77, 77·36	14·56	7·69, 21·49	37·19	19·15, 56·37	5·41	2·81, 8·19	−3·61	−3·80, −3·42

GBD, Global Burden of Disease; SDI, sociodemographic index; UI, uncertainty interval; ASMR, age-standardised mortality rate; EAPC, estimated annual percentage change; CI, confidence interval.

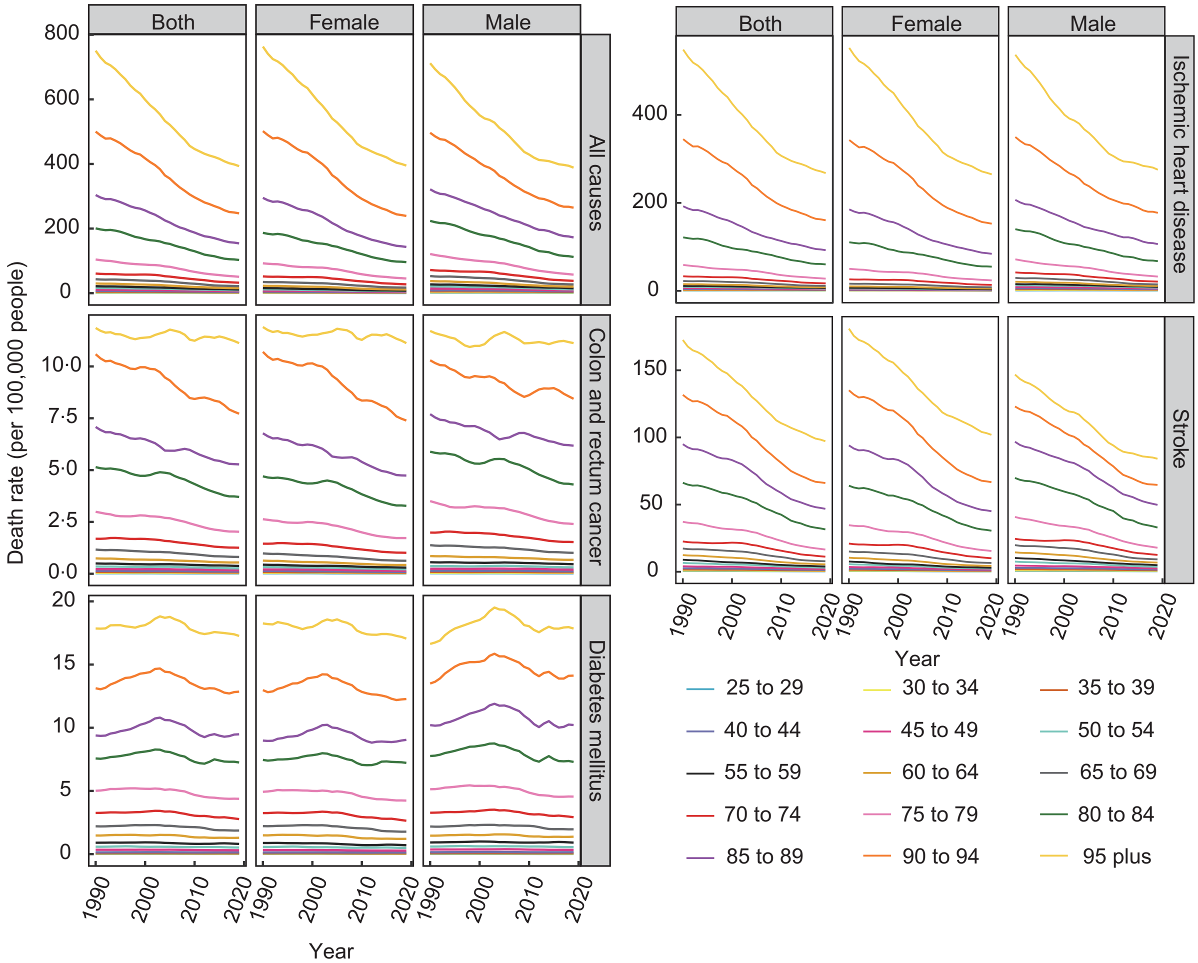

Fig. 1 Age-specific rate of deaths due to a diet low in fibre for males and females from 1990 to 2019

at 4·64, (95 % UI (2·53, 6·76)), and ASDR, at 105·06 (95 % UI (60·80, 149·92)), while low-middle-SDI region had the highest ASMR, at 12·67 (95 % UI (7·81, 17·96)), and ASDR, at 307·58 (95 % UI (191·05, 436·82)) in 2019. From 1990 to 2019, the EAPC in the ASMR attributable to a diet low in fibre were lower in the high-SDI region (−3·67, 95 % CI (−3·82, −3·53)) and high-middle-SDI region (−3·21, 95 % CI (−3·64, −2·78)) than in the middle-SDI region (−2·14, 95 % CI (−2·30, −1·97)), low-middle-SDI region (−1·45, 95 % CI (−1·60, −1·31)) and low-SDI region (−0·85, 95 % CI (−1·09, −0·61)) (Table 1). As shown in Supplemental Table S1, similar trends were observed for the ASDR in the different SDI regions. Intriguingly, the age-standardised YLD rate attributable to a diet low in fibre had different change patterns across the five SDI regions. In 2019, the age-standardised YLD rates in the middle- and low-middle-SDI regions were 23·38 (95 % UI (12·69, 35·58)) and 26·80 (95 % UI (14·65, 40·32)), respectively, which were higher than those in the high-SDI region (22·47, 95 % UI (11·75, 35·29)), low-SDI region (18·61, 95 % UI (9·46, 28·81)) and high-middle-SDI region (17·04, 95 % UI (8·72, 27·10)). From 1990 to 2019, the EAPC in the high- and low-SDI regions were 0·23 (95 % CI (0·10, 0·36)) and 0·21 (95 % CI (0·12, 0·31)), respectively, which were higher than those in the high-middle-SDI region (−0·89, 95 % CI (−1·05, −0·73)), middle-SDI region (−0·93, 95 % CI (−0·99, −0·87)) and low-middle-SDI region (−0·16, 95 % CI (−0·20, −0·11)) (see online Supplemental Table S2). However, upward trends of the age-standardised YLD rates were observed in the high- and low-SDI regions. Coincidentally, the summary exposure value of a diet low in fibre decreased from 1990 to 2019, and its trend was consistent with those of the ASMR and ASDR in different SDI regions (see online Supplemental Fig. S1). As shown in Fig. 2(a) and (b), the ASMR and ASDR initially showed an uptrend followed by a downward trend as the SDI increased. Moreover, the relationship of the ASMR with the SDI was similar to that of the ASDR with the SDI.

In summary, the ASMR and ASDR of the overall disease burden attributable to a diet low in fibre decreased in all five SDI regions from 1990 to 2019, and those of IHD and stroke showed similar trends (Fig. 3(a) and (b)). Although the ASMR and ASDR of CRC in the high-SDI region decreased, they were still higher than those in the other four SDI regions from 1990 to 2019. In addition, the ASMR and ASDR of CRC and diabetes mellitus

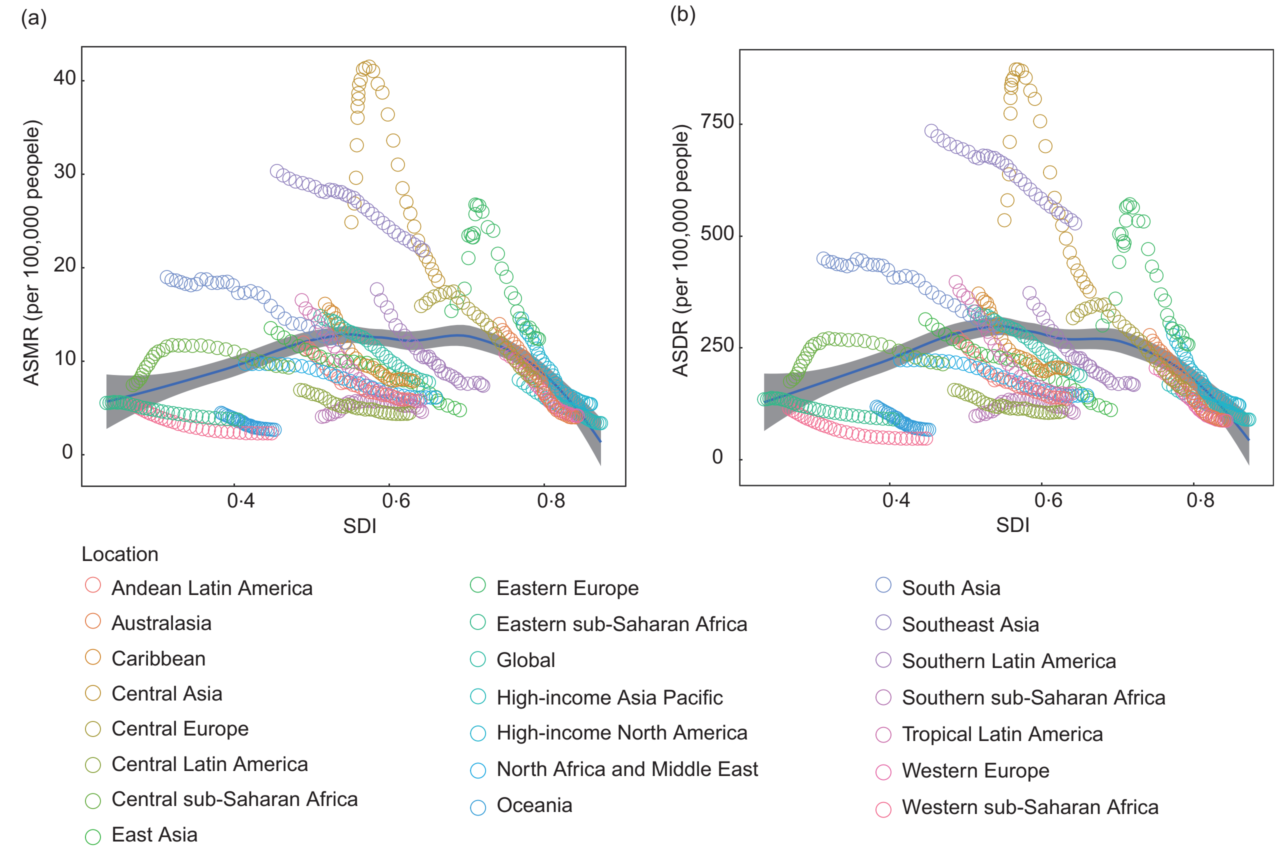

Fig. 2 ASMR and ASDR attributable to a diet low in fibre across twenty-one GBD regions by SDI for both sexes combined, 1990–2019. (a) ASMR; (b) ASDR. ASMR, age-standardised mortality rate; ASDR, age-standardised rate of disability-adjusted life-years (DALY); GBD, Global Burden of Disease; SDI, sociodemographic index

attributable to a diet low in fibre in the high-middle-, middle-, low-middle- and low-SDI regions were stable from 1990 to 2019. However, the age-standardised of YLD rates due to diabetes mellitus attributable to a diet low in fibre in the five SDI regions showed uptrends from 1990 to 2019 (Fig. 3(c)).

Disease burden attributable to a diet low in fibre in different Global Burden of Disease regions and countries

The ASMR of the disease burdens caused by a diet low in fibre in Southern sub-Saharan Africa and Central sub-Saharan Africa increased, although they decreased in most other GBD regions. The ASMR in Southern sub-Saharan Africa increased from 4·07 (95 % UI (2·08, 6·34)) to 4·60 (95 % UI (2·59, 6·90)), and that in Central sub-Saharan Africa increased from 7·46 (95 % UI (3·64, 11·90)) to 9·34 (95 % UI (4·69, 15·25)) from 1990 to 2019. The EAPC in the ASMR in Australasia was the lowest, with an ASMR decrease from 13·98 (95 % UI (7·12, 20·75)) to 4·01 (95 % UI (2·20, 5·87)), followed by Tropical Latin America (−3·97, 95 % UI (−4·23, −3·72)), High-income North America (−3·61, 95 % UI (−3·80, −3·42)) and Western Europe (−3·59, 95 % UI (−3·77, −3·41)) (Table 1). The ASDR attributable to a diet low in fibre in Central sub-Saharan Africa increased from 174·66 (95 % UI (87·00, 278·72)) to 213·16 (95 % UI (108·91, 341·76)), with an EAPC of 0·65 (95 % CI (0·12, 1·17)). The EAPC in the ASDR in Australasia was −4·34 (95 % CI (−4·50, −4·18)), which was lower than those in other GBD regions, and the ASDR in Australasia decreased from 397·20 (95 % UI (229·07, 561·62)) to 148·02 (95 % UI (85·35, 211·57)) from 1990 to 2019 (see online Supplemental Table S1). It is worth mentioning that the trends of the age-standardised YLD rates attributable to a diet low in fibre were different from those of the ASMR and ASDR. The age-standardised YLD rates in Central Latin America, Southern Latin America, High-income Asia Pacific, North Africa, the Middle East, Southern sub-Saharan Africa, Central sub-Saharan Africa and Western Europe increased from 1990 to 2019. Among the above areas, the EAPC in Central sub-Saharan Africa was 1·49 (95 % CI (1·07, 1·91)), which was the highest, with an increase in the age-standardised YLD rate from 13·26 (95 % UI (6·39, 22·16)) to 20·90 (95 % UI (9·83, 34·40)) from 1990 to 2019, followed by High-income Asia Pacific (0·90, 95 % UI (0·83, 0·97)), Central Latin America (0·71, 95 % UI (0·62, 0·81)), North Africa and the Middle East (0·45, 95 % UI (0·41, 0·49)), Western Europe (0·29, 95 % UI (0·23, 0·36)) and

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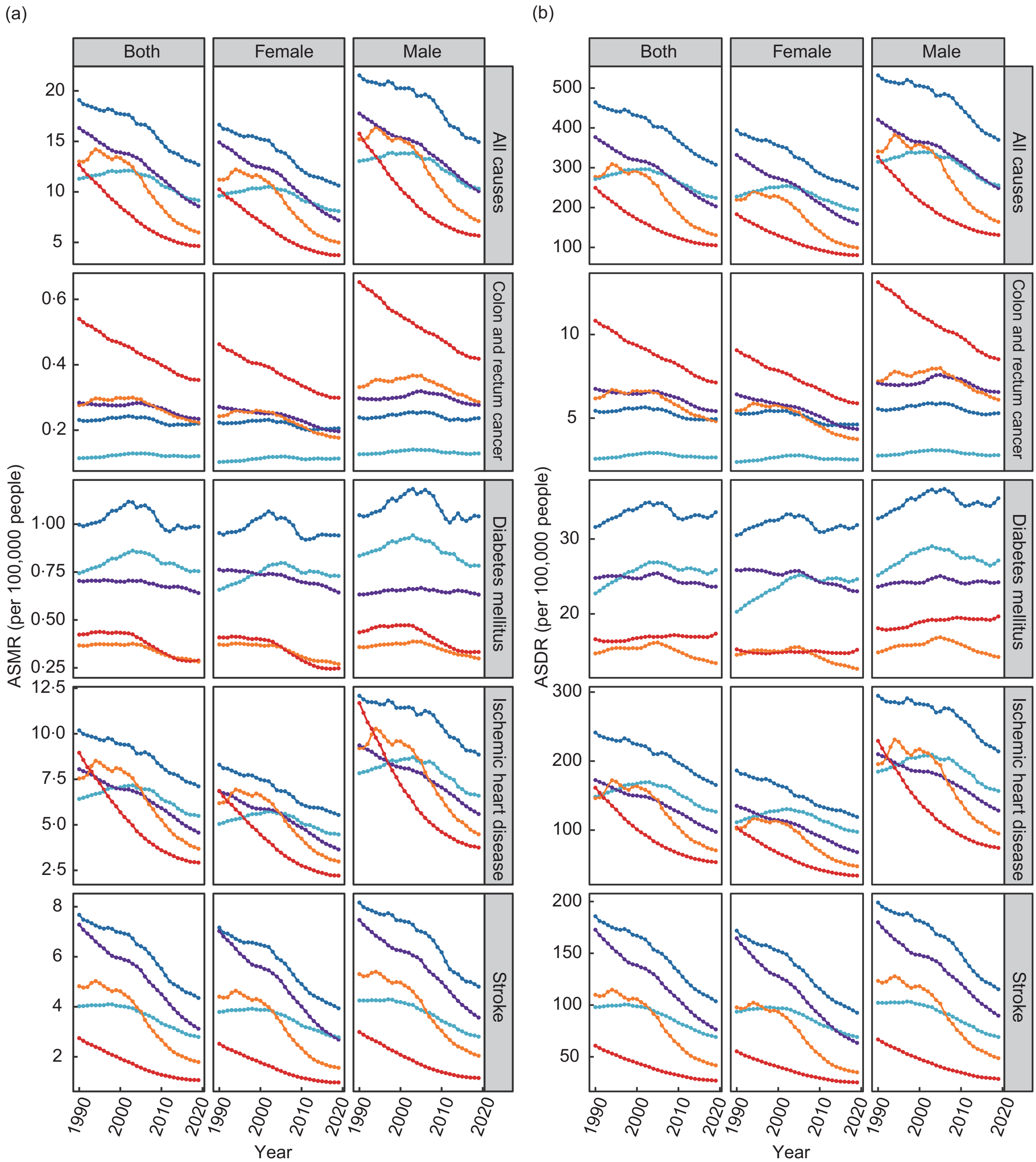

Fig. 3 ASMR, ASDR and age-standardised of YLD rates attributable to a diet low in fibre by SDI regions from 1990 to 2019. (a) ASMR; (b) ASDR; (c) age-standardised of YLD rates. ASMR, age-standardised mortality rate; ASDR, age-standardised rate of disability-adjusted life-years (DALY); YLD, year lived with disability; SDI, sociodemographic index

Southern Latin America (0·24, 95 % UI (0·11, 0·36)). In contrast, the age-standardised YLD rate in Western sub-Saharan Africa decreased from 8·28 (95 % UI (4·16, 13·63)) to 4·59 (95 % UI (2·49, 7·20)), with an EAPC of −2·45 (95 % CI (−2·76, −2·13)). In addition, the age-standardised YLD rates in regions other than the above-mentioned areas showed downtrends from 1990 to 2019 (see online Supplemental Table S2).

Similar trends were observed for the percent change of ASMR attributable to a diet low in fibre in different GBD regions from 1990 to 2019 (Fig. 4(a)). As shown in Fig. 4(b), ASMR of CRC due to a diet low in fibre showed a decreasing trend in most GBD regions, and the High-income North America had the largest percent decline from 1900 to 2019, followed by Australasia, East Asia and so on. However, ASMR of diabetes mellitus attributable to a diet

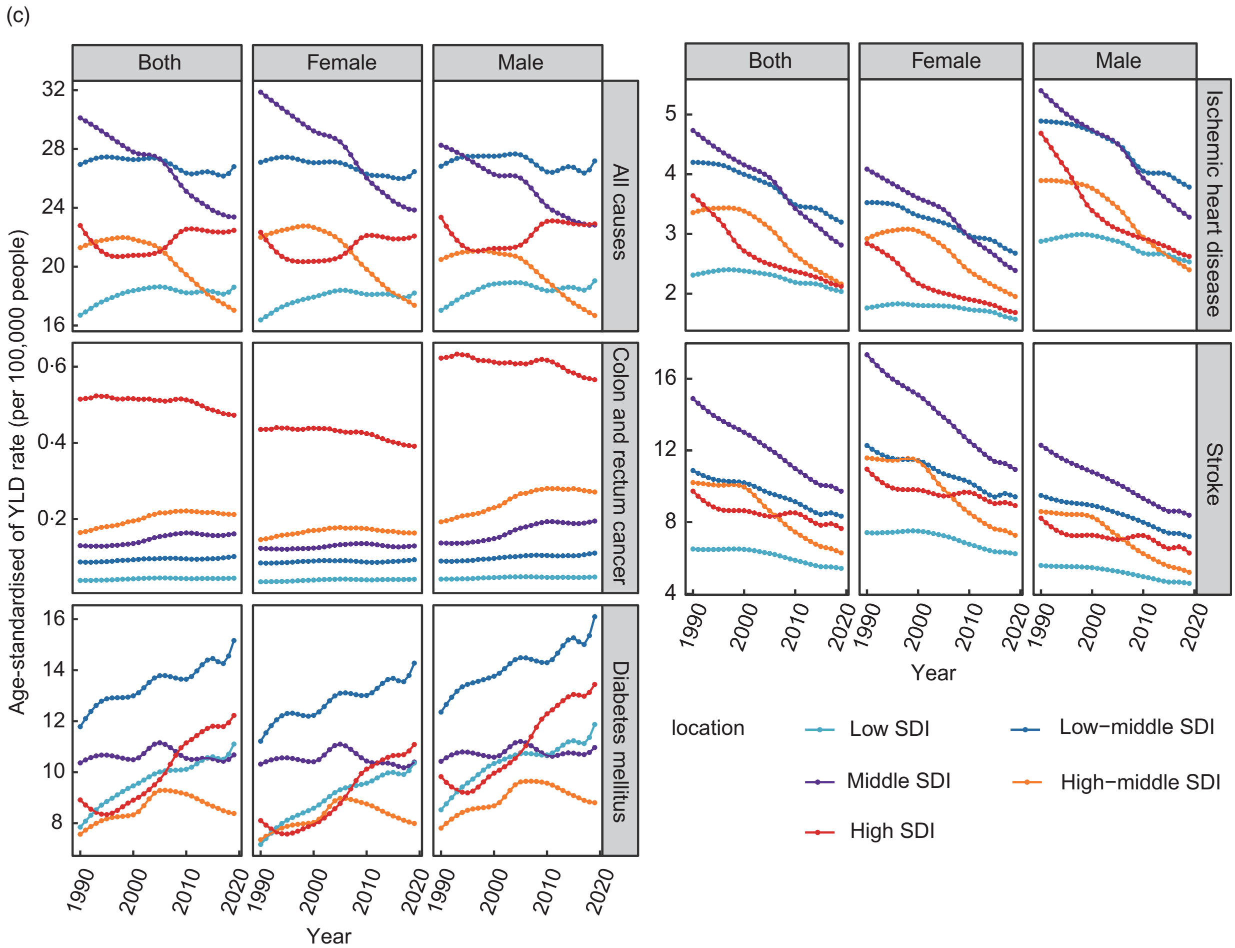

Fig. 3 (Continued)

low in fibre displayed a different pattern. Among the twenty-one GBD regions, Central Asia, Southern sub-Saharan Africa and Eastern Europe showed a marked percent increase in ASMR (Fig. 4(c)). The ASMR of IHD and stroke due to a diet low in fibre were decreased in most GBD regions, which were similar to the changing patterns of those of all diseases (Fig. 4(d) and (e)). In addition, the trends of the summary exposure values in different GBD regions, except High-income Asia Pacific, were consistent with the changes in the ASMR from 1990 to 2019 (see online Supplemental Fig. S2).

At the country level, the EAPC in the ASMR from 1990 to 2019 was the lowest in Cuba, followed by Equatorial Guinea, Estonia and Peru, whereas the EAPC for the Democratic Republic of the Congo was the highest. Further analyses of the EAPC in the ASMR between males and females showed that the EAPC in males were higher than those in females in China, Japan, Kuwait and several other countries (see online Supplemental Table S3). Unlike the trend of the ASMR, the YLD trend for Burundi increased, with the highest EAPC, and similar upward trends were observed for Lebanon, the Democratic Republic of the Congo and so on (see online Supplemental Table S4).

Discussion

In this study, the trend of the NCD burden attributable to a diet low in fibre was estimated systematically from 1990 to 2019 using GBD Study 2019 data. Globally, the ASMR and ASDR caused by a diet low in fibre declined in males and females from 1990 to 2019. It is worth mentioning that the burden of disease in males was more serious than that in females despite the declining trends. In addition, the ASMR declined in all GBD regions except Southern sub-Saharan Africa and Central sub-Saharan Africa. Different patterns were observed for YLD attributable to a diet low in fibre in several GBD regions, with increases from 1990 to 2019 and a lower value in males than in females. Compared with the trends of the ASMR due to IHD and stroke, the trends of the ASMR due to CRC and diabetes mellitus attributable to a diet low in fibre were more stable from 1990 to 2019. Further analyses of the relationship between the summary exposure value and ASMR in different SDI and GBD regions showed that the changes were consistent.

For the burden of disease attributable to a diet low in fibre, all-age mortality and DALY increased from 1990 to

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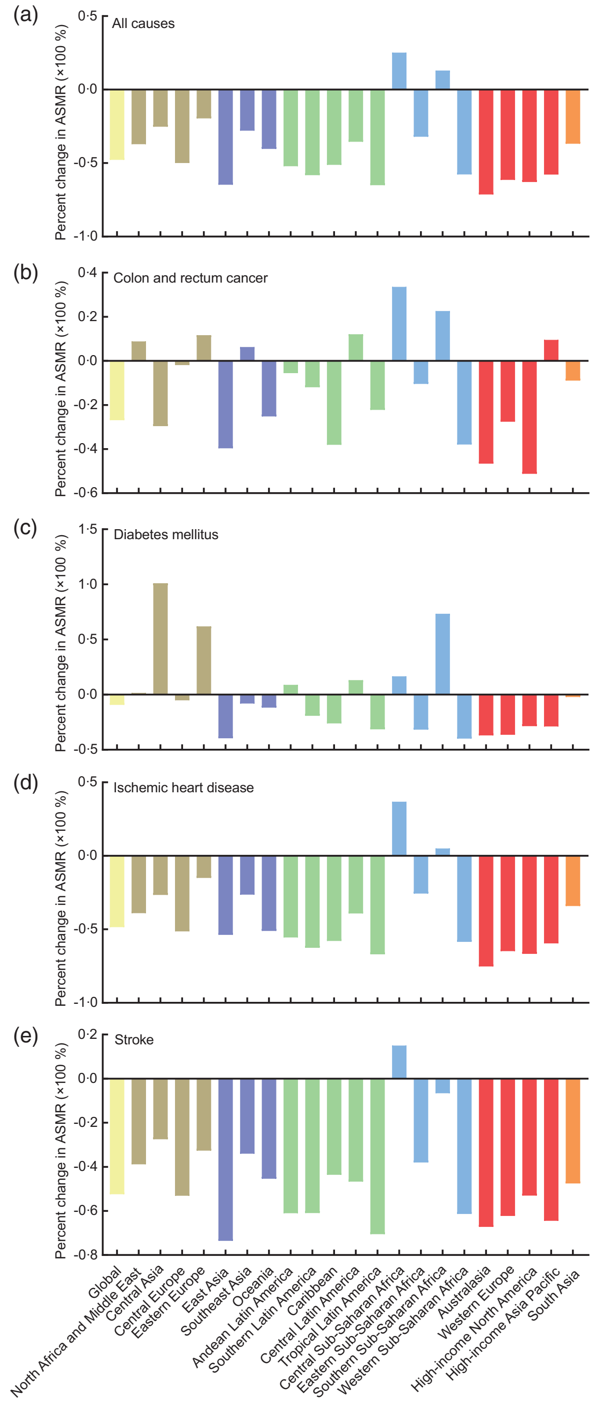

Fig. 4 Percent change in ASMR attributable to a diet low in fibre across twenty-one GBD regions by diseases for both sexes combined, 1990–2019. (a) All causes; (b) Colon and rectum cancer; (c) Diabetes mellitus; (d) Ischemic heart disease; (e) Stroke. ASMR, age-standardised mortality rate; GBD, Global Burden of Disease

2019 in both males and females, and the corresponding ASR also declined. This may result from population growth and the ageing of the population. In this study, we found that the burden of disease caused by a diet low in fibre in males in 1990 and 2019 was higher than that in females, and older individuals had a higher burden than younger people. Evidence has shown that males are more likely to consume unhealthy foods, and females tend to have better dietary patterns and consume more fibre[28]. Although older individuals had a higher intake of fibre than younger individuals, they had a higher burden of disease attributable to a diet low in fibre, which might strongly be associated with the time lag between fibre intake and health outcomes. In addition, energy intake, which varies by sex, age group and physical activity level, may play a critical role in the mechanism driving the difference in the burden between older and younger individuals[29]. Indeed, males and older individuals are more likely to ignore the correlation between diet and health outcomes. Other findings have revealed that these age differences in the burden may result from the higher mortality rates of cancer and CVD in males under 70 years old[30,31]. Females had a low ASMR and ASDR attributable to a diet low in fibre, which may be closely related to oestrogen before menopause, as oestrogens have a known antioxidant and antiapoptotic effect on cardiomyocytes in ischaemia[32]. Therefore, early dietary interventions for younger males and cost-effective intervention strategies for older males are needed to reduce the burden of disease attributable to a diet low in fibre.

Geographically, the high- and high-middle-SDI regions had lower burdens of disease attributable to a diet low in fibre than the other regions. The correlations of the ASMR and ASDR with the SDI showed similar trends. As revealed in many other studies, socio-economic status is a major determinant of health. Individuals in high-SDI regions with higher socio-economic status tend to have healthier dietary patterns and consume healthier foods, such as wholegrains, fruits and vegetables, which are rich in fibre, than those in lower-SDI regions[33–35]. The corresponding correlation between the summary exposure value and the ASMR in different regions supports the notion that people in high-SDI regions consume more fibre than those in low-SDI regions. In addition, data from fifty-two countries showed that urban areas with increasing income levels consume more fruits and vegetables[36]. The explanation for these associations is that people in low- and middle-income countries may lack knowledge about the health benefits of fibre and have limited access to fresh food markets due to transportation limitations[37,38]. In addition, many countries in the low-SDI region produce fruits and vegetables that provide large amounts of dietary fibre for export rather than local consumption, which is also an important reason for the increased exposure to a low-fibre diet[39].

Poor dietary habit is another critical factor resulting in an increased disease burden. People with low-income levels in low-SDI regions have less access to healthy foods and are more likely to have poor dietary habits. In contrast, people in the high-SDI region tend to have healthier eating habits and lower burdens of disease attributable to a diet

Public Health Nutrition

low in fibre, probably due to greater accessibility to fresh fruits and vegetables, early health education, and high awareness of disease prevention.

The analyses by GBD regions and countries showed that the disease burdens in Southern sub-Saharan Africa and Central sub-Saharan Africa increased; the ASMR for the Democratic Republic of Congo increased the most, with the highest EAPC. The causes of this disparity may be multi-faceted, region-specific and associated with socio-economic factors. For example, food prices are relatively high and dietary quality is relatively low in Northwestern sub-Saharan Africa[40]. In addition, domestic and international conflicts in some countries may play an important role in dietary quality. For example, conflicts in the Democratic Republic of the Congo (1996–2008) and neighbouring countries impeded food production and trade, which may be an important explanation for poor dietary quality.

A previous study described the change pattern of the burden of IHD and CRC attributable to a diet low in fibre in China. The results indicated that China has a large and growing burden of IHD and CRC attributable to a diet low in fibre, especially in males and older adults. The fraction of deaths caused by IHD and CRC attributable to a diet low in fibre elevated from 1·4 % to 2·1 % from 1990 to 2017 in China[41]. In our study, a different change pattern of the disease burden caused by a low-fibre diet is observed at a global level, with a decreasing trend of IHD and CRC burden worldwide. It is worth noting that dietary fibre consumption is currently low globally, not just in several specific regions. The dietary fibre intake in some developed countries such as the USA, Canada, United Kingdom and Japan is lower than 25–35 g, which is a daily intake recommended by most countries[42]. Similarly, in some developing countries such as China, although adults consume more dietary fibre than in the above-mentioned developed countries, their consumption is still lower than the required intake, and China remains having a high burden of disease attributed to a diet low in fibre[2]. To reduce disease burden due to diet low in fibre in different regions, population-level dietary interventions are needed, especially for low-SDI regions. For example, mass media and educational campaigns may increase the intake of dietary fibre by raising public awareness of a healthy diet[43]. Moreover, appropriate food pricing strategies minimising taxes for high-fibre foods may also be helpful[44]. In addition, more appropriate public health strategies based on dietary habits and the correlation with disease burden should be proposed in different regions. Recently, the Chinese government formulated the Healthy China Action 2019–2030 to deal with the increasing burden of NCD (http://www.gov.cn/xinwen/2019-07/15/content_5409694.htm). Additionally, the 2020–2025 Dietary Guidelines for Americans (DGA) were released to reduce the increasing risk of NCD due to diet low in fibre in America[45].

In summary, we conducted a systematic analysis of data on the burden of NCD attributable to a diet low in fibre using data from the GBD database from 1990 to 2019. It is worth noting that the GBD Study utilises PAF to estimate the disease burden attributable to a diet low in fibre. PAF represents the estimated fraction of all cases that would not have occurred if there had been no exposure, which allows a causal interpretation[46]. Thus, the disease burden present in our study is caused by, rather than just associated with, a diet low in fibre. In this study, we analysed comprehensive and up-to-date data on the burden of disease attributable to a diet low in fibre by year, age, SDI, GBD region and country. Moreover, we attempted to analyse and explain the possible reasons behind these phenomena. However, our study has several limitations. Similar methodological limitations as those in other GBD studies existed in the present study[19,47,48]. First, the data collected from different regions and countries may have large discrepancies in terms of data quality, accuracy, comparability and degrees of missing data. Thus, certain degrees of deviation in the estimated disease burden is inevitable, even though many statistical approaches have been applied to adjust the data as much as possible. Second, the use of a universal effect size across countries for a given age-sex group could be another shortfall of this GBD Study, because diet low in fibre could have different effects on NCD outcomes across different population subgroups (e.g. urban *v.* rural populations). Third, the dietary risks in the GBD dataset were not strictly classified, and the definitions and measurements of dietary risk factors are different around the world. In addition, many differently composed foods are consumed in real life, making an accurate division into distinct food or nutrient groups impossible. Therefore, some degrees of measurement errors are inevitable in GBD Study[49]. Moreover, interrelations between dietary factors may affect the estimated disease burden attributable to a single dietary component. In terms of the limitations existed, further well-designed large-scale epidemiological studies with accurately documented amounts and types of food products as well as individual-level variables are needed to get a deeper understanding of the NCD burden induced by a diet low in fibre. Furthermore, intervention studies by giving participants foods containing different amounts of fibre are of particular importance to further explore the real effect size of a low-fibre diet on the risk of NCD.

Conclusions

The study demonstrates the significant disease burden attributable to a diet low in fibre over the past two decades. Though the global trend has been decreasing, the burdens of disease attributable to a diet low in fibre increase in Southern sub-Saharan Africa and Central sub-Saharan Africa and countries such as the Democratic Republic of the Congo. In addition, the burden caused by diabetes mellitus attributable to a diet low in fibre increases in Central Asia, Southern sub-Saharan Africa and Eastern Europe. Multisectoral efforts and interventions that focus on increasing dietary fibre consumption are needed to reduce the risk-attributable disease burden.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980022001987

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