ORIGINAL RESEARCH

Global, Regional, and National Burdens of Ischemic Heart Disease Attributable to Smoking From 1990 to 2019

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BACKGROUND: This study was conducted to estimate the distribution of and changes in the global disease burden of ischemic heart disease attributable to smoking between 1990 and 2019.

METHODS AND RESULTS: Data used in this study come from the GBD 2019 (Global Burden of Disease Study 2019). Age-standardized rates and estimated annual percentage change of age-standardized rates were used to describe this burden and its changing trend. Pearson's correlation coefficient was used to evaluate the correlation between the sociodemographic index and changing trend. From 1990 to 2019, the burden of ischemic heart disease attributable to smoking has shown a downward trend globally; estimated annual percentage changes of age-standardized mortality rates and age-standardized disability-adjusted life-years rates were −2.012 (95% CI, −2.068 to −1.956) and −1.907 (95% CI, −1.975 to −1.838). Nineteen countries experienced an increase in disease burden, and the changes in 17 countries were not statistically significant. In addition, this burden was higher in men and older age groups. Estimated annual percentage change of the age-standardized rates of this burden were negatively correlated with the sociodemographic index.

CONCLUSIONS: Although the burden of ischemic heart disease attributable to smoking has decreased in >80% of countries or regions in the past 30 years, it has remained a significant issue in low- and middle-income countries, particularly among men and elderly populations. Therefore, active tobacco control measures, focusing on key populations, are required to reduce the associated burden of ischemic heart disease, especially in those countries or regions with increasing prevalence and disease burden.

Key Words: global disease burden ∎ ischemic heart disease ∎ smoking ∎ spatiotemporal trends

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Ischemic heart disease (IHD) is a common cardiovascular disease[1] and is considered a significant threat to sustainable development in the 21st century.[2] According to the World Health Organization, IHD led to 8.9 million deaths in 2019, accounting for 16% of total deaths worldwide. Since 2000, IHD has seen the largest increase in mortality globally, and it is associated with a significant disability. Global burden of disease data[3] show that IHD has led to the loss of >182 million disability-adjusted life-years (DALYs) and >176 million years of life because of premature mortality in 2019 alone. Thus,

effective prevention and control of IHD is an important global public health challenge.

The risk factors of IHD include genetic factors, environmental factors, and behavioral factors, among which smoking is one of the most important.[4,5] In a large prospective cohort study[6] of Black adults with a median follow-up of >10 years, current smokers had a 2-fold increased risk of coronary heart disease. Compared with never-smokers, current smokers with stable coronary artery disease have significantly increased risk of future cardiovascular events, including

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CLINICAL PERSPECTIVE

What Is New?
- Smoking is one of the risk factors for ischemic heart disease (IHD), but studies on the distribution and change of the disease burden of IHD attributable to smoking are lacking.
- This study describes the distribution of IHD burden attributable to smoking in 2019 and analyzes the trends of this burden at global, regional, and national levels from 1990 to 2019.

What Are the Clinical Implications?
- The burden of IHD attributable to smoking decreased in >80% of countries or regions around the world from 1990 to 2019.
- The burden of IHD attributable to smoking has remained a significant issue in low- and middle-income countries, particularly among men and elderly populations.
- Active tobacco control measures are required to reduce the associated burden of IHD, especially in those countries or regions with increasing prevalence and disease burden.

Nonstandard Abbreviations and Acronyms

ASDR	age-standardized disability-adjusted life-years rate
ASMR	age-standardized mortality rate
ASR	age-standardized rate
DALYs	disability-adjusted life-years
EAPC	estimated annual percentage change
GBD 2019	Global Burden of Disease Study 2019
IHD	ischemic heart disease
SDI	sociodemographic index
UI	uncertainty interval

death.[7] In patients with coronary heart disease undergoing interventional therapy, smoking was the strongest and the only modifiable risk factor found to be associated with mortality after coronary revascularization.[8] Moreover, continued smoking after coronary revascularization significantly increased the risk of death, with 16.6% of mortality being attributable to smoking.

The World Health Organization proposes that a comprehensive population-wide approach to tobacco control is a "best buy" or cost-effective intervention for cardiovascular disease prevention, even in low-resource settings. Therefore, it is important to understand the distribution of IHD disease burden attributable to smoking in the global population. In this study, we analyzed the distribution of and changes in the global disease burden of IHD attributable to smoking between 1990 and 2019 using publicly available databases.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Study Data

Data used in this study come from the GBD 2019 (Global Burden of Disease Study 2019). The GBD 2019 database provides information relating to deaths and health losses attributable to 369 diseases, injuries, and impairments and 87 risk factors in 204 countries and territories around the world from 1990 to 2019.[9] The spatial range was divided into 4 levels[10,11]: global, sociodemographic, epidemiologic similarity and geographic proximity, and individual countries or regions. For the second category, the sociodemographic index (SDI), a composite indicator that measures per-capita income, average education level, and total fertility rate, was used to divide countries and regions into 5 super regions: low, low-middle, middle, high-middle, and high SDI. The third category, based on epidemiologic similarity and geographic proximity, divided the world into 21 geographic regions, such as East Asia, Australasia, and Central Europe. The fourth category included 204 separate countries or regions.

Data Availablility Statement

The data underlying this article are available in GBD 2019 data, at https://vizhub.healthdata.org/gbd-results/.

Definition of Smoking Exposure

According to the GBD 2019 Risk Factors Collaborators,[12] to calculate the burden of disease attributable to risk factors, GBD 2019 uses a rule-based synthesis of evidence to provide comparable quantification of risk over time and across populations. There were 6 analytical steps: (1) include 560 risk-outcome pairs that met criteria for convincing or probable evidence on the basis of research studies; (2) estimate relative risks; (3) estimate levels of exposure in each age-sex-location-year included in the study; (4) determine the theoretical minimum risk exposure level; (5) compute attributable deaths, years of life lost, years of healthy life lost because of a disability, and DALYs by multiplying population attributable fractions by the relevant outcome quantity for each age-sex-location-year; and (6)

estimate population-attributable fractions and attributable burden for combinations of risk factors and take into account mediation of different risk factors through other risk factors. Smoking exposure was defined as current or previous use of any tobacco product, excluding electronic cigarettes or vaporizers. For current smokers, exposure was estimated using 2 continuous measures: the number of cigarettes smoked per day and the cumulative number of cigarettes smoked annually. For those who have quit smoking, exposure was estimated using the number of years elapsed since quitting.

Statistical Analysis

In this study, the disease burden of IHD attributable to smoking focused on deaths and DALYs. Methods for calculating mortality (deaths (n) × 100 000/population) and DALYs (the sum of years of life lost because of premature mortality and years lived with disability) have been described previously by global burden of disease.[13,14] GBD 2019 used population data from the World Population Prospects 2012 revision for standardization.[12] Use of age-standardized rates (ASRs) and its 95% uncertainty interval (UI) removes the effects of variable age distributions across different populations and different time periods, ensuring comparability.[15] Therefore, IHD burden attributable to smoking in different regions was described using age-standardized mortality rates (ASMRs) and age-standardized DALY rates (ASDRs).

Trends in the disease burden of IHD attributable to smoking are described using percentage change and estimated annual percentage change (EAPC). The natural logarithm of ASRs was fitted to a regression line model: $\ln(ASR)=\alpha+\beta x+\varepsilon$, where x=calendar year. EAPC and its 95% CI were derived from the regression model: $y=100\times(\exp(\beta)-1)$, where y=EAPC.[16] When the lower limit of the 95% CI of the EAPC was >0, ASRs were considered to increase over the observation period. Conversely, ASRs were assumed to have decreased when the upper limit of the 95% CI of the EAPC was <0. When the 95% CI contained both positive and negative values, ASRs were considered stable. Pearson correlation coefficients were used to evaluate the correlation between SDI and disease burden and any trends therein. A 2-sided P value <0.05 was considered statistically significant. All of the statistical analyses were performed using R software version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria).

Ethical Approval and Consent to Participate

Not applicable.

RESULTS

Global Burden of IHD Attributable to Smoking From 1990 to 2019

In 2019, smoking-related IHD led to >1.68 million deaths and to 43 452 750.84 DALYs globally. Compared with 1990, the burden of IHD attributable to smoking has increased in terms of absolute numbers. However, when we adjusted for the effects of time and age structures within the populations, the burden was found to decrease. The ASMR per 100 000 people of IHD attributable to smoking decreased from 35.59 (95% UI, 33.93–37.18) in 1990 to 20.52 in 2019 (95% UI, 18.99–22.03) (EAPC, −2.012 [95% CI, −2.068 to −1.956]). Correspondingly, ASDRs per 100 000 people decreased from 872.16 in 1990 to 519.48 in 2019 (EAPC, −1.907 [95% CI, −1.975 to −1.838]). These findings indicate that the global burden of IHD attributable to smoking has significantly decreased from 1990 to 2019.

Detailed results are provided in Tables 1 and 2.

Global Burden of IHD Attributable to Smoking by Sex and Age

In 2019, the global burden of IHD attributable to smoking was higher in men than in women. In absolute terms, this burden led to 1.357 million deaths in men, significantly more than in women (≈325 000 deaths). Similarly, DALYs were higher for men (36 251 278.37) than for women (7 201 472.47). The ASMRs per 100 000 people of IHD attributable to smoking in women and men were 7.41 (95% UI, 6.63–8.19) per 100 000 and 35.47 (95% UI, 32.54–38.43) per 100 000, respectively (EAPC, −3.029 [95% CI, −3.117 to −2.942]) and −1.794 [95% CI, −1.856 to −1.732]. ASDRs per 100 000 people were 165.10 (95% UI: 148.77–181.95) per 100 000 and 900.23 (95% UI, 828.14–978.01) per 100 000 in women and men, respectively (EAPC, −2.858 [95% CI, −2.948 to −2.768] and −1.634 [95% CI, −1.720 to −1.549]). Overall, from 1990 to 2019, the global burden of disease attributable to smoking trended downward in both sexes. However, women have experienced a more pronounced decrease. Detailed results are provided in Tables 1 and 2.

The GBD 2019 study divided those aged >30 years into 5-year age groups. Using these stratified data, we examined how the burden of IHD attributable to smoking changed in different age groups from 1990 to 2019. With increasing age, the mortality of IHD attributable to smoking gradually increased, reaching 192.01 (95% UI, 167.98–210.88) per 100 000 in individuals aged ≥80 years. The number of DALYs peaked for those aged 70 years old. Different age groups experienced a downward trend in the burden of IHD attributable to smoking from 1990 to 2019, with those aged 65 to 69 years

Table 1. The Death Burden of IHD Attributable to Smoking in 1990 and 2019 and the Temporal Trends From 1990 to 2019

Characteristics	1990		2019		EAPCs (1990–2019)
	No. (95% UI)	ASMR (95% UI)	No. (95% UI)	ASMR (95% UI)	No. (95% CI)
Global	1 377 801 (1 317 052–1 439 222)	35.59 (33.93–37.18)	1 681 987 (1 558 419–1 805 333)	20.52 (18.99–22.03)	−2.012 (−2.068 to −1.956)
Sex					
Female	349 957 (325 062–376 467)	16.89 (15.60–18.18)	324 987 (290 466–359 375)	7.41 (6.63–8.19)	−3.029 (−3.117 to −2.942)
Male	1 027 844 (977 420–1 078 661)	58.19 (55.18–60.98)	1 357 001 (1 244 771–1 471 953)	35.47 (32.54–38.43)	−1.794 (−1.856 to −1.732)
SDI					
Low	44 958 (39 595–50 938)	18.73 (16.56–21.07)	82 576 (72 014–93 986)	15.69 (13.78–17.75)	−2.038 (−2.289 to −1.785)
Low-middle	163 771 (148 402–178 986)	27.34 (24.80–29.83)	295 225 (264 500–329 391)	21.51 (19.31–23.91)	−4.441 (−4.633 to −4.248)
Middle	260 963 (242 886–279 434)	25.98 (24.17–27.85)	541 128 (485 099–596 149)	22.11 (19.87–24.36)	−0.779 (−0.838 to −0.719)
High-middle	444 110 (424 124–463 359)	41.70 (39.86–43.52)	517 666 (474 111–561 149)	25.31 (23.19–27.43)	−0.579 (−0.668 to −0.491)
High	463 238 (440 087–483 156)	44.06 (41.89–45.91)	244 434 (225 802–261 688)	13.31 (12.40–14.19)	−0.450 (−0.559 to −0.559)
Region					
East Asia	158 412 (134 873–183 207)	18.97 (16.26–21.83)	4 480 457 (3 787 257–5 177 849)	21.26 (17.91–25.05)	0.699 (0.451 to 0.948)
Southeast Asia	61 351 (54 981–67 590)	24.41 (21.97–26.85)	1 781 687 (1 600 693–1 976 522)	21.46 (19.01–24.06)	−0.349 (−0.465 to −0.234)
Oceania	1552 (1259–1984)	46.89 (38.32–59.27)	51 037 (41 064–65 352)	42.42 (33.18–54.79)	−0.153 (−0.239 to −0.067)
Central Asia	24 838 (23 651–25 991)	52.82 (50.22–55.38)	706 108 (673 041–738 627)	50.76 (45.65–56.02)	−0.552 (−0.878 to −0.225)
Central Europe	108 797 (104 604–113 003)	73.99 (71.15–76.86)	2 745 898 (2 654 239–2 842 485)	30.68 (26.48–34.94)	−3.508 (−3.668 to −3.347)
Eastern Europe	155 349 (146 250–163 921)	55.48 (52.23–58.51)	4 225 734 (3 944 953–4 450 770)	56.34 (49.61–63.39)	−0.444 (−1.000 to 0.115)
High-income Asia Pacific	39 864 (37 728–42 007)	20.03 (18.94–21.17)	963 892 (917 532–1 007 475)	5.56 (5.10–5.95)	−4.218 (−4.385 to −4.051)
Australasia	10 403 (9801–10 956)	43.92 (41.35–46.22)	238 434 (226 481–249 647)	7.72 (7.06–8.31)	−6.372 (−6.694 to −6.049)
Western Europe	241 193 (229 061–252 555)	41.37 (39.45–43.19)	5 291 077 (5 087 700–5 500 598)	11.19 (10.36–11.89)	−4.931 (−5.144 to −4.718)
Southern Latin America	16 985 (15 941–18 005)	36.58 (34.28–38.81)	425 417 (404 323–446 812)	14.29 (13.22–15.30)	−3.132 (−3.322 to −2.943)
High-income North America	191 362 (180 409–201 942)	54.43 (51.54–57.28)	4 322 512 (4 139 049–4 522 279)	18.71 (17.38–20.03)	−4.054 (−4.251 to −3.856)
Caribbean	9334 (8710–9973)	36.13 (33.66–38.63)	235 112 (220 567–250 194)	20.61 (17.45–24.22)	−2.007 (−2.207 to −1.806)
Andean Latin America	2205 (1911–2536)	10.99 (9.50–12.61)	58 700 (50 865–67 373)	4.43 (3.55–5.36)	−3.043 (−3.272 to −2.812)
Central Latin America	19 775 (18 466–21 077)	24.27 (22.55–26.00)	529 123 (498 659–562 339)	10.42 (8.81–12.24)	−2.930 (−3.106 to −2.754)
Tropical Latin America	42 183 (39 378–44 833)	46.75 (43.48–49.99)	1 170 581 (1 104 741–1 236 369)	14.79 (13.57–16.06)	−3.876 (−3.929 to −3.823)
North Africa and Middle East	104 993 (96 354–114 318)	60.58 (55.57–65.73)	3 039 331 (2 790 435–3 326 567)	36.57 (31.79–42.36)	−2.018 (−2.137 to −1.899)
South Asia	164 867 (144 796–184 153)	28.74 (25.14–32.02)	4 971 019 (4 369 151–5 545 963)	21.37 (18.29–24.62)	−1.014 (−1.124 to −0.903)
Central sub-Saharan Africa	2926 (2403–3563)	12.11 (9.99–14.71)	88 935 (72 693–107 994)	7.77 (5.92–10.10)	−1.727 (−1.828 to −1.627)
Eastern sub-Saharan Africa	7931 (6744–9053)	10.81 (9.23–12.28)	228 920 (194 499–264 871)	8.06 (6.36–9.96)	−1.164 (−1.274 to −1.053)
Southern sub-Saharan Africa	5877 (5216–6578)	21.31 (18.84–23.90)	172 092 (154 295–191 981)	12.63 (11.19–14.04)	−1.996 (−2.498 to −1.492)
Western sub-Saharan Africa	7604 (6176–9486)	8.65 (7.11–10.74)	214 921 (174 756–268 586)	6.82 (5.59–8.21)	−0.775 (−0.885 to −0.665)

ASMR indicates age-standardized mortality rate; EAPC, estimated annual percentage change; IHD, ischemic heart disease; SDI, sociodemographic index; and UI, uncertainty interval.

Table 2. The DALY Burden of IHD Attributable to Smoking in 1990 and 2019 and the Temporal Trends From 1990 to 2019

Characteristics	1990 No. (95% UI)	1990 ASDR (95% UI)	2019 No. (95% UI)	2019 ASDR (95% UI)	EAPCs (1990–2019) No. (95% CI)
Global	35 940 987.54 (34 339 178.42–37 597 809.51)	872.16 (833.13–912.46)	43 452 750.84 (40 296 865.59–46 783 925.23)	519.48 (481.37–559.19)	−1.907 (−1.975 to −1.838)
Sex					
Female	7 761 534.86 (7 253 121.69–8 320 574.03)	363.01 (339.31–389.27)	7 201 472.47 (7 253 121.69–8 320 574.03)	165.10 (148.77–181.95)	−2.858 (−2.948 to −2.768)
Male	28 179 452.68 (26 731 234.72–29 560 186.79)	1432.98 (1360.81–1505.42)	36 251 278.37 (33 313 628.46–39 467 913.75)	900.23 (828.14–978.01)	−1.634 (−1.720 to −1.549)
SDI					
Low	1 339 046.23 (1 178 704.43–1 518 226.13)	499.71 (440.41–564.15)	2447 107.20 (2 120 099.52–2 810 144.79)	415.83 (361.09–474.33)	−2.225 (−2.509 to −1.939)
Low-middle	4 827 371.12 (4 374 236.79–5 270 805.43)	720.29 (651.39–786.15)	8 330 848.05 (7 424 759.89–9 355 632.77)	565.94 (506.38–631.93)	−4.097 (−4.277 to −3.916)
Middle	7 474 207.54 (6 951 627.82–8 018 502.39)	663.18 (617.53–709.96)	14 316 946.54 (12 852 937.46–15 790 197.29)	544.91 (489.76–600.15)	−0.757 (−0.832 to −0.683)
High-middle	11 837 146.53 (11 283 931.23–12 362 188.53)	1068.75 (1018.78–1115.98)	12 787 563.91 (11 776 051.88–13 910 452.37)	628.50 (578.19–683.61)	−0.606 (−0.702 to −0.510)
High	10 443 462.93 (10 054 866.19–10 831 133.05)	1026.01 (990.18–1062.65)	5544 140.55 (5 223 746.26–5 885 842.27)	334.86 (316.06–355.50)	−0.586 (−0.679 to −0.493)
Region					
East Asia	422 193 (354 122–501 829)	475.71 (403.89–547.78)	10 136 498 (8 483 369–12 145 195)	482.56 (406.14–575.11)	0.309 (0.117 to 0.503)
Southeast Asia	132 103 (116 334–149 432)	628.46 (565.38–695.29)	3 814 168 (3 331 416–4 335 653)	567.08 (498.57–641.91)	−0.230 (−0.343 to −0.117)
Oceania	3392 (2624–4397)	1384.49 (1127.70–1768.76)	112 739 (86 832–147 698)	1254.26 (969.53–1627.06)	−0.153 (−0.241 to −0.065)
Central Asia	37 099 (33 312–41 204)	1425.57 (1358.87–1491.70)	1 036 896 (929 389–1 160 407)	1265.28 (1135.81–1407.37)	−0.931 (−1.291 to −0.569)
Central Europe	65 411 (56 474–74 513)	1850.47 (1790.68–1914.43)	1 488 994 (1 279 650–1 705 219)	747.87 (640.98–857.09)	−3.625 (−3.794 to −3.456)
Eastern Europe	192 844 (169 991–216 679)	1506.11 (1405.22–1586.44)	4 897 317 (4 311 867–5 532 573)	1488.51 (1308.39–1684.43)	−0.682 (−1.304 to −0.055)
High-income Asia Pacific	23 441 (21 054–25 409)	468.98 (446.39–490.69)	510 764 (473 383–546 334)	144.14 (135.13–153.91)	−3.803 (−3.959 –3.648)
Australasia	3706 (3336–4004)	1023.62 (973.83–1071.07)	85 975 (80 425–91 942)	197.10 (184.61–210.92)	−5.928 (−6.251 to −5.603)
Western Europe	100 566 (92 038–107 612)	962.34 (927.26–997.95)	2 112 395 (1 977 660–2 240 326)	269.41 (254.23–284.65)	−4.743 (−4.945 to −4.541)
Southern Latin America	11 819 (10 911–12 672)	905.16 (860.15–950.61)	292 300 (272 089–311 076)	362.28 (337.47–385.99)	−3.067 (−3.235 to −2.899)
High-income North America	114 907 (105 999–123 677)	1294.07 (1242.58–1349.35)	2 646 234 (2 499 671–2 820 969)	462.96 (438.08–493.07)	−3.847 (−4.025 to −3.668)
Caribbean	10 671 (9046–12 537)	887.81 (833.06–944.13)	267 103 (224 459–314 933)	514.26 (432.22–605.89)	−1.938 (−2.128 to −1.749)
Andean Latin America	2469 (1976–2993)	271.36 (235.08–311.23)	64 962 (51 941–79254)	113.15 (90.21–137.59)	−2.937 (−3.161 to −2.712)
Central Latin America	24 495 (20 672–28 854)	593.60 (557.34–631.99)	634 106 (531 949–749 853)	261.09 (219.59–308.48)	−2.876 (−3.044 to −2.708)
Tropical Latin America	36 253 (33 321–39 295)	1179.34 (1110.53–1110.53)	987 484 (915 417–1 062 663)	393.23 (364.47–423.83)	−3.688 (−3.758 to −3.617)

(Continued)

Table 2. (Continued)

Characteristics	1990		2019		EAPCs (1990–2019)
	No. (95% UI)	ASDR (95% UI)	No. (95% UI)	ASDR (95% UI)	No. (95% CI)
North Africa and Middle East	158 902 (137 523–185 513)	1590.71 (1461.38–1736.85)	4 497 212 (3 859 761–5 311 813)	929.95 (802.04–1092.35)	−2.137 (−2.254 to −2.019)
South Asia	304 343 (259 832–352 461)	761.77 (670.38–848.19)	8 773 414 (7 501 863–10 185 538)	573.98 (490.59–666.67)	−0.916 (−1.041 to −0.790)
Central sub-Saharan Africa	4452 (3335.41–5828.38)	332.76 (274.49–402.93)	139 657 (102 985–183 322)	216.22 (162.59–282.71)	−1.691 (−1.785 to −1.597)
Eastern sub-Saharan Africa	12 927 (10 160.26–16 083.18)	277.06 (235.49–317.45)	377 919 (296 449–470 484)	206.34 (163.86–255.50)	−1.173 (−1.298 to −1.048)
Southern sub-Saharan Africa	7119 (6306.89–7944.29)	570.83 (510.14–636.83)	200 558 (177 244–224 472)	327.40 (289.57–365.55)	−2.122 (−2.621 to −1.621)
Western sub-Saharan Africa	12 873 (10 408.64–15 643.21)	223.65 (182.29–278.94)	376 052 (303 419–463 323)	176.17 (142.46–215.41)	−0.788 (−0.911 to −0.664)

ASDR indicates age-standardized DALY; DALYs, disability-adjusted life-year; EAPC, estimated annual percentage change; IHD, ischemic heart disease; and UI, uncertainty interval.

experiencing the most significant decrease. The EAPCs in ASMR and ASDR were −2.34 (95% CI, −2.46 to −2.21) and −2.30 (95% CI, −2.42 to −2.18), respectively.

Detailed results are provided in Figures 1 and 2.

The Burden of IHD Attributable to Smoking by SDI Super-Region

The burden of IHD attributable to smoking varied with SDI-defined super-regions. In 2019, this burden was greatest in countries with high-middle SDI, with an ASMR and ASDR per 100 000 people of 25.31 (95% UI, 23.19–27.43) and 628.50 (95% UI, 578.19–683.61), respectively. Conversely, the least burden was seen in high-SDI countries, where ASMR and ASDR per 100 000 people were 13.31 (95% UI, 12.40–14.19) and 334.86 (95% UI, 316.06–355.50), respectively. Over time, the 5 SDI super-regions had downward trending IHD burdens attributable to smoking. The most significant decrease was seen in low–middle-SDI countries, with EAPCs in ASMR and ASDR of −4.441 (95% CI, −4.633 to −4.248) and −4.097 (95% CI, −4.277 to −3.916), respectively. In contrast, high-SDI countries experienced the least change over time, with EAPCs in ASMR and ASDR of −0.450 (95% CI, −0.559 to −0.559) and −0.586 (95% CI, −0.679 to −0.493), respectively.

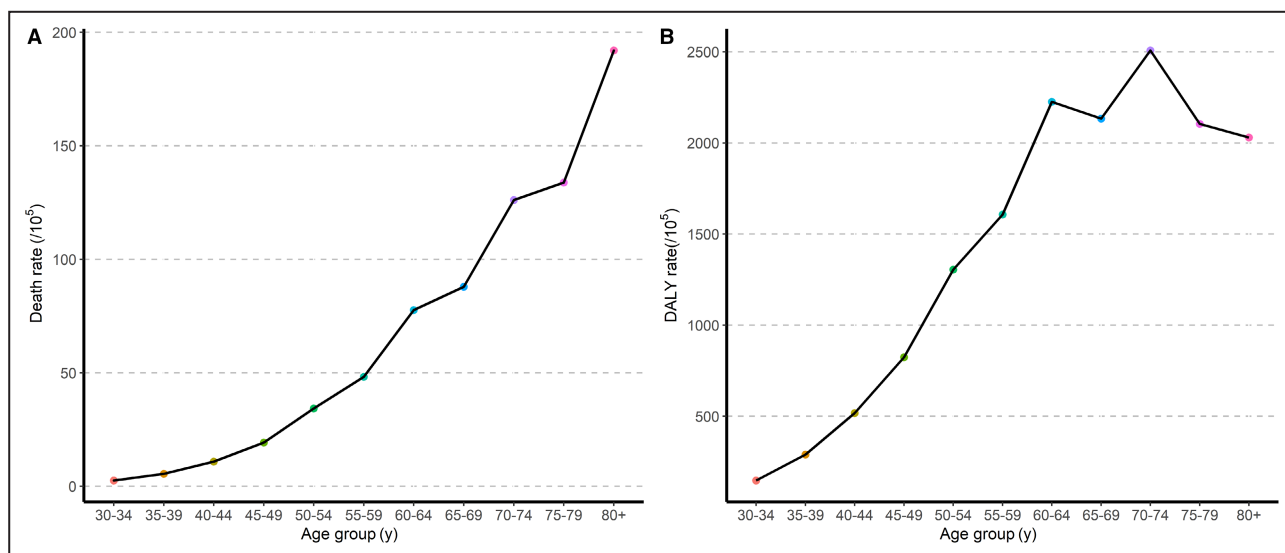The burdens of IHD attributable to smoking in the other SDI super-regions are shown in Table 1.

Burden of IHD Attributable to Smoking by Geographic Super-Region

In 2019, across all 21 geographic super-regions, regions with ASMRs for IHD attributable to smoking of <10 per 100 000 people included Andean Latin America, high-income Asia Pacific, high-income Australasia, Western sub-Saharan Africa, Central sub-Saharan Africa, and Eastern sub-Saharan Africa. Correspondingly, the ASDRs for these areas were ≈200 per 100 000 people. Conversely, the most severe burden of IHD attributable to smoking occurred in Eastern Europe, Central Asia, and Oceania.

From 1990 to 2019, East Asia was the only super-region to show an upward trend in smoking-related IHD burden, with EAPCs in ASMR and ASDR of 0.699 (95% CI, 0.451–0.948) and 0.309 (95% CI, 0.117–0.503), respectively. The other geographic super-regions trended downward to varying degrees, with high-income Australasia, Western Europe, high-income Asia Pacific, and high-income North America experiencing the most significant decreases in disease burden.
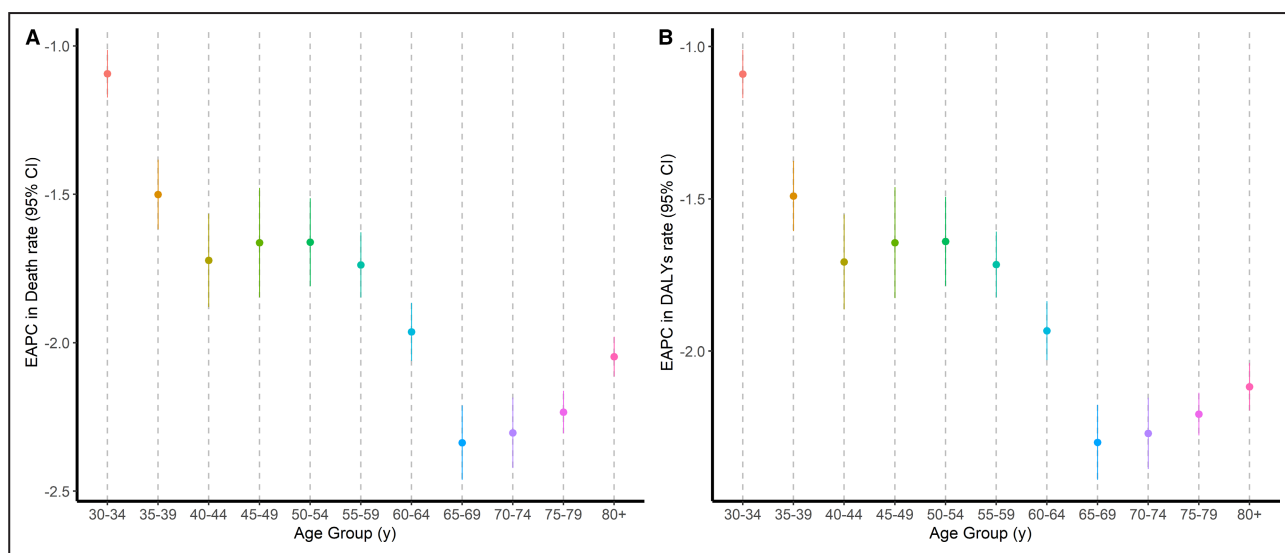
Burden of IHD Attributable to Smoking by Country

In both 1990 and 2019, the burden of IHD attributable to smoking was extremely variable among countries.

Figure 1. Age-specific rate of global IHD deaths (A) and DALYs (B) attributable to smoking in 2019.
DALYs indicates disability-adjusted life-years; and IHD, ischemic heart disease.

In 2019, ASRs of smoking-related IHD burden varied as much as 50-fold between countries, with ASMRs per 100 000 people ranging from 2.43 (95% UI, 1.69–3.38) in Peru to 118.14 (95% UI, 93.74–144.71) in the Solomon Islands. Concomitantly, ASDRs per 100 000 people ranged from 62.12 (95% UI, 43.48–85.92) in Peru to 3522.84 (95% UI, 2765.79–4375.83) in the Solomon Islands. Although ASMR and ASDR values are not the highest globally, China, India, and the Russian Federation had the greatest absolute number of deaths and DALYs attributable to smoking-related IHD because of their large populations. Detailed results are provided in Figure 3.

Over the 3 decades from 1990 to 2019, significant changes have occurred in the burden of IHD attributable to smoking in different countries. Figure 4 shows the trends of each country. In 17 countries/regions, including Egypt, Afghanistan, Pakistan, Kenya, Uganda, and Zimbabwe, the changes in ASMRs were not statistically significant, and the 95% CIs of the EAPCs were centered around 0, suggesting stable levels of disease burden. In contrast, 19 countries experienced an increase in disease burden, of which Uzbekistan and the Philippines had the most significant growth, with EAPCs in ASMRs >2. The remaining countries trended downward, with the most significant decreases occurring

Figure 2. EAPCs in age-specific rate of deaths (A) and DALYs (B) of IHD attributable to smoking by age group from 1990 to 2019.
DALYs indicates disability-adjusted life-years; EAPC, estimated annual percentage change; and IHD, ischemic heart disease.

in Israel, the Netherlands, Denmark, Australia, Ireland, and Norway, where the EAPCs in ASMRs were all <−6. Generally, the ASDR trends mirrored the ASMR trends.

Correlations Between the SDI and EAPCs in ASRs

The correlation between SDI and EAPCs in ASRs was estimated using a scatter plot (Figure S1). Pearson correlation analysis showed that the EAPCs in the ASRs of IHD attributable to smoking significantly negatively correlated with SDI ($\rho_1 = -0.573$, $\rho_1 < 0.001$ and $\rho_2 = -0.574$, $p_2 < 0.001$, respectively).

DISCUSSION

This study describes the distribution of IHD burden attributable to smoking in 2019 and analyzes the trends in this burden at global, regional, and national levels from 1990 to 2019. Globally, the burden of IHD attributable to smoking has increased in terms of absolute numbers, particularly in countries with large populations. As of 2019, countries in Eastern Europe, North Africa, North Asia, Central Asia, and South Asia have the greatest burden of IHD attributable to smoking, whereas countries in Europe, the Americas, and Oceania have a relatively light burden. In the past 3 decades, although this burden has shown a downward trend globally, this trend is dominated by countries in Northern Europe, Oceania, and North America. In contrast, some countries in East Asia, Southeast Asia, West Asia, Central Asia, and Africa have increased levels of disease burden. Finally, the burden of IHD attributable to smoking was higher in men and older age groups.

Smoking is a known risk factor for a variety of diseases, especially chronic noncommunicable diseases such as IHD.[17,18] Smoking-induced inflammation, impaired endothelial function, platelet dysfunction, increased oxidative stress, and atherosclerosis are all related to the development of IHD.[19,20] Most countries have implemented active tobacco control measures to prevent IHD at the population level. In 2005, the World Health Organization Framework Convention on Tobacco Control, came into force for state parties.[21] Following the implementation of a series of key measures, including price and tax controls, smoking bans in public places, efforts to increase public awareness of the dangers of tobacco, and increased international exchange and cooperation, the prevalence of smoking has generally decreased globally. In 2015, the mean smoking prevalence across 126 countries was 22.18%, down 2.55 percentage points from 2005.[22] However, the emphasis on tobacco control and the implementation of tobacco control measures has not been consistent across countries and regions, resulting in variable success.

The results of the correlation analysis suggested that the higher the SDI reflecting the socioeconomic development level of a country or region, the more obvious the decreasing trend of IHD burden attributable to smoking might be. This may be influenced by factors such as tobacco control efforts, medical resource allocation, and access to health interventions. High-income countries have had the greatest success in reducing tobacco consumption and the burden of tobacco-related diseases thanks to strong regulatory frameworks.[23] In China, some progress has been made in tobacco control in recent years; however, the current population smoking rate is higher than the world average. Only by actively implementing additional tobacco control measures and significantly increasing tobacco taxes will the goal of reducing smoking prevalence to
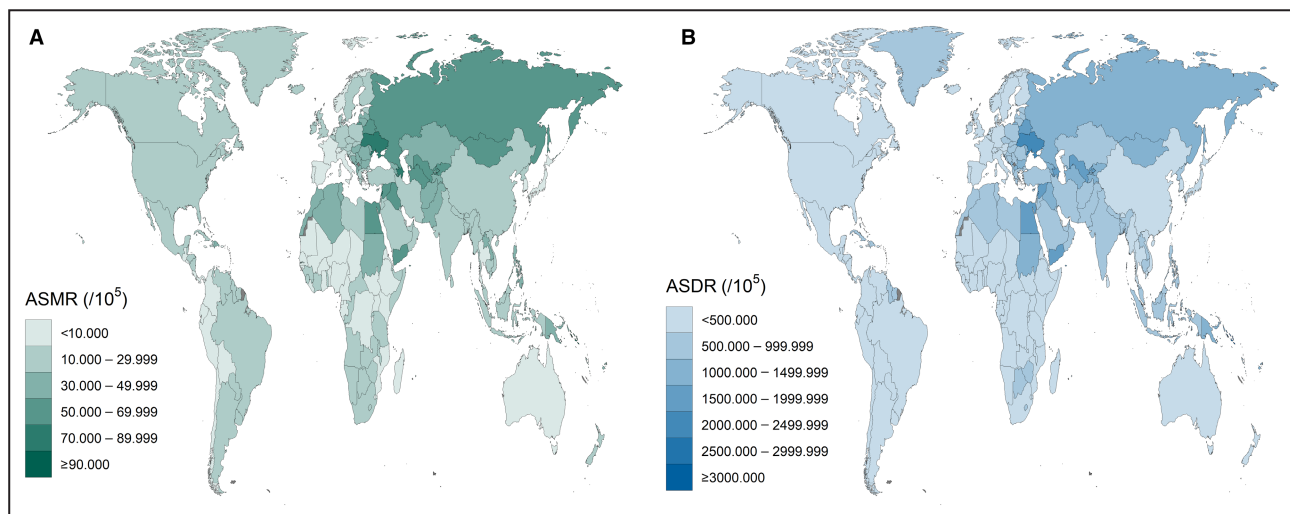
Figure 3. **ASMRs (A) and ASDRs (B) of IHD attributable to smoking by country in 2019.**
ASDR indicates age-standardized DALYs rate; ASMR, age-standardized mortality rate; and IHD, ischemic heart disease.
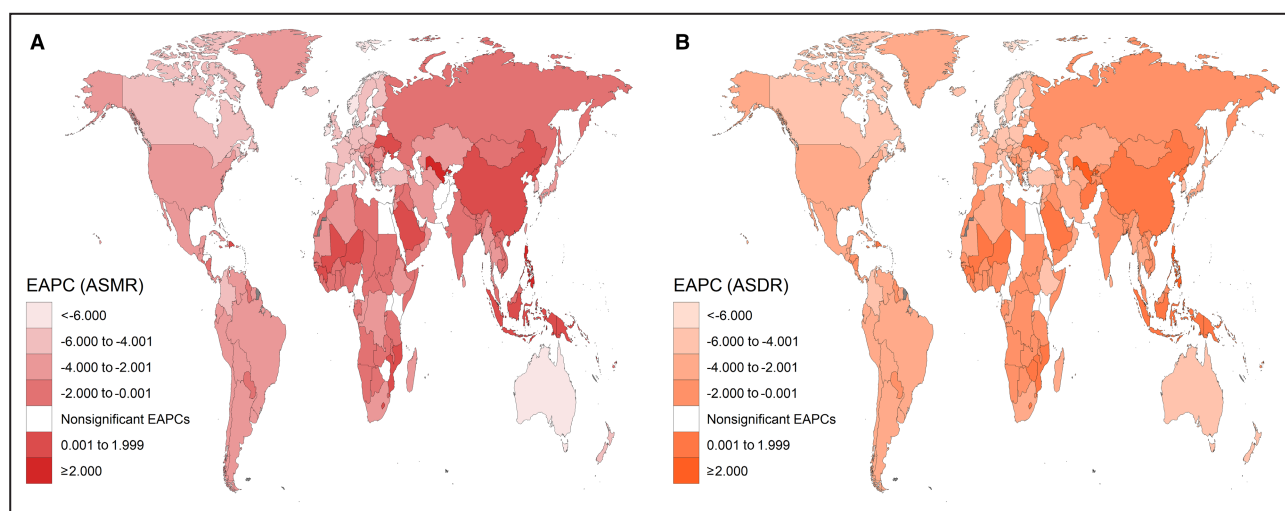
Figure 4.   EAPCs in ASMRs (A) and age-standardized DALYs (B) of IHD attributable to smoking by country from 1990 to 2019.
ASMR indicates age-standardized mortality rate; DALYs, disability-adjusted life-years; EAPC, estimated annual percentage change; and IHD, ischemic heart disease.

20% of the population by 2030 be achieved.[24] In addition, countries or regions with higher economic levels are more likely to have adequate medical resources and effective public health services, such as health education and health intervention, which are crucial for reducing the disease burden of IHD.[25] These factors may explain the differences seen in the distribution of and changing trends in the burden of IHD attributable to smoking in different countries or regions.

The burden of IHD attributable to smoking is much higher among men than among women, perhaps because men experience a higher risk of mortality from IHD. In 2019, IHD was the leading cause of death among men in 146 countries, whereas for women, this was the case in only 98 countries. Additionally, the risk of death from IHD for men is as high as 20% in some countries.[26] However, smoking rates among men are generally higher than those among women. In 2019, the age-standardized prevalence of smoking among people aged ≥15 years in 204 countries and regions around the world was 32.7% for men and only 6.62% for women, with 151 countries reporting a smoking prevalence of >20% among men.[27] This suggests that we should pay close attention to the risk of IHD in men who smoke. However, tobacco use among women is increasingly complex, especially in low- and middle-income countries, because of a combination of factors, including tobacco marketing, globalization, and the changing social status of women.[28,29] Moreover, there are inherent sex-related differences in the complex relationship between angina pectoris, atherosclerosis, and ischemia, meaning that both the diagnosis and treatment of IHD should fully consider sex-specific factors.[30]

Both the age distribution and changing characteristics of IHD burden attributable to smoking suggest that

we should pay more attention to the prevention of IHD in elderly smokers. Cardiovascular disease is the leading cause of death and major disability in adults aged ≥75 years.[31] The risk factors for IHD, such as hypertension, diabetes, and dyslipidaemia, are more prevalent in the elderly,[32] and elderly individuals are more likely to have comorbidities. However, good mental health and social support are critical factors influencing the development of IHD,[33] both of which are generally lacking in elderly populations.[34] The accelerated aging process seen in smokers might also further exacerbate the IHD burden, especially in high-income countries. Therefore, it is important to improve control of IHD risk factors, such as smoking, and actively promote the implementation of cardiac rehabilitation programs in elderly populations. In addition, prospective studies using real-world data should be conducted to assess the risk of IHD in smokers, especially in low- and middle-income countries.

There is currently a lack of population-level research on the burden of IHD attributable to smoking, particularly in terms of the changing characteristics of this burden in countries or regions with different socioeconomic development levels. Therefore, this study may have significance for further promoting the implementation of tobacco control strategies and improving the health management of key populations with IHD. This fits with the Sustainable Development Goals for good health and well-being.[35] However, our findings must be interpreted in the context of several limitations. First, the data are derived from public databases, and data relating to smoking habits are self-reported, potentially resulting in an underestimation of smoking prevalence, particularly in female populations. Second, the databases used assess exposure to only traditional

smoking tobacco products and do not include emerging tobacco products, such as electronic cigarettes, the health effects of which are becoming increasingly apparent. Third, only the burden of IHD attributable to smoking was analyzed, as data relating to secondhand smoke exposure were not available.

CONCLUSIONS

Although the burden of IHD attributable to smoking has decreased in >80% of countries or regions in recent years, it has remained a significant issue in low- and middle-income countries, particularly among men and elderly populations. Therefore, active tobacco control measures, focusing on key populations, are required to reduce the associated burden of IHD, especially in those countries or regions with increasing prevalence and disease burden.

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SUPPLEMENTAL MATERIAL

Figure S1. Scatter plot-the correlations between the SDI and EAPCs of ASRs.
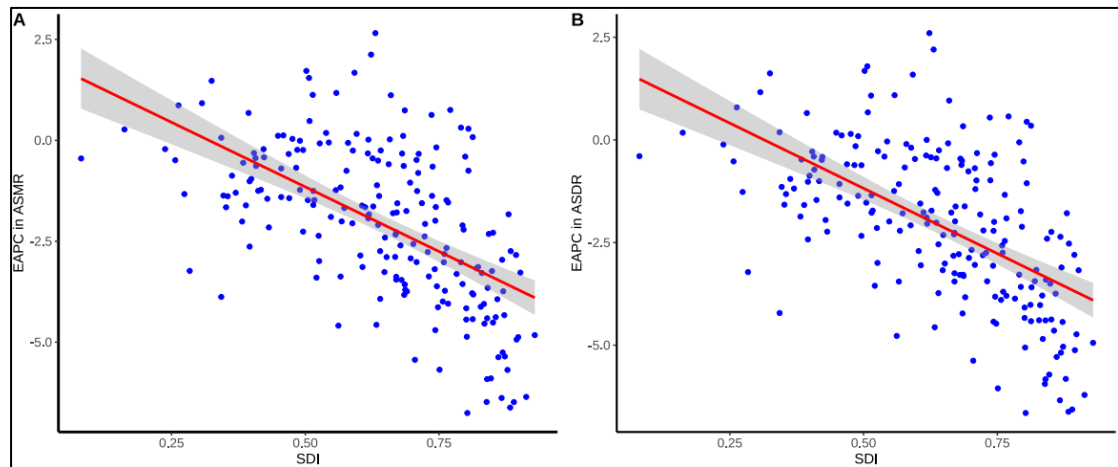
SDI: sociodemographic index，EAPC: Estimated Annual Percentage Change, ASRs:

age-standardized rates.