Heliyon 9 (2023) e22671

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Global, regional, and national burdens of hypertensive heart disease from 1990 to 2019 : A multilevel analysis based on the global burden of Disease Study 2019

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ARTICLE INFO

Keywords:
Hypertensive heart disease
Global burden of disease
Prevalence
Deaths
Disability-adjusted life-years

ABSTRACT

Aim: This study aimed to describe the prevalence, deaths, and disability-adjusted life-years (DALYs) of hypertensive heart disease (HHD) at the global, regional, and national levels and analyze epidemiological trends.

Method: We extracted global estimates of prevalence, deaths, and DALYs related to HHD in 204 countries and regions from the 2019 Global Burden of Diseases Study. Average annual percent change (AAPC) was calculated to represent temporal trends. Joinpoint regression models were used to analyze time trends from 1990 to 2019. Finally, the decomposition analysis showed the driving factors of burden changes.

Results: From 1990 to 2019, the global prevalence of HHD cases increased by 138 %, reaching 18,598,025 cases (95 % uncertainty interval [UI]: 13,544,365–24,898,411). DALYs also rose by 154 %, reaching 21,508,002 (95 % UI, 16,400,051–23,899,879). The death rate increased to 14.95 (95 % UI, 11.11–16.52) per 100,000 people. Of the five sociodemographic index (SDI) regions, the prevalence rate related to HHD was the highest in the high-middle SDI region. In contrast, the death and DALY rate related to HHD were the highest in the middle SDI region. In other regions, the prevalence rate was the highest in East Asia (548.87 per 100,000 people; 95 % UI, 395.40–747.83), and the death rate was the highest in Central Europe (42.64 per 100,000 people; 95 % UI, 30.58–49.38). At the national level, the Cook Islands had the highest prevalence rate for HHD (703.08 per 100,000 people; 95 % UI, 532.87–920.72), Bulgaria had the highest death rate (75.08 per 100,000 people; 95 % UI, 46.38–92.81), and Afghanistan had the highest DALY rate (1374.12 per 100,000 people; 95 % UI, 467.17–2020.70). High body mass index, a diet high in sodium, alcohol use, lead exposure, high temperature, and low temperature were identified as risk factors for death and DALYs related to HHD in 2019. Aging and population growth were the major drivers of prevalence, death, and DALYs. Finally, over the past 30 years, the global age-standardized prevalence rate (ASPR) of HHD has significantly risen (AAPC = 0.21 %, 95 % confidence interval [CI]: 0.17–0.24; $P < 0.001$), while the age-standardized deaths rate (ASDR)

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https://doi.org/10.1016/j.heliyon.2023.e22671
Received 4 September 2023; Received in revised form 13 November 2023; Accepted 16 November 2023
Available online 23 November 2023

has shown significant declining trends (AAPC = −0.86 %, 95 % CI: 1.00 to −0.71; P < 0.001), and age-standardized DALY rates (AAPC = −1.08 %, 95 % CI: 1.23 to −0.93; P < 0.001).
Conclusion: Despite a significant decline in the global ASDR and age-standardized DALY rate of HHD over the past 30 years, the ASPR continues to rise. The burden of HHD is more heavily skewed towards non-high-income economies. Active prevention, control of risk factors, and improvement of medical protection levels to address the disease burden caused by population growth and aging are needed.

1. Introduction

Hypertensive heart disease (HHD) is a suite of conditions marked by abnormalities in the morphology and function of the left ventricle. These conditions are caused by hypertension-induced increases in the afterload of the left ventricle, along with remodeling of the atria, ventricles, and arterial system [1,2]. The likelihood of adverse cardiovascular events such as myocardial infarction and congestive heart failure increases in individuals with HHD [3]. HHD is the second leading cause of heart failure [4]. With global aging and population growth, mortality due to infectious diseases has declined in recent years. Conversely, the burden of non-communicable diseases has surged [5]. The prevalence of hypertension has notably increased, with the number of global adults with hypertension increasing from 594 million in 1975 to 1.13 billion in 2015 [6]. By 2020, HHD and other noncommunicable cardiovascular diseases have become the predominant causes of death and disability worldwide [7]. Despite the significant contribution of hypertension to the global burden of noncommunicable cardiovascular diseases, efforts to control it remain limited [8]. The pace at which diabetes and hypertension burdens grow in low- and middle-income countries vastly exceeds that in high-income nations. The age-related nature of hypertension compounds this issue and positions it as a critical global public health challenge [9]. Given its chronic nature, many individuals with HHD frequently confront sustained out-of-pocket medical expenses, potentially pushing families into poverty and imposing substantial financial strain [10]. Moreover, the adverse effects of long-term antiypertensive medication use and cardiovascular complications can negatively affect health-related quality of life [9]. In China, the direct economic burden for adult patients with hypertension was estimated to be approximately $114,520.8 million in 2015, surpassing that of other diseases [11]. Despite these realities, the global burden of HHD has markedly increased from 1990 to 2017 [8], with notable disparities between countries, possibly attributed to environmental, dietary, and sociodemographic factors [12]. Hence, an in-depth analysis of epidemiological trends, particularly at the global, regional, and national levels, can augment our understanding of HHD epidemiology and reveal potential regional disparities.

Not only early prevention and control of risk factors are crucial in reducing the mortality rate of HHD, but prevention and treatment of HHD are important goals in reducing complications from cardiovascular diseases. To date, few studies have provided a comprehensive discussion of the disease burden of HHD, primarily focusing on specific regions or countries [12,13] and lacking detailed descriptions of risk factors, trend analyses, and decomposition analyses. Therefore, further detailed studies and analyses are required. These findings could aid policymakers in allocating and optimizing limited healthcare resources to minimize the risk of this disease. In this study, we used the 2019 Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) to describe the global, regional, and national prevalence of HHD, along with the associated deaths and disability-adjusted life-years (DALYs) driving factors and related risk factors, and analyzed their prevalence trends.

2. Methods

The methodological details of the 2019 GBD have been previously published [14–17]. The 2019 GBD reported the burdens of 369 diseases and injuries in 204 countries and regions, categorized by sex and age group from 1990 to 2019, and 87 risk factors divided by incidence, prevalence, deaths, and DALYs. We extracted the available estimates of HHD prevalence, mortality, and DALYs from 1990 to 2019 and their 95 % uncertainty intervals (UI), along with their corresponding sex, age, and age-standardized rates for analysis using the Global Health Data Exchange query tool (http://ghdx.healthdata.org/gbd-results-tool) [18]. Based on our use of public datasets, this study was exempted from approval by the Ethics Committee of the Second People's Hospital of Hefei.

HHD prevalence and mortality were estimated using extensive data representing broad population segments. These data were derived from literature reviews and corroborated through research collaborations encompassing published scientific reports on registries and cohorts, data from cohort studies and registries, administrative health data, and population surveys [19]. DisMod-MR software V2.1 and meta-regression-Bayesian, regularized, trimmed (MR-BRT) software were used to generate consistent disease estimates. Posterior distributions, ranging from the 25th to 975th order values across 1000 posterior draws, were used to produce UI for each metric [19]. Details of the flowcharts, definitions, input data, and modeling strategies can be accessed in Supplementary Appendix 1 of the GBD 2019 study (https://www.thelancet.com/cms/10.1016/S0140-6736(20)30,925-9/attachment/7709ecbd-5dbc-4da6-93b2-3fd0bedc16%20cc/mmc1.%20pdf, pages 228–229 and 1397–1403).

The sociodemographic index (SDI) is a comprehensive indicator that measures a country's or region's level of development based on factors such as fertility rate, education level, and per capita income, with an SDI ranging from 0 to 1. It is a comprehensive indicator that quantifies the level of social and population development in a country or region [20]. Higher levels indicate better socioeconomic development. The SDI is related to disease incidence and death rates [17]. In this study, countries and geographical regions were divided into five SDI regions (high, high-middle, middle, low-middle, and low) to explore the relationship between HHD and

Table 1
Prevalence of hypertensive heart disease between 1990 and 2019 at the global and regional level.

Location	Rate per 100,000 (95 % UI)					
	1990		2019		1990–2019	
	Prevalent cases	Prevalent rate	Prevalent cases	Prevalent rate	Cases change	AAPC
Global	7817320.08 (5616194.04–10643040.23)	146.12 (104.98–198.94)	18598024.58 (13544364.95–24898411.52)	240.36 (175.05–321.79)	1.38 (1.3–1.48)	0.21 (0.17–0.24)
SDI						
High	1634665.71 (1191952.94–2187356.05)	198.86 (145–266.1)	3062685.45 (2270564.98–4088967.2)	302.22 (224.06–403.5)	0.87 (0.71–1.06)	−0.03 (−0.09 to 0.03)
High Middle	2005609.17 (1405550.68–2840361.16)	174.34 (122.18–246.9)	4848235.3 (3464814.24–6677514.9)	338.94 (242.23–466.83)	1.42 (1.29–1.57)	0.48 (0.43–0.52)
Middle	2955973.47 (2110328.32–4003951.3)	172.18 (122.93–233.23)	7578850.83 (5501472.88–10180181.34)	316.24 (229.56–424.78)	1.56 (1.49–1.65)	−0.17 (−0.20 to −0.13)
Low middle	849543.71 (598334.27–1181918.51)	75.2 (52.97–104.63)	2248275.98 (1607934.83–3122625.53)	127.45 (91.15–177.02)	1.65 (1.55–1.76)	0.08 (0.07–0.10)
Low	367296.27 (256099.19–514454.99)	69.55 (48.49–97.41)	850281.25 (595063.05–1169116.26)	75.33 (52.72–103.58)	1.31 (1.24–1.4)	0.02 (0.00–0.04)
Regions						
Andean Latin America	21046.79 (14078.74–30859.02)	55.13 (36.88–80.83)	74403.81 (51477.84–105633.25)	117 (80.95–166.1)	2.54 (2.25–2.92)	0.53 (0.5–0.56)
Australasia	26072.69 (18753.73–35736.18)	128.58 (92.49–176.24)	42553.99 (30483.49–57289.99)	146.42 (104.88–197.12)	0.63 (0.48–0.8)	−1.27 (−1.36 to −1.18)
Caribbean	51475.58 (37403.17–70940.81)	145.93 (106.04–201.11)	104764.7 (76579.4–144495.09)	222.11 (162.36–306.35)	1.04 (0.94–1.16)	−0.09 (−0.1 to −0.08)
Central Asia	86570.75 (62030.87–117013.57)	124.98 (89.55–168.93)	116888.3 (83381.71–159100.86)	124.97 (89.15–170.11)	0.35 (0.24–0.47)	−0.33 (−0.38 to −0.28)
Central Europe	272434.91 (187077.7–391798.03)	221.55 (152.14–318.62)	392400.68 (275255.65–555968.29)	343.54 (240.98–486.74)	0.44 (0.3–0.61)	−0.43 (−0.48 to −0.38)
Central Latin America	113215.98 (79225.69–160501.64)	68.98 (48.27–97.79)	343582.6 (244586.81–482450.86)	137.42 (97.83–192.96)	2.03 (1.91–2.21)	−0.14 (−0.17 to −0.11)
Central Sub-Saharan Africa	28244.9 (18160.84–43434.63)	50.87 (32.71–78.23)	66013.27 (43794.96–99015.46)	50.18 (33.29–75.27)	1.34 (1.12–1.55)	−0.06 (−0.06 to −0.05)
East Asia	3042447.34 (2152424.28–4183547.61)	248.34 (175.69–341.48)	8080427.12 (5821120.66–11009519.57)	548.87 (395.4–747.83)	1.66 (1.56–1.79)	−0.21 (−0.26 to −0.16)
Eastern Europe	146906.86 (97883.99–218306.67)	64.86 (43.22–96.38)	198892.42 (133630.45–295133.95)	94.72 (63.64–140.56)	0.35 (0.29–0.43)	0.03 (−0.02 to 0.08)
Eastern Sub-Saharan Africa	170962.14 (117520.12–234458.14)	89.9 (61.8–123.29)	394197.93 (272501.16–537479.49)	95.73 (66.18–130.53)	1.31 (1.22–1.4)	0.15 (0.13–0.18)
High-income Asia Pacific	166815.84 (114304.92–231899.12)	96.14 (65.88–133.65)	434592.78 (304460.38–608286.94)	232.04 (162.56–324.78)	1.61 (1.18–2.13)	−0.34 (−0.37 to −0.32)
High-income North America	843289.34 (603037.13–1130928.91)	300.18 (214.66–402.57)	1540543.87 (1125393.77–2037712.78)	422.58 (308.7–558.95)	0.83 (0.59–1.09)	0.09 (−0.02 to 0.2)
North Africa and Middle East	505024.55 (359681.25–689938.44)	146.37 (104.25–199.97)	1331825.87 (975252.89–1764466.68)	218.79 (160.22–289.87)	1.64 (1.5–1.79)	0.09 (0.06–0.11)
Oceania	7764.6 (5477.5–10544.99)	120.01 (84.66–162.99)	18807.12 (13405.14–25671.13)	141.66 (100.97–193.36)	1.42 (1.25–1.61)	0.04 (0.03–0.05)
South Asia	432561.34 (302776.09–619930.18)	39.41 (27.58–56.48)	1305144.24 (917050.5–1870773.93)	72.3 (50.8–103.63)	2.02 (1.86–2.21)	0.05 (0.04–0.06)
Southeast Asia	737432.72 (527506.94–986792.52)	157.98 (113.01–211.4)	1847718.32 (1330747.64–2473049.47)	274.23 (197.5–367.04)	1.51 (1.43–1.59)	0 (−0.02 to 0.02)
Southern Latin America	86517.03 (57958.72–127888.13)	174.63 (116.99–258.14)	158612.72 (108714.33–229191.03)	237.61 (162.86–343.34)	0.83 (0.65–1.04)	−0.34 (−0.41 to −0.26)

(*continued on next page*)

Table 1 (*continued*)

Location	Rate per 100,000 (95 % UI)					
	1990		2019		1990–2019	
	Prevalent cases	Prevalent rate	Prevalent cases	Prevalent rate	Cases change	AAPC
Southern Sub-Saharan Africa	39950.58 (26152.69–58731.21)	76.11 (49.82–111.88)	74240.26 (48395.51–110535.25)	94.48 (61.59–140.68)	0.86 (0.78–0.94)	−0.33 (−0.35 to −0.31)
Tropical Latin America	128400.63 (87298.3–183773.14)	83.99 (57.1–120.21)	392809.56 (272306.36–557651.19)	175.68 (121.79–249.4)	2.06 (1.9–2.29)	−0.05 (−0.1 to 0)
Western Europe	738822.8 (523897.48–1040758.07)	192.11 (136.22–270.61)	1298346.76 (923593.81–1798391.76)	297.58 (211.68–412.18)	0.76 (0.62–0.92)	0.02 (−0.03 to 0.07)
Western Sub-Saharan Africa	171362.71 (121203.53–233716.88)	88.98 (62.94–121.36)	381258.25 (267068.56–513647.4)	83.55 (58.53–112.56)	1.22 (1.14–1.31)	0.19 (0.15–0.23)

socioeconomic development.

Joinpoint regression analysis was used to analyze the time trends of HHD epidemiology at global, regional, and national scales [21]. This type of analysis can identify points where trends change significantly (i.e., joinpoints), divide the overall trend into multiple segments based on the observed joinpoints, and further evaluate each segment's epidemiological trends by calculating the annual percentage change (APC) and 95 % confidence interval (CI). In addition, the average APC (AAPC), a summary measure of predefined fixed-interval trends (1990–1999, 2000–2009, 2010–2019, and 1990–2019), was calculated as the weighted average of the APCs for segments spanning these intervals [22]. The total asymptotic significance level was maintained through the Bonferroni correction using with the Monte Carlo permutation method and 4499 datasets of random permutations. If the APC/AAPC estimates and their 95 % CI lower bounds were >0, an upward trend was observed over a certain period. Conversely, if the APC/AAPC estimates and their 95 % CI upper bounds were all <0, a downward trend was observed over a certain period. Otherwise, the trend was considered stable [23,24].

Decomposition analysis was used to visually show the roles of three factors driving changes in prevalence, deaths, and DALYs from 1990 to 2019: aging, population, and epidemiological changes. Epidemiological changes refer to changes in age- and population-adjusted deaths and prevalence [5,25,26]. Specific details are in the Supplemental Methods.

The definition of HHD used the codes from the ninth and tenth editions of the International Classification of Diseases (ICD-9 and -10). Diseases coded as 402–402.91 in ICD-9 or I11–I11.9 in ICD-10 were identified as HHD. Detailed information on the data selection strategy using the above ICD codes has been previously published [5].

2.1. Statistical analysis

All statistical analyses and visualizations were conducted using R software (version 4.3.0) (http://www.R-project.org). The environment of joinpoint regressions was configured using the "configr" package in R V.4.3.0, with the "dplyr," "tidyr," and "purr" package for data cleaning and calculation, and the "ggplot2" package was utilized for data visualization.

3. Results

3.1. Global

3.1.1. Prevalence

In 2019, there were 18,598,025 global cases of HHD (95 % UI, 13,544,365–24,898,411). From 1990 to 2019, the global prevalence of HHD increased by 138 % (95 % UI, 130%–148 %). Correspondingly, the morbidity rate increased from 146 per 100,000 individuals (95 % UI, 105–199) in 1990 to 240 per 100,000 individuals (95 % UI, 175–322) in 2019 (Table 1). Globally, between 1990 and 2019, the prevalence of HHD started to increase with age in the 15–19 age group, peaking in the oldest age group (≥95 years). Before 85 years of age, the prevalence was higher in men than women. However, the prevalence was higher in women aged >85 years (Fig. 2A and D).

3.1.2. Deaths

Over the past 30 years, the number of HHD-related deaths worldwide has increased by 177 %, from 654,906 (95 % UI, 530,566–732,728) in 1990 to 1,156,732 (95 % UI, 859,825–1,278,562) in 2019. Similarly, the death rate of HHD rose from 12.24 per 100,000 (95 % UI, 9.92–13.70) in 1990 to 14.95 per 100,000 (95 % UI, 11.11–16.52) in 2019 (Table S1). The death rate due to HHD began to increase with age, starting in the 15–19 age group in 1990 and 2019, with the highest rates observed in the oldest age group (≥95 years). In 1990, among the HHD-related death rates in the age group of 15–34 years, women had higher death rates than men, while in the age group of 35–74 years, men had higher death rates than women. Similarly, in 2019, among the HHD-related death rates in the 15–19 age group, women had higher death rates than men; for those aged 20–74 years, men had higher death rates than women.

However, the death rate was higher in women aged >74 years (Fig. 2B and E).

3.1.3. DALYs

The global number of DALYs related to HHD increased by 154 % from 1990 to 2019, reaching 21,508,002 (95 % UI, 16,400,051–23,899,879) in 2019. The rate of DALYs increased by 6.65 %, equating to 277.97 per 100,000 (95 % UI, 211.96–308.89) (Table S2). In 1990, among men, from 15 to 85 years, the DALYs rate for HHD increased and subsequently decreased with age beyond 85 years. In women, the DALYs rate increased with age. Among the HHD-related DALY rates, women were higher than men in the 15–34 age group; men were higher than women in the 35–74 age group, but women were again higher than men in those over 75 years of age with HHD. In 2019, the global DALYs rate for HHD began to increase with age in the 15–19 age group, reaching its peak in the oldest age group (≥95 years) (Fig. 2C and F).

3.1.4. SDI regional

3.1.4.1. Prevalence. In 2019, the middle SDI region reported the highest HHD cases (7,578,851, 95 % UI, 5,501,471–10,180,181). The

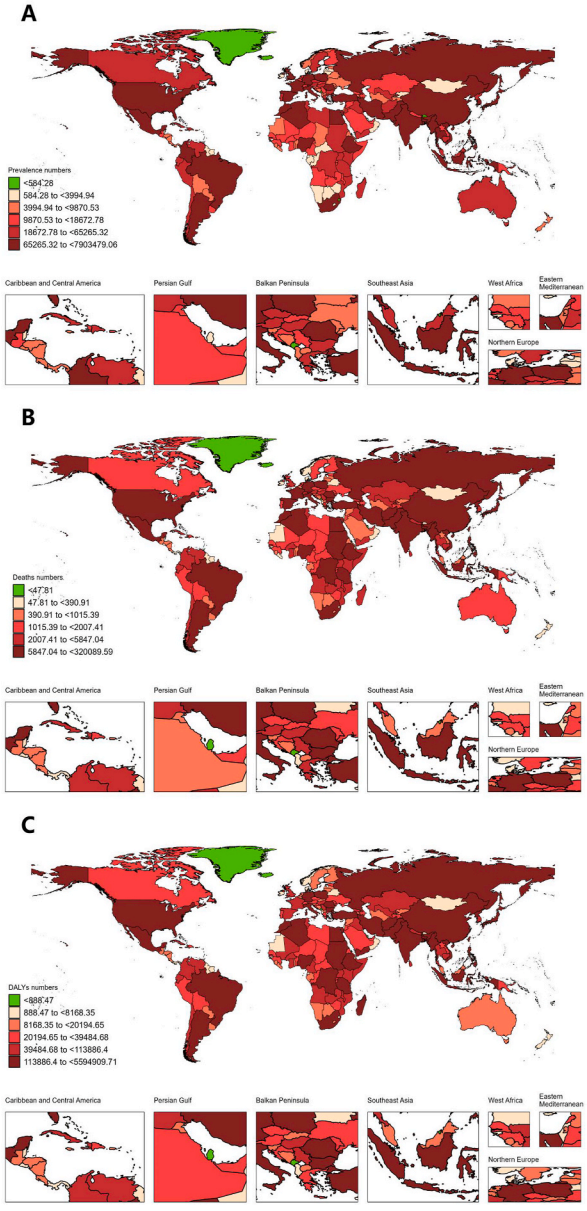

Fig. 1. Prevalence (A), death (B), and disability-adjusted life-years (DALYs) (C) cases of hypertensive heart disease in 204 countries and territories.

largest increase in cases was in the low-middle SDI region, with a 165 % increase (95 % UI, 155%–176 %). The highest rate of HHD was observed in the high-middle SDI region, with 338.94 cases per 100,000 (95 % UI, 242.23–466.83) (Table 1 and Fig. S3).

3.1.4.2. Deaths. The high SDI region showed the largest increase in HHD-related deaths (94 %) among the five SDI regions. The middle SDI region reported the highest number of HHD-related deaths (433,855; 95 % UI, 280,141–486,394) in 2019. The HHD-related death rate was also highest in the middle SDI region in 2019, at 18.10 per 100,000 (95 % UI, 11.69–20.30) (Table S1 and Fig. S3).

3.1.4.3. DALYs. In 2019, the middle SDI region had the highest number and rate of DALYs related to HHD, at 7,578,851 (95 % UI, 5,501,472–10,180,181) and 347.19 per 100,000 (95 % Confidence Interval, 236.57–387.51), respectively. From 1990 to 2019, the largest DALY increase due to HHD (72 %) was observed in the low SDI region (Table S2 and Fig. S3).

3.1.4.4. Geographic regional

3.1.4.4.1. Prevalence. Of the 21 geographic regions, East Asia reported the highest number of HHD cases (8,080,427; 95 % UI, 5,821,121–11,009,519) in 2019, whereas Oceania reported the lowest (18,807; 95 % UI, 13,405–25,671). The greatest increase in cases from 1990 to 2019 (254 %) was observed in Andean Latin America. The highest prevalence of HHD was in East Asia (SDI, 0.69) (548.87; 95%UI, 395.40–747.83). Conversely, Central Sub-Saharan Africa (SDI, 0.47) reported the lowest rate (50.18 per 100,000; 95 % UI, 33.29–75.27). In 2019, the global SDI was 0.65 in five regions (Western Europe, Central Europe, Southeast Asia, East Asia, and high-income North America) and was higher than the global average, whereas 16 regions had a prevalence rate lower than the global average (240.36) (Table 1 and Fig. S2).

3.1.4.4.2. Deaths. In 2019, East Asia reported the highest number of HHD-related deaths (330,520; 95 % UI, 211,770–384,586). The largest increase in the number of deaths from 1990 to 2019 (158 %) was observed in Eastern Europe. Central Europe (SDI, 0.79) had the highest death rate due to HHD (42.64 per 100,000; 95 % UI, 30.58–49.38), while Australasia (SDI, 0.84) had the lowest. Eleven regions reported death rates higher than the global average, while 10 reported death rates lower than the global average (14.95) (Table S1 and Fig. S2).

3.1.4.4.3. DALYs. In 2019, East Asia had the highest number of hypertension-related DALYs at 5,780,823 (95 % UI: 4,053,566–6,713,463), while Australasia had the lowest (20,378; 95 % UI: 16,878–24,230). Between 1990 and 2019, Western Sub-Saharan Africa experienced the greatest increase in hypertension-related DALYs (122 %). Central Europe had the highest DALY rate (639.89; 95 % UI: 478.26–741.25), with Australasia having the lowest (70.12; 95 % UI: 58.07–83.37). Ten regions had DALY rates higher than the global average, whereas 11 had rates below the global average of 278 (Table S2 and Fig. S2).

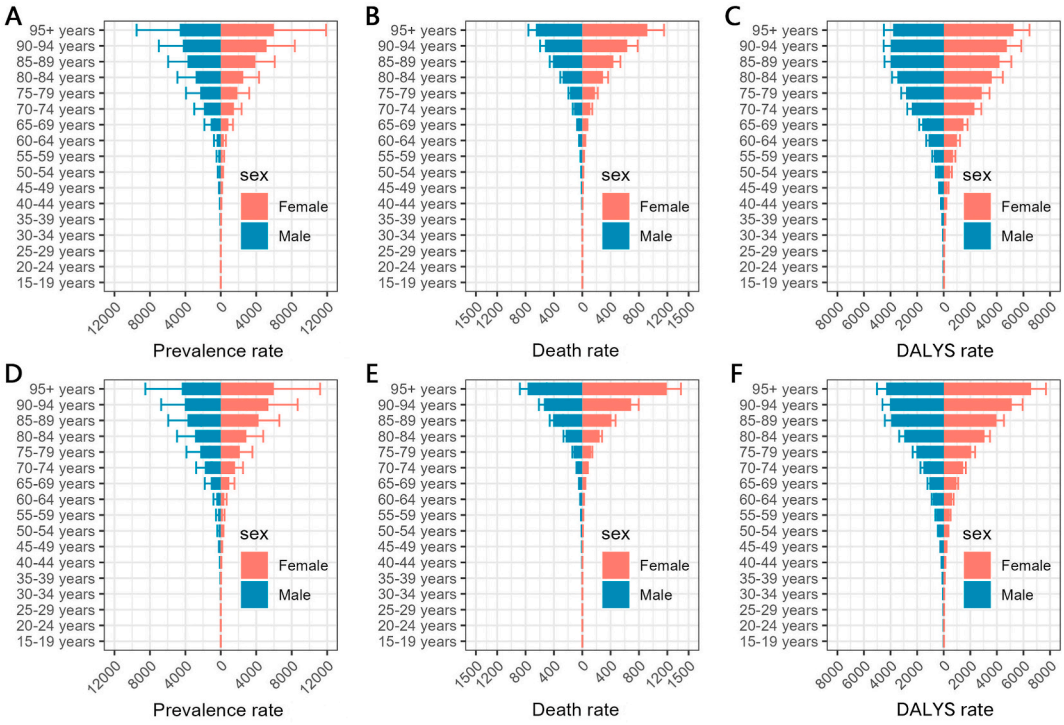

Fig. 2. Age and sex distribution of global Prevalence (A, D), Death (B, E), and Disability-Adjusted Life-Years (DALYs) (C, F) rate (per 100,000 people) of Hypertensive Heart Disease in 1990 (A, B, C) and 2019 (D, E, F).

4. National trends

4.1. Prevalence

Among the 204 countries in 2019, China had the highest number of hypertension cases (7,903,479; 95 % UI: 5,679,082–10,769,047). The Cook Islands (SDI, 0.76) had the highest hypertension prevalence rate (703.08; 95 % UI: 532.87–920.72), while Ukraine (SDI, 0.74) had the lowest rate (11.88; 95 % UI: 7.98–17.26). Meanwhile, the rate of HHD was 433.54 (95 % UI: 311.59–582.98) in China. From 1990 to 2019, the United Arab Emirates had the largest increase in the hypertension prevalence rate (884 %). In 2019, 81 countries had a prevalence rates higher than the global average, whereas 123 had prevalence rates below the global average (Table S3, Fig. 1A, Fig. S1, and Fig. S4).

4.2. Deaths

In 2019, China had the highest number of HHD-related deaths (320,090; 95 % UI: 201,652–373,927). Bulgaria (SDI, 0.76) had the highest HHD-related death rate (75.08; 95 % UI: 46.38–92.81), while Ukraine (SDI, 0.73) had the lowest rate (1.59; 95 % UI: 1.32–2.31). Furthermore, the rate of HHD-related deaths was 20.58 (95 % UI: 12.74–23.91) in China. From 1990 to 2019, Estonia showed the largest increase in HHD-related deaths (1151 %). In 2019, 127 countries had death rates higher than the global average, whereas 77 had death rates below the global average (Table S4, Fig. 1B, Fig. S1, and Fig. S4).

4.3. DALYs

In 2019, China had the highest number of hypertension-related DALYs (5,594,910; 95 % UI: 3,877,275–6,532,987). Afghanistan (SDI, 0.34) had the highest hypertension-related DALY rate (1374.12; 95 % UI: 467.17–2020.70), while Israel (SDI, 0.80) had the lowest (27.79; 95 % UI: 21.78–63.59). In addition, the rate of HHD-related DALY rate was 312.88 (95 % UI: 214.08–363.65) in China. From 1990 to 2019, the United Arab Emirates experienced the largest increase in HHD-related DALYs (869 %). In 2019, 121 countries had DALY rates higher than the global average, whereas 83 had rates below the global average (Table S5, Fig. 1C, Fig. S1, and Fig. S4).

4.4. risk factors

In addition to metabolic risk factors (high systolic blood pressure), the GBD database identified the following six risk factors for hypertension: high body mass index, a diet high in sodium, alcohol use, lead exposure, high temperature, and low temperature. Specifically, a high body mass index and sodium diet were responsible for 23.1 % and 19.1 % of global hypertension-related deaths,

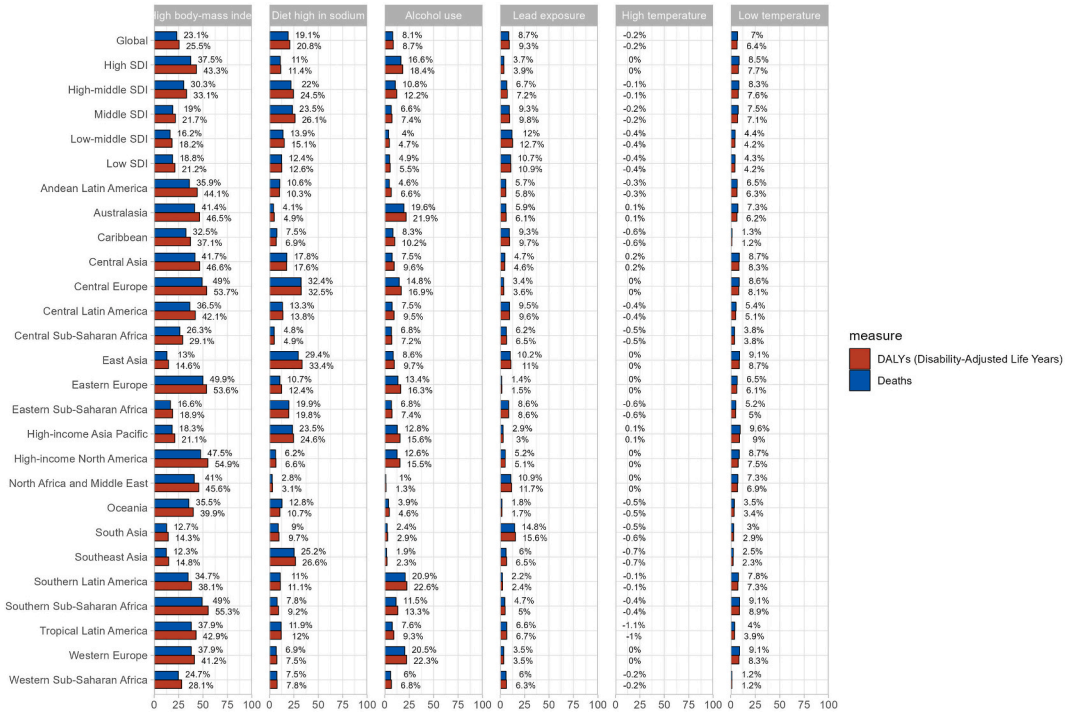

Fig. 3. The proportion of Hypertensive Heart Disease Deaths and Disability-Adjusted Life-Years (DALYs) Attributable to Risk Factors.

respectively. The regions with the highest percentages were Eastern Europe (49.9 %) and Central Europe (32.4 %), followed by East Asia (13.0 %). North Africa, and the Middle East (2.8 %). In 2019, alcohol use caused 8.1 % of global HHD-related deaths, with the highest percentage in Southern Latin America (20.9 %) and the lowest in North Africa and the Middle East (1 %). Globally, 8.7 % of HHD-related deaths were due to lead exposure, with the highest percentage in Southeast Asia (14.8 %) and the lowest in Eastern Europe (1.4 %). Among the 21 geographic regions, low temperatures accounted for 7 % of global HHD-related deaths, with the highest percentage in the high-income Asia Pacific (9.6 %) and the lowest in Western Sub-Saharan Africa (1.2 %). Additionally, HHD-related deaths caused by high temperatures were mostly negative and all were below 1 %. The proportion of hypertension-related deaths due to these risk factors was similar to that of the DALYs (Fig. 3).

4.5. Decomposition analysis

4.5.1. Prevalence

Over the past 30 years, a significant global increase in HHD prevalence has occurred. Population growth and aging contributed to

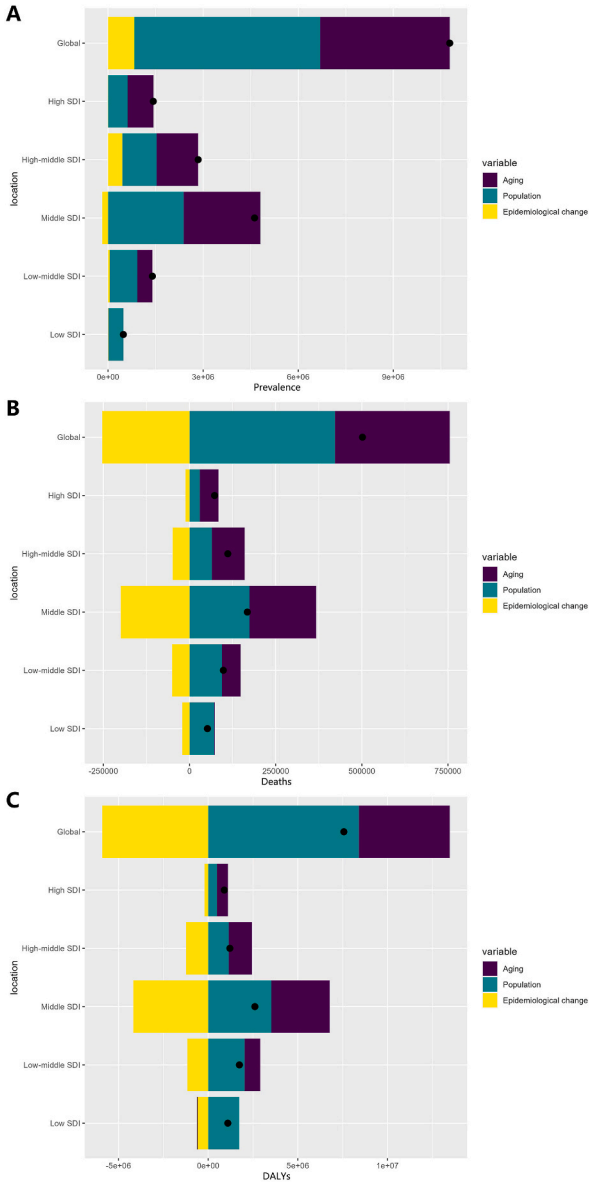

Fig. 4. Changes in Hypertensive Heart Disease Of Prevalence (A), Death (B), and Disability-Adjusted Life-Years (DALYs) (C) according to population-level determinants of population growth, aging, and epidemiological change from 1990 to 2019 at the global level and five Socio-demographic Index (SDI) region.

54.40 % and 37.91 % of the increased burden of HHD, respectively. The contribution of population growth was greatest in the low SDI regions (98.74 %) and lowest in the high-middle SDI regions (38.11 %). Aging contributed the most to high SDI regions (57.31 %) and the least to low SDI regions (−0.54 %). Epidemiological changes greatly affected the global prevalence growth in the high-middle SDI regions (15.85 %) (Fig. 4A and Table S6). The decomposition analysis results for population growth, aging, and epidemiological changes in prevalence differed globally and between regions and countries (Table S6 and Table S7).

4.5.2. Deaths

Global deaths have significantly increased, with population growth and aging contributing to 84.07 % and 66.40 % of the burden of HHD-related deaths, respectively. HHD-related deaths were greatest in the middle SDI regions, and aging contributed to 115.34 % of these deaths. The greatest impact of population growth on the increase in mortality was observed in the low-SDI regions (138.37 %). Epidemiological changes globally reduced deaths, and in all five SDI regions, epidemiological changes also reduced deaths, with the greatest impact in the middle SDI regions (−118.91 %) (Fig. 4B and Table S8). However, some regions showed contributions of epidemiological changes to the death burden, including Eastern Europe (65.55 %), Western Europe (8.38 %), high-income North America (23.08 %), Southern Sub-Saharan Africa (2.84 %), Central Europe (15.71 %), Western Sub-Saharan Africa (0.55 %), and Central Asia (58.60 %) (Table S8).

4.5.3. DALYs

From 1990 to 2019, global population growth and aging contributed 111.01 % and 67.01 % of the burden of DALYs due to HHD, respectively. Among the five SDI regions, the largest contributors to the DALYs were population growth in the low SDI region (157.57 %) and aging in the middle SDI region (125.34 %). However, a reduction in DALYs due to aging was observed only in the low-SDI region, accounting for −4.42 %. Epidemiological changes across the five SDI regions led to DALY reductions, with the most significant impact observed in the middle SDI region (67.52 %) (Fig. 4C and Table S10). A few regions demonstrated a contribution to the DALY burden from epidemiology, specifically Eastern Europe (−160.28 %), high-income Asia Pacific (9078.69 %), high-income North America (26.29 %), Central Europe (2.31 %), and Central Asia (38.29 %) (Table S10). The effects of demography and epidemiology on deaths and DALYs varied by country and region (Tables S8–S11).

4.5.4. Temporal trends

4.5.4.1. Prevalence. Between 1990 and 2019, the age-standardized prevalence rate (ASPR) of HHD globally demonstrated a significant upward trend (AAPC = 0.21 %, 95 % CI: 0.17–0.24; P < 0.001) (Table 1), with the most substantial change occurring from 2017 to 2019 (APC = 0.97 %, 95 % CI: 0.74–1.20; P < 0.001) (Fig. 5A and Table S15). Among the five SDI regions, the global ASPR of HHD showed a significant upward trend in the high-middle, low-middle, and low SDI regions. A significant downward trend was observed in the middle SDI region, whereas the trend in the high SDI regions was insignificant (Table 2). In other regions, the largest increase in the ASPR of HHD was in Andean Latin America (AAPC, 0.53 %; 95 % CI, 0.5–0.56), and the largest decrease was in Australasia (AAPC, −1.27 %; 95 % CI, −1.36 to −1.18) (Table 1). At the country level, the largest increase in the ASPR was in Bolivia (AAPC, 2.51 %; 95 % CI, 2.3–2.73), and the most significant decrease was in Serbia (AAPC, −1.78 %; 95 % CI, −1.85 to −1.7) (Table S3 and Fig. S5).

4.5.4.2. Deaths. From 1990 to 2019, the age-standardized deaths rate (ASDR) of HHD globally showed a significant downward trend (AAPC = −0.86 %, 95 % CI: 1.00 to −0.71; P < 0.001) (Table S1), with the most substantial change occurring from 2001 to 2004 (APC = −2.04 %, 95 % CI: 2.87 to −1.20; P < 0.001) (Fig. 5B and Table S15). The global ASDR of HHD showed a significant downward trend at the regional level in all five SDI regions (Table 2). In other regions, the largest increase in the ASDR was in Eastern Europe (AAPC, 2.32 %; 95 % CI, 1.7–2.95), and the most significant decrease was in the high-income Asia Pacific (AAPC, −3.74 %; 95 % CI, −3.97 to

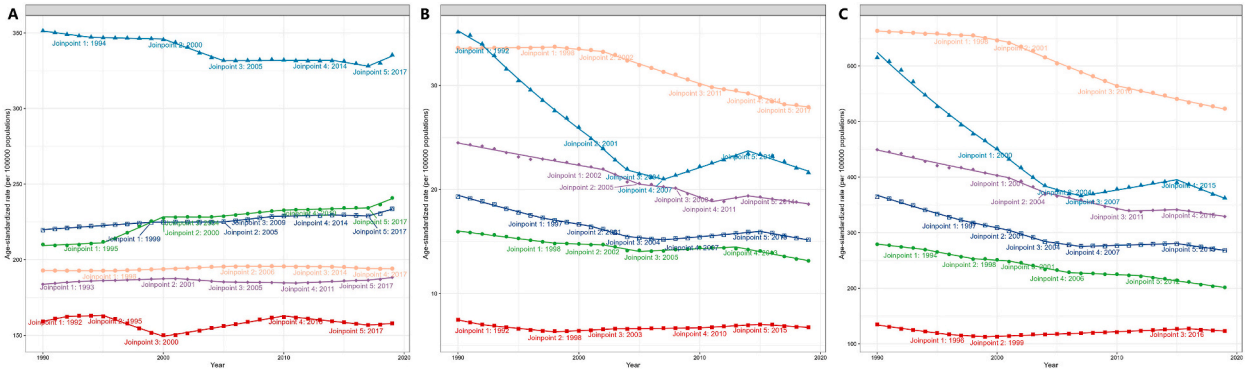

Fig. 5. Joinpoint regression analysis of ASPR (A), ASDR (B), Age-standardized DALYs Rate (C) of Hypertensive Heart Disease at the global level and five Sociodemographic Index (SDI) region (Global-Dark blue, High SDI-Red, High-middle SDI-Green, Middle SDI-Light blue, Low-middle SDI-Purple, Low SDI-Orange) levels from 1990 to 2019. Abbreviations: ASPR, age-standardized prevalence rate; ASPR, age-standardized deaths rate.

Table 2
AAPCs of Global and SDI region in ASPR of Hypertensive Heart Disease.

Hypertensive heart disease							
		In ASPR		In ASDR		In Age-standardized DALYs Rate	
		AAPC (95 % CI)	p-value	AAPC (95 % CI)	p-value	AAPC (95 % CI)	p-value
Global	1990–1999	0.24 (0.22–0.27)	<0.001	−1.57 (−1.70 to −1.45)	<0.001	−1.75 (−1.88 to −1.62)	<0.001
	2000–2009	0.18 (0.13–0.23)	<0.001	−0.90 (−1.27 to −0.53)	<0.001	−1.22 (−1.60 to −0.83)	<0.001
	2010–2019	0.22 (0.14–0.31)	<0.001	−0.22 (−0.42 to −0.03)	0.022	−0.37 (−0.55 to −0.19)	<0.001
	1990–2019	0.21 (0.17–0.24)	<0.001	−0.86 (−1.00 to −0.71)	<0.001	−1.08 (−1.23 to −0.93)	<0.001
High SDI	1990–1999	−0.52 (−0.67 to −0.36)	<0.001	−1.74 (−1.97 to −1.52)	<0.001	−1.90 (−2.33 to −1.47)	<0.001
	2000–2009	0.87 (0.83–0.90)	<0.001	0.43 (0.30–0.57)	<0.001	0.71 (0.66–0.77)	<0.001
	2010–2019	−0.35 (−0.44 to −0.25)	<0.001	0.07 (−0.15 to 0.30)	0.518	0.10 (−0.16 to 0.37)	0.441
	1990–2019	−0.03 (−0.09 to 0.03)	0.302	−0.35 (−0.47 to −0.24)	<0.001	−0.29 (−0.45 to −0.13)	<0.001
High-middle SDI	1990–1999	0.80 (0.73–0.86)	<0.001	−0.87 (−0.96 to −0.79)	<0.001	−1.15 (−1.45 to −0.85)	<0.001
	2000–2009	0.18 (0.09–0.27)	<0.001	−0.38 (−0.62 to −0.14)	0.002	−1.16 (−1.39 to −0.94)	<0.001
	2010–2019	0.36 (0.27–0.44)	<0.001	−0.93 (−1.07 to −0.78)	<0.001	−1.19 (−1.37 to −1.01)	<0.001
	1990–2019	0.48 (0.43–0.52)	<0.001	−0.68 (−0.78 to −0.57)	<0.001	−1.12 (−1.28 to −0.96)	<0.001
Middle SDI	1990–1999	−0.16 (−0.20 to −0.12)	<0.001	−3.03 (−3.31 to −2.74)	<0.001	−3.23 (−3.36 to −3.09)	<0.001
	2000–2009	−0.47 (−0.50 to −0.43)	<0.001	−1.91 (−2.25 to −1.57)	<0.001	−2.05 (−2.47 to −1.63)	<0.001
	2010–2019	0.10 (0.01–0.18)	0.024	−0.17 (−0.38 to 0.03)	0.095	−0.45 (−0.76 to −0.13)	0.006
	1990–2019	−0.17 (−0.20 to −0.13)	<0.001	−1.65 (−1.81 to −1.49)	<0.001	−1.86 (−2.04 to −1.69)	<0.001
Low-middle SDI	1990–1999	0.20 (0.18–0.22)	<0.001	−0.91 (−1.01 to −0.82)	<0.001	−1.07 (−1.19 to −0.95)	<0.001
	2000–2009	−0.15 (−0.18 to −0.12)	<0.001	−1.39 (−2.03 to −0.76)	<0.001	−1.62 (−2.12 to −1.11)	<0.001
	2010–2019	0.21 (0.18–0.24)	<0.001	−0.37 (−0.80 to 0.07)	0.102	0.46 (0.78–0.14)	0.004
	1990–2019	0.08 (0.07–0.10)	<0.001	−0.94 (−1.20 to −0.67)	<0.001	−1.06 (−1.25 to −0.87)	<0.001
Low SDI	1990–1999	0.04 (0.03–0.06)	<0.001	0.00 (−0.06 to 0.07)	0.849	−0.21 (−0.30 to −0.12)	<0.001
	2000–2009	0.09 (0.08–0.10)	<0.001	−1.01 (−1.09 to −0.93)	<0.001	−1.34 (−1.43 to −1.25)	<0.001
	2010–2019	−0.08 (−0.14 to −0.02)	0.004	−0.85 (−1.14 to −0.57)	<0.001	−0.86 (0.91 to −0.80)	<0.001
	1990–2019	0.02 (0.00–0.04)	0.024	−0.63 (−0.73 to −0.53)	<0.001	−0.82 (−0.89 to −0.75)	<0.001

−3.51). At the country level, the largest AAPC was in Estonia (AAPC, 7.33 %; 95 % CI, 6.2–8.47), while the most significant decrease was in Israel (AAPC, −1.27 %; 95 % CI, −5.34 to −4.38) (Table S4 and Fig. S5).

4.5.4.3. DALYs. From 1990 to 2019, the age-standardized DALY rate of HHD globally showed a significant downward trend (AAPC = −1.08 %, 95 % CI: 1.23 to −0.93; P < 0.001) (Table S2), with the most substantial change occurring from 2001 to 2004 (APC = −2.25 %, 95 % CI: 3.13 to −1.37; P < 0.001) (Fig. 5C and Table S15). The global age-standardized DALY rate of HHD at the regional level demonstrated a significant downward trend in all five SDI regions (Table 2). In other regions, the largest increase in the age-standardized DALY rate was in Eastern Europe (AAPC, 1.65 %; 95 % CI, 0.9 to 2.41), and the most significant decrease was in the High-income Asia Pacific (AAPC, −3.65 %; 95 % CI, −3.8 to −3.5). At the country level, the largest AAPC was in Estonia (AAPC, 6.22 %; 95 % CI, 5.29–7.17), and the most significant decrease was in Israel (AAPC, −4.89 %; 95 % CI, −5.53 to −4.24) (Table S5 and Fig. S5).

Significant differences were observed in the ASPR, ASDR, and age-standardized DALY rate trends across the 204 countries (Tables S12–S14). The most significant changes occurred in different periods during various regions and countries (Tables S14–S16).

5. Discussion

Over the past 30 years, the numbers and rates of prevalence, deaths, and DALYs of global HHD have gradually increased and are closely related to age growth. The increasing disease burden has gradually become a significant public health issue. This study aimed to investigate the prevalence, mortality, and DALYs of HHD in regions and countries worldwide from 1990 to 2019, along with the associated risk factors, and to explore the driving factors of temporal trends and disease burden changes of HHD. Our findings provide in-depth insights into the burden of HHD in various regions and countries over the past 30 years. These results further strengthen the findings of previous studies, demonstrating that some regions and countries worldwide need to proactively prevent and control risk factors, improve medical security levels, and cope with the disease burden caused by population growth and aging. The global evaluations of HHD can aid governments and clinicians in formulating appropriate prevention and management strategies.

From 1990 to 2019, significant decreases in the number, prevalence, mortality rate, and DALYs associated with HHD were observed. However, a significant increase in the ASPR of global HHD was noted, In contrast, the ASDR and age-standardized DALYs showed a significant downward trend. This is most evident during specific periods. As the burdens of population growth and aging continue to exacerbate, the healthcare systems in some countries have been evolving. Moreover, HHD is primarily mediated by high blood pressure, Lifestyle habits and physical conditions vary across countries and periods. The increase in the prevalence of HHD is primarily related to population growth and aging. Moreover, the greatest reduction in HHD-related mortality occurred in the middle SDI regions. This decrease may be linked to advancements in diagnostic and therapeutic technologies over the past 30 years, improved understanding of health and disease, early detection and prevention of HHD, and a decrease in late-stage cardiovascular complications in countries such as China, where a significant reduction in the AAPC was observed. However, in the low SDI regions in 2019, disease

prevalence and mortality rates were the lowest, possibly because of a lack of advanced diagnostic and therapeutic equipment for these diseases, with a positive correlation observed between each country's SDI and the prevalence rate, mortality rate, and DALYs.

HHD results from chronic hypertension-mediated myocardial remodeling and eventually manifests as heart failure [27]. Current treatments for HHD primarily involve lowering blood pressure, improving quality of life, and preventing complications. Some studies have indicated that when diabetes and hypertension coexist, there is a lingering effect on the myocardium, often leading to early congestive heart failure. Therefore, strict control of the arterial pressure and blood glucose levels could prevent heart disease in patients with hypertension and diabetes mellitus [28]. For hypertension, guidelines emphasize lifestyle changes, including dietary and exercise interventions and antihypertensive drugs [29]. In developed countries, a high body mass index is a major but modifiable cardiovascular disease risk factor that may negatively affect HHD [30]. In some middle SDI and East Asian regions, the number of obese individuals is rapidly increasing, highlighting the need for vigilance concerning the risks posed by a high body mass index to HHD [30,31]. The mechanisms through which various risk factors influence the mortality and DALYs of HHD are unclear and require further exploration. These risk factors vary in percentage contribution to death and DALYs in different regions and may vary owing to differences in environmental diet and behavioral habits. In Central Europe, the highest mortality contributor was from salt intake, while in East Asia, the strongest effect on DALYs was possibly from high sodium intake [32]. Therefore, a moderate reduction in salt intake and maintaining a healthy diet can decrease cardiovascular complication-related mortality rates, save considerable costs, and improve public health [33]. In addition, environmental and occupational lead exposure generally stems from metal extraction, smelting, recycling, and the production of numerous metal products [34,35]. In HHD, high-income countries have identified and controlled many of the most severe environmental pollution issues, and lead exposure primarily manifests as a risk factor in the middle and lower SDI regions [36,37]. Acute and chronic lead exposure may can increase the risk of hypertension and promote arteriosclerosis, thrombosis formation, and the development of CVDs, increasing cardiovascular mortality [38,39]. The burden of lead is highest in South Asia, possibly related to hazardous waste sites and small-scale or informal industrial activities in the population of this region, which are significant sources of exposure to lead and other chemicals [40]. In a large-scale screening of hazard sites, the exposures were primarily located in India, Indonesia, and the Philippines [41]. Furthermore, due to a lack of educational initiatives, there are incidences of lead poisoning among groups engaged in lead production or usage. Interventions typically focus on behavioral and lifestyle choices. With more knowledge, individuals make better choices to avoid [42]. In high-middle SDI and above regions, such as Southern Latin America and Australasia, alcohol consumption is particularly prevalent, which could be associated with local cultural customs. Alcohol can cause myocardial fibroplasia and exacerbate myocardial hypertrophy [43],; therefore implementing certain alcohol interventions can potentially reduce the disease burden caused by hypertension or HHD [44]. Interestingly, low temperature is suggested to be a risk factor for HHD, with an increase in death and DALYs associated with cold-related HHD in middle and high SDI countries, possibly related to economic development. People living in these countries may be less able to adapt to temperature decreases; however, high temperatures have little effect on reducing the risk of HHD. Additionally, with the onset of an aging society, the burden of HHD related to cold temperatures may become amplified [45]. Clinical practitioners can provide patients with medical advice on risks associated with cold exposure, such as maintaining warm housing and receiving flu vaccinations [46]. Previous mechanism studies have attempted to explore the relationship between environmental temperature and HHD, including systemic inflammation, the activation of the sympathetic nervous system, and heat shock proteins [47,48]. However, most of these are based on animal models, and the potential mechanisms in humans remain an area worthy of exploration [49].

This study has several limitations. First, because of the imperfections in the healthcare systems of underdeveloped countries, misdiagnoses and missed diagnoses could have occurred in GBD studies. Therefore, it is necessary to consider the role of primary practices that can strategically improve data quality and promote healthier lifestyles. Second, to overcome the unbalanced quality caused by massive original data from different countries, the GBD collaborators should adopt efficient data-cleaning methods and advanced statistical modeling. However, this may lead to an overreliance on modeled data in GBD studies and a failure to consider sociocultural and ethnic differences. Additionally, the diagnostic capabilities of HHD may evolve with societal and technological advancements as people's understanding of diseases and acceptance of health education change. Finally, high blood pressure is a common risk factor for many diseases. Therefore, patients with HHD often have comorbidities, including cardiovascular diseases such as ischemic heart disease, heart failure, and stroke. This could have posed challenges for accurately assessing HHD and should be considered in future studies.

6. Conclusion

Over the past 30 years, the ASDR and age-standardized DALYs rate of global HHD have shown a significant downward trend, whereas the ASPR has increased, particularly in the high-middle, low-middle, and low SDI regions. With increased population growth and aging, the prevalence of illness, death, and DALYs caused by HHD has increased, and the burden of HHD has shifted more severely towards non-high-income economies. Population growth, aging, and epidemiological differences in different regions influence the burden of disease, with strong heterogeneity. Therefore, in regions with a non-high SDI, there is an increased need for governments and healthcare professionals to proactively address risk factors, conduct health education, deploy extensive hypertension management programs, establish primary healthcare centers in public spaces to offer affordable and straightforward medications and identify lead sources and eliminate this toxin in the environment. Moreover, it is imperative to advise patients and at-risk populations to adopt healthier lifestyles and dietary patterns (e.g., reducing salt intake and adopting plant-based, low-fat diets). Home-based blood pressure monitoring and active participation in physical activity should also be encouraged. Finally, in high SDI regions, clinical practitioners should strengthen medical advice on the risk of cold exposure. Policymakers, clinicians, and communities must collaboratively amplify their efforts to enhance the early detection of HHD, elevate the standards of medical care, and augment patient awareness for self-

management to counter the ensuing disease burden.

Funding

No funding.

Availability of data and materials

Data are available (http://ghdx.Health data. org/gbd-results-tool). Corresponding author will provide the datasets upon reasonable request.

Ethics approval and consent to participate

Not applicable.

CRediT authorship contribution statement

Ben Hu: Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yihang Shi:** Validation, Investigation. **Pengcheng Zhang:** Investigation. **Yinguang Fan:** Writing – review & editing. **Jun Feng:** Investigation. **Linlin Hou:** Writing – review & editing, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors are grateful to all members who participated in the 2019 GBD study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e22671.

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