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ORIGINAL ARTICLE

Burden of cardiovascular disease among elderly: based on the Global Burden of Disease Study 2019

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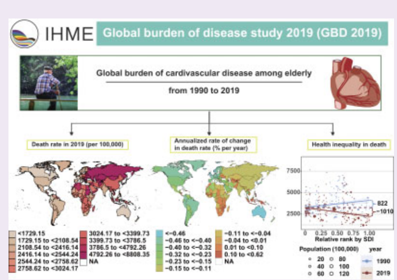
Background The burden of elderly cardiovascular disease (CVD) has received increasing attention with population ageing worldwide.

Aims We reported on the global CVD burden in elderly individuals over 70, 1990–2019.

Methods and results Based on the Global Burden of Disease Study 2019, elderly CVD burden data were analysed. Temporal burden trends were analysed with the joinpoint model. The slope index and concentration index were used to evaluate health inequality. From 1990 to 2019, the global elderly CVD incidence, prevalence, death, and disability-adjusted life year rates generally decreased. However, the current burden remains high. The rapid growth in burden in parts of sub-Saharan Africa and Asia is a cause for concern. Countries with a higher socio-demographic index (SDI) have generally seen a greater decrease in burden, while countries with a lower SDI have generally experienced increases or smaller declines in burden. Health inequality analysis confirmed that the burden was gradually concentrating towards countries with a low SDI. Among the different CVDs, ischaemic heart disease causes the greatest burden in elderly individuals. Most CVD burdens increase with age, but stroke and peripheral vascular disease show markedly different distributional characteristics. In addition, the burden of hypertensive heart disease shows an unusual shift towards high-SDI countries. High systolic blood pressure was consistently the leading risk factor for CVD among elderly individuals.

Conclusion The burden of CVD in older people remains severe and generally tends to shift to lower-SDI countries. Policymakers need to take targeted measures to reduce its harm.

Graphical Abstract



Keywords Cardiovascular disease • Elder • Disease burden • Health inequality • Epidemiology

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Key learning points

What is already known

- As ageing increases, the burden of cardiovascular disease in older people is a growing concern.

What this study adds

- The burden of cardiovascular disease in older people is generally shifting towards lower socio-economic countries, which are likely to face more serious challenges in the future.
- The burden of most types of cardiovascular disease increases with age, but the burden of stroke and peripheral vascular disease show markedly different distributional characteristics.

Introduction

Cardiovascular disease (CVD) is the leading cause of global mortality and a significant contributor to poor quality of life.[1] In 2017, there were >17 million deaths from CVD, almost twice as many as from cancer.[2] In Europe, >60 million potential years of life are lost due to CVD annually.[3] For the past 30 years, the burden of CVD in high-income regions has decreased in general, whereas the burden is still heavy in low-income regions because of the differences between lifestyle, environment, education, and so on.[2,4] For example, ∼75% of deaths from stroke and >80% of deaths from ischaemic heart disease occur in low- and middle-income countries.[5,6]

Age is a separate and unavoidable risk factor that reduces the cardiovascular system's ability to perform at its best.[7] According to the American Heart Association on Heart Disease and Stroke Statistics in 2019, the incidence of CVDs was typically 35–40% in people between the ages of 40 and 60, patients between the ages of 60 and 80 had an average incidence of 77–80%, and patients over the age of 80 had an incidence of over 85%.[7,8] During the last 200 years, average human life expectancy has doubled in most developed countries, and it is forecast that nearly one-fifth of the population in the world will be aged 65 or older by 2030.[9,10] In fact, ageing problems have become prominent worldwide, and the burden of CVD is currently falling mainly on elderly individuals.[10]

Globally, life expectancy at birth has recently increased to over 70 years in 2019.[11] The current growth of elderly adults over 70 is the fastest in many regions, such as Europe, the USA and Asia, and there is a lack of analysis of the global burden of CVD in those aged over 70.[12] Thus, it is urgent to identify the burden of elderly CVD, especially those over 70, providing additional information to local governments for alleviating this stress. The Global Burden of Disease (GBD) study 2019 provided four indicators for the disease burden, allowing for a more thorough and precise analysis. Using data from GBD 2019, we assessed the global, regional, and national burden of CVD in old age, its spatial and temporal distribution characteristics, its relationship to socioeconomic level, and its risk factors. First, we reported the elder CVD burden and its trend for the whole world, 21 regions and 204 countries and territories by gender. Second, we analysed the relationship between the CVD burden in older adults and socioeconomic level and assessed health inequalities. Afterwards, we reported the burden of different CVD subtypes by age and sex, with a specific assessment of the top four CVD subtypes that cause the most deaths. Finally, we analysed risk factors for CVD in older people from 1990 to 2019.

Methods

Data sources

GBD 2019 includes the latest estimation of descriptive epidemiological data on a total of 369 diseases and injuries for 204 countries and territories from 1990 to 2019, which was used to determine the worldwide burden of elderly CVD.[13] All countries and territories were divided into 21 regions and then into five categories based on the socio-demographic index (SDI).[13]

Statistical analyses

In this study, we included the 10 most common global causes of CVD in elderly individuals.[14] People over the age of 70 were included in our analysis and divided into six age strata (70–74, 75–79, 80–84, 85–89, 90–94, and 95+). The burden of elderly CVD was analysed by sex, year, age, location, and cause. Incidence, prevalence, death, disability-adjusted life years (DALYs), and their rates were reported with 95% uncertainty intervals (UIs). Additionally, the annual percentage changes (APCs) and their 95% confidence intervals (CIs) were also calculated. R software (R Core Team, version 4.1.3, Vienna, Austria) and the Surveillance Research Program of the US National Cancer Institute's Joinpoint software (version 4.9.1) were used for analyses. The significance level used to evaluate the *P*-value was 0.05. The decomposition analyses demonstrated the contribution of age, epidemiological change, and population to the change in CVD burden between 1990 and 1991–2019. The slope index of inequality and the concentration index were used to calculate the degree of health inequities in the distribution of elderly CVD burden across countries (details in supplementary methods).

Results

Age and cardiovascular disease burden

Among all types of non-communicable diseases in 2019, CVD showed the greatest death rate and DALY rate in all age groups, especially in the 25–49, 50–69, and over 70 years groups, in which CVD ranked first (Supplementary online, *Table S1*). The CVD burdens were analysed among age groups 0–9, 10–24, 25–49, 50–69, and over 70 years. In 2019, patients aged over 70 years accounted for the largest incidence, prevalence, death, and DALY rates (Supplementary online, *Figure S1*). With the baseline of 1990, the burden change of CVD owing to ageing continued to increase from 1991 to 2019. From 1991 to 2019, the percentage of incidence and prevalence change attributed to ageing showed a general increase. Meanwhile, the proportion of death changes and DALY changes due to ageing rose broadly between 1991 and 2019 (Supplementary online, *Figure S2*). Based on these findings, we focused on elderly individuals over 70.

Global cardiovascular disease burden and its trend among elderly individuals

In 2019, 21 172 117 (95% UI, 19 279 481–23 193 109) new cases and 12 168 381 (10 817 275–12 969 353) deaths from elderly CVD were recorded, with 195 943 227 (185 037 643–207 466 433) prevalent cases and 162 402 754 (149 298 184–172 522 790) DALYs (*Table 1*). The global elderly CVD incidence, prevalence, death, and DALY rates have noticeably decreased since 1990. Specifically, the global incidence rate is continuing to decrease, with the fastest fall occurring between 1996 and 2000 (APC = −1.09%). However, the rate of this decline has slowed in recent years. The APC of incidence rate in 2017–19 was greater than the APC of incidence rate for any previous time period between 1990 and 2017 (2017–19 APC = −0.04). The prevalence rate decreased most of the time, but an increasing trend was observed in 2008–15 (APC = 0.07%). Since 1990, there has been a considerable decline in both the global death rate and the DALY rate, with the greatest reductions occurring between 2003 and 2007 (death rate: APC = −1.79%; DALY rate: APC = −1.95%) (*Figure 1*). For both sexes, from 1990 to 2019, decreasing trends were similar to the global trend. However, the rates of incidence, death, and DALY in males were consistently higher than those in females, whereas the prevalence rate in males was lower than that in females before 1997 (Supplementary online, *Figure S3*).

Regional and national cardiovascular disease burden and its trend in elderly individuals

For region, in 2019, the incidence, death, and DALY rates of elderly CVD were highest in Central Asia, and prevalence rates were highest in Eastern Europe (Supplementary online, *Figure S4* and *Table S2*). Although the global burden has decreased, there were still some regions where the burden was on the rise and required special attention. Since 1990, in incidence and prevalence rates, the greatest decrease had been observed in Western Europe and the highest increase in East Asia. The second highest increase in incidence rate was in Central Asia, while the second highest increase in prevalence rate was in Western sub-Saharan Africa. Most regions have experienced a decline in death and DALY rates, with high-income Asia Pacific and Australasia, respectively, showing the largest declines. However, Central Asia experienced the largest increases, followed by southern sub-Saharan Africa (Supplementary online, *Figure S4* and *Table S2*).

At the national level, in 2019, the highest incidence, death, and DALY rates of elderly CVD were shown in Uzbekistan, while the highest prevalence rates were shown in Iran (Islamic Republic of) (*Figure 2* and Supplementary online, *Table S3*). Uzbekistan also had the greatest increase in incidence and DALY rates from 1990 to 2019. In addition, Tajikistan had the largest increase in mortality rate, while Guam had the largest increase in prevalence rate. The Republic of Korea showed the highest decline in incidence, prevalence, death, and DALY rates (Supplementary online, *Figure S5* and *Table S3*).

Relationship between socioeconomic development status and cardiovascular disease burden among elderly individuals

Over this 30-year period, there were large differences between burden trends in countries with different SDIs. The burden has fallen the most in high-SDI countries, followed by high-middle-SDI countries. The decreasing trend in the burden is smaller in low-, low-middle-, and middle-SDI countries, whose prevalence rate has even shown an increasing trend (*Table 1*).

To further validate the relationship between the burden of CVD in old age and socioeconomic level, we conducted an SDI-related health inequality analysis. The slope index indicated that SDI showed a significant positive correlation with the burden of CVD among elderly individuals in 1990. However, the burden showed a trend towards lower-SDI countries. In 2019, the positive correlation between incidence and prevalence rates and SDI was significantly weaker than that in 1990, while death and DALY rates even showed a significant negative correlation with SDI (Incidence 1990: 2338 to Incidence 2019: 470; Prevalence 1990:18 361 to Prevalence 2019: 9758; Death 1990: 822 to Death 2019: −1010; DALY 1990: 3270 to DALY 2019: −20 016) (*Figure 3*). The concentration index was also evidence of a gradual concentration of burden towards lower-SDI countries (Incidence 1990: 0.06 to Incidence 2019: −0.01; Prevalence 1990: 0.07 to Prevalence 2019: 0.02; Death 1990: 0.02 to Death 2019: −0.06; DALY 1990: −0.02 to DALY 2019: −0.09) (Supplementary online, *Figure S6*).

Burdens of different cardiovascular diseases among elderly individuals

We further assessed the burden of different CVDs in elderly individuals. In 2019, except for the inaccessible incidence and prevalence of aortic aneurysm, ischaemic heart disease, the most common form of elderly CVD, was also the top cause of death and DALYs in elderly individuals with CVD of both sexes worldwide. Stroke, hypertensive heart disease, and atrial fibrillation and flutter were the other three most common reasons for death (Supplementary online, *Table S4*). From 1990 to 2019, the incidence, death, and DALY rates of rheumatic heart disease fell the most, and peripheral artery disease had the greatest decrease in prevalence. Meanwhile, endocarditis has had the most marked rise in incidence, death, and DALY rates.

In most CVDs, the burden increased with age, with the largest proportions of incidence, prevalence, death, and DALY rates occurring in those aged 95 years or older and the smallest in those aged 70–74 years. There was no significant difference between males and females in the rates at different ages. Interestingly, the distribution of certain disease burdens did not follow this pattern. In particular, the incidence rate of peripheral arterial disease even decreased with age after the age of 75–79. Furthermore, the prevalence and DALY rates for stroke in men tended to increase and then decrease with age (Supplementary online, *Figure S7*).

Further analysis of the top four global cardiovascular diseases among elderly individuals

A more detailed assessment of the top four CVD burdens on elderly individuals worldwide was performed. Our ranking was based on the death rate brought about by different CVDs. For ischaemic heart disease in 2019, low-middle-SDI settings had the greatest rates of incidence and prevalence, while high-SDI settings had the lowest rates. Meanwhile, the lowest death and DALY rates also occurred in high-SDI settings. The greatest rates of DALY and death were found in high-middle-SDI settings. For stroke, high-SDI settings had the lowest rates of death and DALY. Among various age groups, the incidence and death rates increased with age, in which elders aged over 95 had the highest incidence and death rates, whereas elders aged 70–74 had the lowest. However, the rates did not increase simply with age in prevalence and DALY rates. In terms of subtypes, ischaemic stroke contributed to most death and DALY rates among all age groups and had the highest rates of incidence and prevalence (Supplementary

Table 1 Global burdens of elderly cardiovascular disease in 2019 and their annualized changes in rates from 1990 to 2019

Location	Sex	Incidence (95% UI)			Prevalence (95% UI)			Death (95% UI)			DALYs (95% UI)		
		Count	Rate (per 100 000)	Annualized rate of change (%)	Count	Rate (per 100 000)	Annualized rate of change (%)	Count	Rate (per 100 000)	Annualized rate of change (%)	Count	Rate (per 100 000)	Annualized rate of change (%)
Global	Both	21 172 117 (19 279 481–23 193 109)	4566.16 (4157.97–5002.02)	−0.17 (−0.18 to −0.16)	195 943 227 (185 037 643–207 466 433)	42 258.75 (39 906.77–44 743.95)	−0.06 (−0.07 to −0.05)	12 168 381 (10 817 275–12 969 353)	2624.33 (2332.94–2797.08)	−0.26 (−0.3 to −0.22)	162 402 754 (149 298 184–172 522 790)	35 025.14 (32 198.89–37 207.71)	−0.3 (−0.34 to −0.26)
	Male	9 467 435 (8 571 848–10 415 229)	4654.27 (4213.99–5120.21)	−0.17 (−0.18 to −0.15)	86 244 709 (81 173 320–91 742 076)	42 398.63 (39 905.49–45 101.18)	−0.05 (−0.06 to −0.04)	5 571 366 (5 091 330–5 950 407)	2738.93 (2502.94–2925.27)	−0.25 (−0.3 to −0.2)	78 158 159 (72 371 447–83 273 683)	38 423.21 (35 578.41–40 938.05)	−0.29 (−0.34 to −0.24)
	Female	11 704 682 (10 663 374–12 830 464)	4497.29 (4097.19–4929.85)	−0.18 (−0.19 to −0.16)	109 698 517 (103 401 178–116 224 320)	42 149.43 (39 729.81–44 656.84)	−0.07 (−0.08 to −0.06)	6 597 015 (5 706 263–7 189 079)	2534.77 (2192.52–2762.26)	−0.27 (−0.32 to −0.21)	84 244 596 (75 239 349–90 818 198)	32 369.28 (28 909.2–34 895.05)	−0.31 (−0.36 to −0.26)
High SDI	Both	5 318 583 (4 897 814–5 789 680)	4144.25 (3816.38–4511.33)	−0.33 (−0.35 to −0.32)	56 100 053 (53 249 405–58 985 250)	43 713.24 (41 492.01–45 961.39)	−0.15 (−0.17 to −0.14)	2 297 855 (1 947 277–2 475 656)	1790.49 (1517.32–1929.03)	−0.45 (−0.49 to −0.42)	27 551 141 (24 294 244–29 467 071)	21 467.89 (18 930.11–22 960.78)	−0.5 (−0.52 to −0.48)
	Male	2 364 015 (2 171 547–2 573 582)	4281.79 (3933.18–4661.36)	−0.36 (−0.38 to −0.34)	24 586 974 (23 321 750–25 873 995)	44 532.82 (42 241.2–46 863.92)	−0.16 (−0.17 to −0.14)	1 004 298 (896 158–1 059 029)	1819.02 (1623.15–1918.15)	−0.49 (−0.52 to −0.47)	13 162 322 (12 108 835–13 869 685)	23 840.07 (21 931.96–25 121.27)	−0.53 (−0.55 to −0.51)
	Female	2 954 567 (2 718 841–3 215 480)	4040.4 (3718.04–4397.2)	−0.32 (−0.34 to −0.3)	31 513 079 (29 887 111–33 193 992)	43 094.45 (40 870.92–45 393.11)	−0.15 (−0.17 to −0.14)	1 293 557 (1 052 854–1 423 053)	1768.95 (1439.79–1946.04)	−0.42 (−0.47 to −0.39)	14 388 819 (12 230 736–15 631 067)	19 676.85 (16 725.65–21 375.64)	−0.48 (−0.52 to −0.46)
High-middle SDI	Both	5 911 087 (5 372 276–6 472 306)	4968.51 (4515.61–5440.23)	−0.18 (−0.2 to −0.16)	52 744 462 (49 775 863–55 845 908)	44 333.85 (41 838.62–46 940.74)	−0.05 (−0.06 to −0.04)	3 745 253 (3 343 075–4 022 169)	3148.04 (2809.99–3380.8)	−0.28 (−0.33 to −0.24)	48 090 816 (43 832 039–51 232 096)	40 422.27 (36 842.6–43 062.64)	−0.34 (−0.38 to −0.3)
	Male	2 351 246 (2 127 969–2 584 108)	4789.52 (4334.7–5263.86)	−0.18 (−0.2 to −0.16)	20 763 430 (19 540 008–22 146 202)	42 295.36 (39 803.23–45 112.08)	−0.05 (−0.06 to −0.04)	1 574 483 (1 425 096–1 699 213)	3207.24 (2902.94–3461.32)	−0.29 (−0.35 to −0.23)	21 559 932 (19 686 522–23 284 636)	43 917.85 (40 101.69–47 431.09)	−0.33 (−0.39 to −0.28)
	Female	3 559 841 (3 230 380–3 900 026)	5094.25 (4622.78–5581.07)	−0.18 (−0.19 to −0.16)	31 981 033 (30 135 076–33 815 197)	45 765.91 (43 124.29–48 390.66)	−0.04 (−0.05 to −0.03)	2 170 770 (1 880 394–2 379 982)	3106.44 (2690.91–3405.83)	−0.28 (−0.34 to −0.23)	26 530 884 (23 564 760–28 824 354)	37 966.57 (33 721.95–41 248.6)	−0.35 (−0.4 to −0.3)
Middle SDI	Both	5 803 644 (5 263 216–6 368 404)	4630.58 (4199.39–5081.19)	−0.03 (−0.05 to −0.01)	51 114 746 (47 857 690–54 598 628)	40 783.16 (38 184.43–43 562.86)	0.05 (0.04–0.06)	3 720 613 (3 331 750–4 027 398)	2968.58 (2658.32–3213.36)	−0.13 (−0.22 to −0.05)	51 995 623 (47 552 064–56 020 928)	41 485.99 (37 940.58–44 697.68)	−0.18 (−0.26 to −0.11)
	Male	2 676 834 (2 419 010–2 950 656)	4710.16 (4256.5–5191.98)	−0.07 (−0.09 to −0.05)	22 784 446 (21 284 187–24 443 270)	40 091.57 (37 451.71–43 010.44)	0.05 (0.04–0.07)	1 827 052 (1 640 177–1 998 978)	3214.89 (2886.06–3517.41)	−0.09 (−0.19 to 0.03)	26 242 617 (23 679 709–28 769 475)	46 176.57 (41 666.87–50 622.84)	−0.14 (−0.23 to −0.02)
	Female	3 126 809 (2 831 743–3 427 813)	4564.55 (4133.81–5003.96)	0.01 (−0.01 to 0.03)	28 330 300 (26 548 103–30 157 230)	41 356.92 (38 755.25–44 023.89)	0.05 (0.04–0.06)	1 893 560 (1 640 417–2 109 114)	2764.24 (2394.7–3078.91)	−0.18 (−0.28 to −0.06)	25 753 006 (22 808 092–28 387 637)	37 594.55 (33 295.53–41 440.62)	−0.23 (−0.32 to −0.13)
Low-middle SDI	Both	3 165 772 (2 834 341–3 505 218)	4637.65 (4152.13–5134.92)	−0.01 (−0.02 to 0.01)	27 494 293 (25 676 315–29 485 107)	40 277.36 (37 614.14–43 193.77)	0.04 (0.04–0.05)	1 810 028 (1 641 337–1 960 038)	2651.57 (2404.45–2871.33)	−0.09 (−0.17 to 0)	26 009 605 (23 803 192–28 136 822)	38 102.38 (34 870.13–41 218.62)	−0.14 (−0.21 to −0.06)
	Male	1 575 907 (1 404 093–1 755 865)	5014.99 (4468.23–5587.67)	−0.01 (−0.02 to 0.01)	13 674 411 (12 752 625–14 668 430)	43 515.89 (40 582.51–46 679.15)	0.05 (0.04–0.06)	884 275 (800 422–966 237)	2814.02 (2547.17–3074.84)	−0.06 (−0.15 to 0.05)	12 950 467 (11 744 512–14 149 664)	41 212.1 (37 374.4–45 028.28)	−0.11 (−0.19 to −0.01)
	Female	1 589 866 (1 427 470–1 755 752)	4315.78 (3874.94–4766.08)	0 (−0.01 to 0.02)	13 819 882 (12 886 630–14 855 707)	37 514.82 (34 981.45–40 326.62)	0.04 (0.03–0.05)	925 754 (804 268–1 032 059)	2513.01 (2183.23–2801.58)	−0.11 (−0.24 to 0.03)	13 059 138 (11 440 772–14 498 904)	35 449.74 (31 056.6–39 358.06)	−0.16 (−0.28 to −0.03)

Table 1 Continued

Location	Sex	Incidence (95% UI) Count	Incidence Rate (per 100 000)	Incidence Annualized rate of change (%)	Prevalence (95% UI) Count	Prevalence Rate (per 100 000)	Prevalence Annualized rate of change (%)	Death (95% UI) Count	Death Rate (per 100 000)	Death Annualized rate of change (%)	DALYs (95% UI) Count	DALYs Rate (per 100 000)	DALYs Annualized rate of change (%)
Low SDI	Both	962 744 (858 906–1 073 321)	4271.82 (3811.08–4762.46)	−0.06 (−0.07 to −0.04)	8 393 595 (7 828 237–9 014 812)	37 243.48 (34 734.91–39 999.9)	0.03 (0.02–0.04)	588 470 (531 394–640 608)	2611.12 (2357.87–2842.46)	−0.08 (−0.18 to 0.01)	8 674 796 (7 934 750–9 410 397)	38 491.2 (35 207.52–41 755.16)	−0.13 (−0.22 to −0.05)
	Male	494 651 (438 538–554 378)	4600.68 (4078.79–5156.2)	−0.1 (−0.11 to −0.08)	4 389 961 (4 086 936–4 732 382)	40 830.45 (38 012.05–44 015.26)	0.05 (0.04–0.06)	278 426 (251 452–305 469)	2589.6 (2338.73–2841.13)	−0.1 (−0.19 to 0.04)	4 203 709 (3 817 735–4 587 403)	39 098.14 (35 508.25–42 666.83)	−0.15 (−0.23 to −0.02)
	Female	468 093 (419 285–520 389)	3971.8 (3557.66–4415.54)	−0.01 (−0.03 to 0.01)	4 003 634 (3 732 433–4 294 792)	33 971.13 (31 669.96–36 441.62)	0.02 (0.01–0.03)	310 045 (272 302–345 163)	2630.75 (2310.5–2928.73)	−0.06 (−0.22 to 0.12)	4 471 088 (3 978 731–4 939 279)	37 937.5 (33 759.82–41 910.13)	−0.11 (−0.25 to 0.05)

Abbreviations: UI, uncertainty interval; DALYs, disability-adjusted life years; SDI, sociodemographic index.

online, *Figure S8*). In 2019, for hypertensive heart disease, high-SDI settings presented the lowest prevalence and the lowest rates of death and DALY. The greatest death rate and DALY rate were observed in low-SDI settings. In 2019, the highest incidence and prevalence rates of atrial fibrillation and flutter were found in high-SDI settings, while low-SDI settings were the lowest. Meanwhile, the lowest death and DALY rates occurred in low-SDI settings, and the highest occurred in high-SDI settings. The 30-year trend in ischaemic heart disease, stroke, and atrial fibrillation and flutter burden was broadly consistent with the trend in overall CVD burden, all of which showed a gradual shift in burden towards lower-SDI countries. However, hypertensive heart disease showed unusual characteristics, with high- and high-middle-SDI countries accounting for a greater share of its burden in 2019 than in 1990. Detailed data on the top four causes are shown in Supplementary online, *Tables S5–8*.

Changes in leading risk factors

High systolic blood pressure consistently accounted for the greatest proportion of elderly CVD deaths between 1990 and 2019, followed by dietary risks, which remained the top two causes of death in 1990 and 2019 (*Figure 4A*).

The leading risks were similar between males and females. For males and females, the leading risks in 2019 were high systolic blood pressure, dietary risks, high LDL cholesterol, and high fasting plasma glucose. Tobacco was the fifth risk factor for males, while it ranked eighth for females. Additionally, for the risk factors for death from CVD, the rank of air pollution was higher in females than in males. In terms of the top five risks, males had three metabolic risks and two behavioural risks, while females had three metabolic risks, one behavioural risk, and one environmental or occupational risk (*Figure 4B* and *C*).

Discussion

Principal findings

This study explored comprehensively the global burden and trend of CVD among elderly individuals over 70 and generated some new findings. From 1990 to 2019, the global incidence, prevalence, death, and DALY rates of CVD in older people all showed promising declines (*Table 1*). However, the current global burden of CVD among elderly individuals remains high, and the decline in incidence has slowed (*Table 1* and *Figure 1*). At the regional level, Central Asia and Eastern Europe had the greatest burden, and parts of sub-Saharan Africa and Asia experienced the sharpest increase in burden (Supplementary online, *Table S2* and *Figure S4*). As a representative of the high risk of CVD in older people in Central Asia, Uzbekistan had the largest incidence, death, and DALY rates and the largest increase in death and DALY rates of any country and territory, requiring special attention (Supplementary online, *Table S3*, *Figure 2*, and Supplementary online, *Figure S5*). Trends in burden changes varied across countries with different SDIs. High-SDI and high-middle-SDI countries generally experienced a significant decline in burden, while most of the lower-SDI countries experienced only a small decline or even a slight increase (*Table 1*). Further analysis of health inequalities suggested that the concentration of burden was shifting to low-SDI countries (*Figure 3*, Supplementary online, *Figure S6*). The burden of CVD increased with age in different 5-year age groups (Supplementary online, *Figure S7*). However, the burden due to different CVD subtypes showed different characteristics. The incidence rate of peripheral vascular disease decreased with age after the age of 75–79. The prevalence and DALY rates for stroke in males tended to increase and then decrease with age (Supplementary online, *Figure S7*). Among the different subtypes, ischaemic heart disease caused the greatest burden, while the trend towards increased incidence, death, and DALY rates was

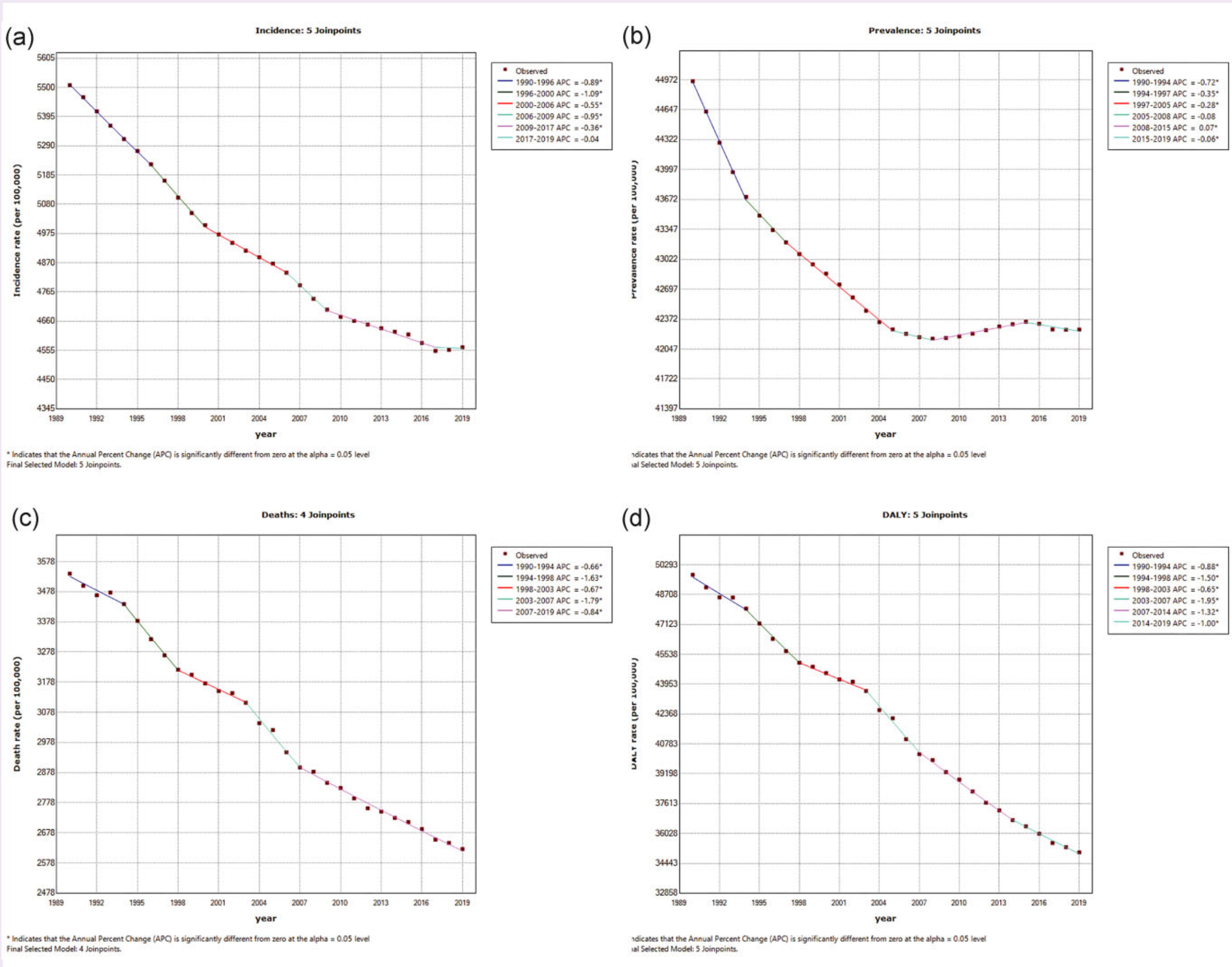

Figure 1 Global trends for incidence rate, prevalence rate, death rate, and DALY rate (per 100 000 population) of elderly cardiovascular disease from 1990 to 2019. (*a*) Incidence rate; (*b*) prevalence rate; (*c*) death rate; and (*d*) DALY rate. Abbreviation: DALY, disability-adjusted life year.

most pronounced in endocarditis (Supplementary online, *Table S4*). In addition, the burden of hypertensive heart disease in older people showed a trend towards countries with high SDI (Supplementary online, *Table S7*). Of the different risk factors, the one that had the greatest impact on CVD mortality in older people was high systolic blood pressure, followed by dietary factors (*Figure 4*). Our study provides a systematic analysis of the global burden caused by CVD among elderly individuals to help implement more effective and targeted measures to minimize harm.

Comparison with other studies

To the best of our knowledge, this study provides the most recent and comprehensive analysis available on the burden of CVD among elderly individuals over 70 on a global, regional, and national level from 1990 to 2019. CVD remains the main cause of disease burden worldwide, and ageing is an important risk factor affecting cardiovascular homeostasis.[14,15] Consistent with previous studies, this analysis revealed a global decline in rates of death and DALY since 1990, which is attributable to recent more precise diagnoses and better therapies (*Table 1*).[14] The incidence and prevalence rates of CVD in the elderly are also on the decline, and healthier lifestyles and better prevention strategies may be important reasons for this (*Table 1*).[16,17] However, the decline in incidence has slowed in recent years (*Figure 1*). Global warming, long-term air pollution exposure, etc. may be associated with the slowing of this trend.[18,19] Ageing is strongly associated with CVD burden, and it is forecast that approximately one-fifth of the global population will be over the age of 65 by 2030, with the prevalence of CVD increasing exponentially[9]; thus, there is still a huge challenge to elderly health and social development.

Although the global burden was declining, there were still some regions where the burden was trending upwards. Of the 21 regions, East Asia, Central Asia, and western sub-Saharan Africa have seen the sharpest increases in incidence and prevalence rates, while Central Asia and southern sub-Saharan Africa have seen non-negligible increases in death and DALY rates (Supplementary online, *Figure S4*, and *Table S2*). The incidence and prevalence rates of most CVDs increased with age (Supplementary online, *Figure S7*). The generally lower birth rates and longer life expectancy in East Asian countries have led to changes in age structure,[20] which may be the main reason for the increased incidence and prevalence burden in the region. From

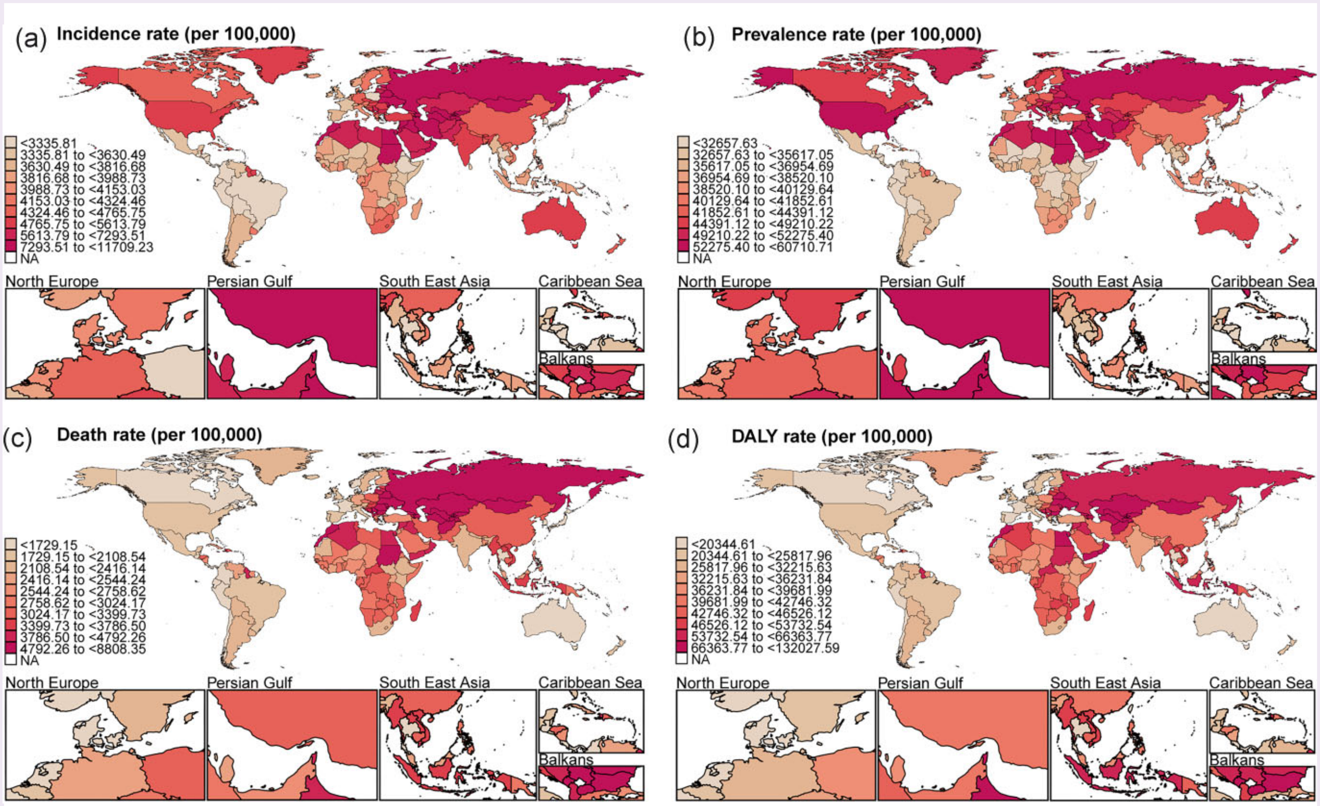

Figure 2 National incidence rate, prevalence rate, death rate, and DALY rate (per 100 000 population) of elderly cardiovascular disease for both sexes combined in 2019. (*a*) Incidence rate; (*b*) prevalence rate; (*c*) death rate; and (*d*) DALY rate. Notes: The raw data are from GBD2019, and possible zoning issues are not our focus. Abbreviations: DALY, disability-adjusted life year; GBD, Global Burden of Disease.

1990 to 2030, East Asia is also expected to have the largest worldwide increase in the proportion of people aged 65+ (from 12.9 to 18.1%).[21] The local area may face an even greater challenge of CVD in old age in the future. According to our study, dietary risk was an important risk factor for CVD in the elderly (*Figure 4*). The large increase in the risk of CVD among older people in sub-Saharan Africa may be strongly associated with the large amount of extra-regional trade experienced by the southern African Development Community. The main diet of the local population shifted from highly nutritious and fibrous staples to imported processed foods and sugary beverages, which often led to higher CVD incidence and death rates among the elderly.[22–24] The 'collision' epidemic of HIV and CVDs in ~2000 is also a possible cause of the rising local death burden.[25] The rapidly increasing burden in Central Asia may be related to local dietary habits.[2] Apart from the risk of diet, diabetes, hypertension, alcohol, tobacco, insufficient preventive care, and education also take part in the progressive burden of elderly CVD in Central Asia.[26,27] In addition, the break-up of the former Soviet Union is also a possible cause of this increase.[28]

Among the different countries and territories, as a prominent representative of Central Asian countries at high risk of CVD in older age, Uzbekistan has shown the largest increases in incidence and DALY rates over the past 30 years (Supplementary online, *Figure S5* and *Table S3*). In 2019, Uzbekistan also had the highest rates of CVD incidence, death, and DALY rates in older age in the world (*Figure 2*, Supplementary online, *Table S3*). The shortage of healthcare resources, income inequality, limited drug affordability, and excessive use of alcohol and tobacco participated in the progress of burden of CVD among elders in Uzbekistan.[29] However, current research on CVD among elderly individuals in Uzbekistan is inadequate, which is not conducive to improving this situation. Interestingly, in terms of countries and territories, the Republic of Korea showed the largest decrease in rates of incidence, prevalence, death, and DALY from 1990 to 2019 (Supplementary online, *Figure S5* and *Table S3*). The range of measures taken by local authorities to reduce the burden of CVD in old age, such as establishing legal frameworks and new regional cardio-cerebrovascular centres, are worthy of study by policymakers in other countries.[30]

Although the burden has generally fallen, the downwards trend varies between SDI regions. Burden tended to fall more in high SDI areas, while it often fell slightly or even rose in low SDI areas (*Table 1*). The SDI-related health inequality analysis confirmed that the burden of CVD in older people was gradually shifting to countries with lower SDI (*Figure 3*, Supplementary online, *Figure S6*). The most plausible explanation for the greater decline in high-SDI countries may be better control of risk factors such as hypertension and obesity in older people and higher budgets for CVD prevention and treatment.[31,32] Low-SDI countries, on the other hand, tend to have lower budgets for CVD screening, prevention and treatment, and relatively inadequate education and skills of health workers.[33] Although treatment modalities for CVD are improving, the effect of this improvement may be uneven across countries. The low availability and accessibility of drugs in low-SDI countries is a major barrier to the use of and adherence to essential CVD drugs.[34] In addition, unlike developed countries, the older population in less developed countries is growing significantly slower than younger people in terms of access to health services, and

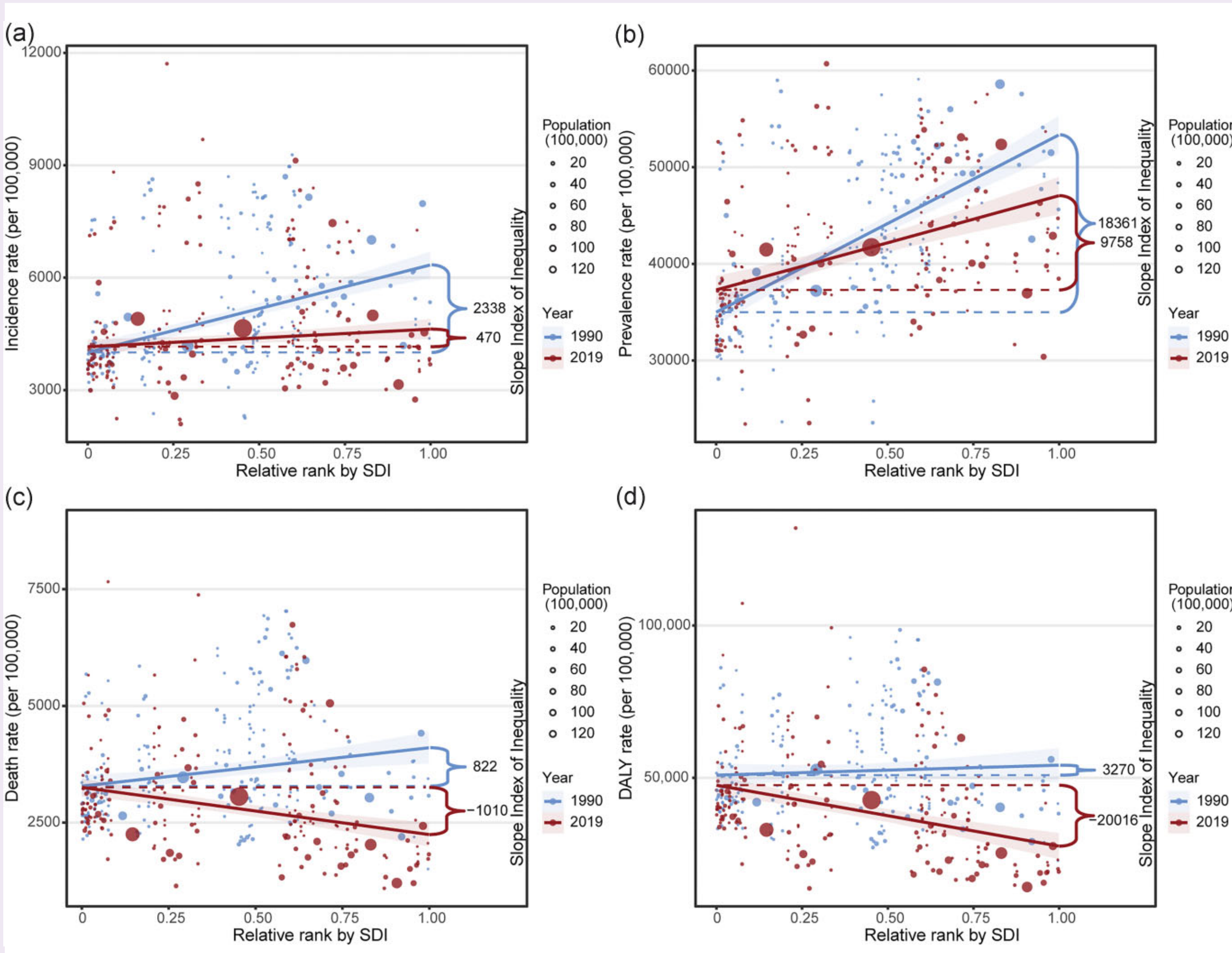

Figure 3 SDI-related health inequality regression lines for the burden of cardiovascular disease in older people in 1990 and 2019. (*a*) Incidence rate; (*b*) Prevalence rate; (*c*) Death rate; and (*d*) DALY rate. Abbreviations: SDI, socio-demographic index; DALY, disability-adjusted life year.

the link between age discrimination and the health of older people appears to be stronger.[35,36] It is expected that in the future, countries with low socioeconomic levels will face a greater challenge of CVD in old age, which requires urgent attention.

We found that the burden of overall CVD among older people increases with age (Supplementary online, *Figure S7*), which has been verified in previous studies.[37] However, the distribution of burden for certain CVD subtypes did not follow this profile. The incidence of peripheral vascular disease decreased with age from 75 to 79 years onwards (Supplementary online, *Figure S7*). An increase followed by a decrease with age was also observed in the prevalence and DALY rates of stroke in men (Supplementary online, *Figure S7*). Although the exact mechanisms still need to be further explored, this is a reminder of the need for increased attention to the burden of disease in specific age groups.

Of the different subtypes of CVD, ischaemic heart disease caused the greatest burden (Supplementary online, *Table S4*). Its risk has been described in previous studies.[38] The most widespread increase in the burden of endocarditis in the elderly cannot be ignored (Supplementary online, *Table S4*), and the increasing risk of healthcare-associated infective endocarditis is a major reason for this.[39,40] It is certainly necessary to develop more effective treatment and care for elderly patients with healthcare-associated infective endocarditis. In contrast to the overall CVD burden, the burden of atrial fibrillation and flutter quantified by all four indicators was unusually higher in countries with high SDI than in countries with low SDI (Supplementary online, *Table S8*). This suggests that high socioeconomic levels may be an important risk factor for atrial fibrillation and flutter. Genetic factors may also take part in this, with European ancestry associated with increased risk while both African and South Asian populations at lower risk.[41–44] In addition, unlike overall CVD, the burden of hypertensive heart disease exhibited a trend towards higher SDI areas (Supplementary online, *Table S7*). Although the exact causes need to be further explored, this is a reminder that targeted measures are needed in high-SDI countries to reduce the current huge burden of atrial fibrillation and flutter in older people and to solve the potentially huge future problem of hypertensive heart disease in older people.

In 2019, high systolic blood pressure was still the top risk factor for elderly CVD (*Figure 4*). Studies have shown the protective effect of blood pressure lowering on CVD.[45,46] Behavioural risk seems to be more important in men, such as tobacco (*Figure 4*).

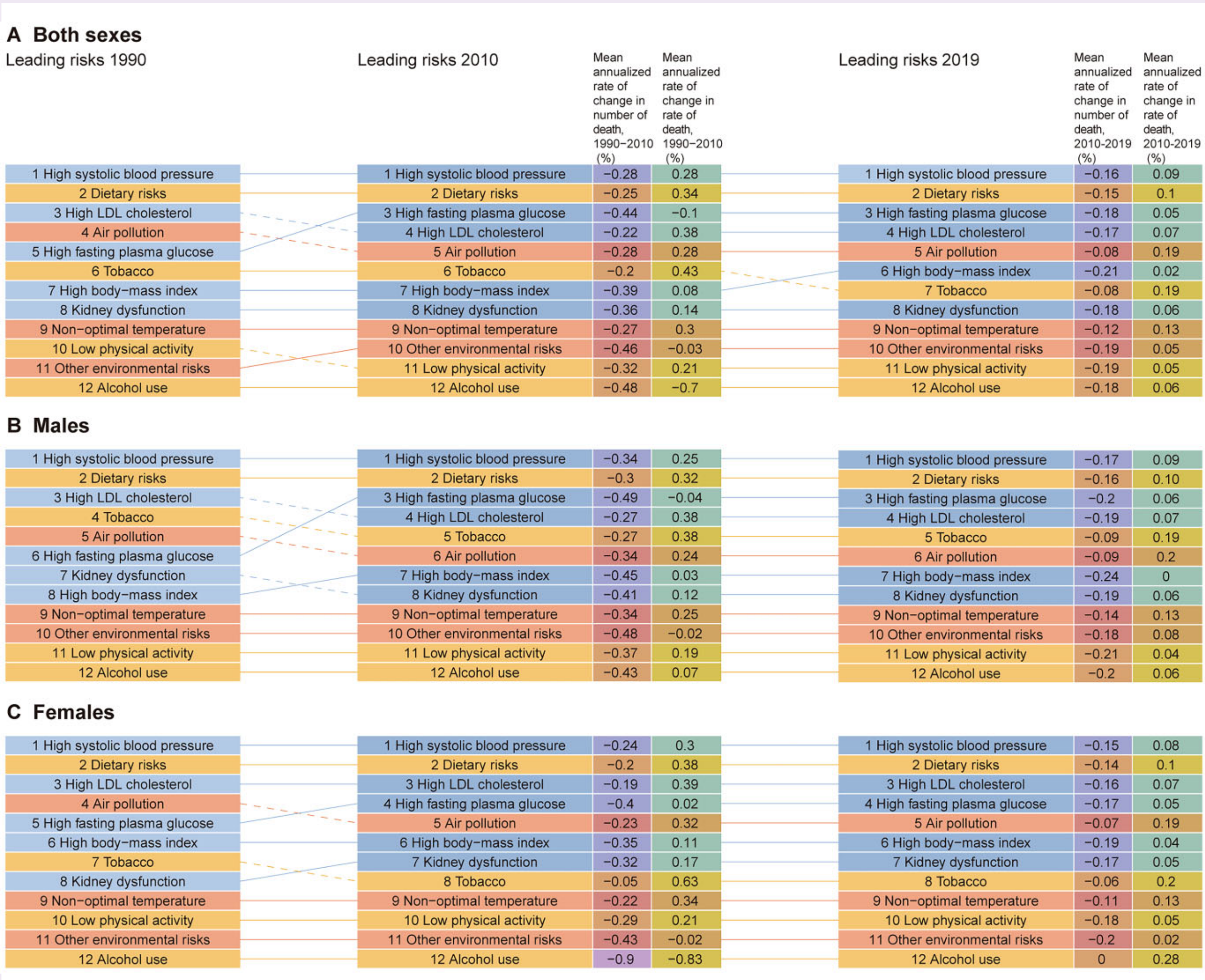

Figure 4 Mean annualized rate of change in the number and rate of death in elderly cardiovascular disease due to various risk factors and their ranking change between sexes from 1990 to 2010 and 2010 to 2019. Notes: Solid lines indicate a rise, and dotted lines indicate a fall. Yellow for behavioural risks, blue for metabolic risks, and red for environmental/occupational risks.

Strengths and limitations

To the best of our knowledge, this study provides the first comprehensive assessment of the global burden of CVD in old age and its spatial-temporal distribution characteristics through four indicators. We also provide an in-depth analysis of the relationship between burden and socioeconomic levels.

This work has some limitations. First, the burden on countries with low socioeconomic levels may be underestimated due to underdeveloped public health systems and unstable national situations. Second, the GBD study did not provide data on burden by ethnicity. However, ethnicity and genetic factors can greatly influence the distribution of CVD in older people in different countries and territories. Third, the most recent changes in CVD among elderly individuals cannot be captured owing to time lags in information reporting by national authorities in the GBD study. Fourth, the distribution of CVD burden in older people within a given country may vary considerably, for example, in the USA, which has a large geographical area. It is therefore necessary to assess the burden in different subnational regions, and this will be done in further studies. Fifth, access to CVD diagnostic techniques may affect the accuracy of the estimated results. For example, electrocardiogram of atrial fibrillation—which can underestimate disease prevalence. Sixth, data on the incidence and prevalence of aortic aneurysms could not be obtained from the GBD, and further research is needed.

Future directions

As the global population ages, CVD among the elderly is becoming an increasingly serious public health issue, warranting further investigation. The overall burden of CVD demonstrates a trend towards countries with lower socioeconomic levels, indicating that low-SDI countries may face a substantial CVD challenge in the future. Moreover, the actual burden in these countries might exceed the observed burden. Despite this, current research on CVD in the elderly remains predominantly focused on developed countries, highlighting an urgent need for additional studies in low-SDI countries. The increasing trend of endocarditis burden in the elderly is far ahead of other CVD burden changes and needs more attention in the future. To fully understand the distributional characteristics of the burden of CVD in older people, more assessments should also be conducted on the burden in different ethnic and subnational regions.

Conclusion

Our study offers an extensive evaluation of the global burden of CVD in older adults and its spatiotemporal distribution patterns. Despite a general decrease in burden, the impact of CVD in the elderly remains substantial. The burden trends vary across SDI regions and are progressively shifting towards lower SDI regions. Ischaemic heart disease poses the most significant burden among all CVDs, while the pervasive upwards trend in endocarditis burden is concerning. The distribution characteristics of different CVDs are distinct. The insights provided by our research will assist policymakers in devising targeted strategies to effectively mitigate the burden of CVD in older adults.

Supplementary material

Supplementary material is available at *European Heart Journal—Quality of Care and Clinical Outcomes* online.

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Author Contribution

All authors contributed to the study conception and design. Material preparation and data collection were performed by C.Q. and S.L. Statistical analyses were performed by C.Q. and S.L. The first draft of the manuscript was written by C.Q. and S.L. J.Z., H.C., H.Z., N.Z., L.Y., and G.C. reviewed and made significant revisions to the manuscript. P.L., Q.Z., and Q.C. guided the preparation of this manuscript. All authors read and approved the final manuscript.

Data availability

All data are accessible through the GBD query tool (http://www.healthdata.org/gbd/2019).

Ethics approval and consent to participate

For the Global Burden of Disease study, a waiver of informed consent was reviewed and approved by the Institutional Review Board of the University of Washington. All the information about ethical standards is available through the official website (http://www.healthdata.org/gbd/2019). Informed patient consent is not required.

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