Worldwide Trends in Prevalence, Mortality, and Disability-Adjusted Life Years for Hypertensive Heart Disease From 1990 to 2017

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ABSTRACT: Hypertensive heart disease (HHD) is a major cause of global morbidity and mortality. Understanding its current burden among various countries and populations is crucial for formulating effective strategies for preventing and managing HHD. This study aimed to use the estimates from the Global Burden of Disease Study 2017 to describe the prevalence, mortality, and disability-adjusted life years for HHD for 195 countries and territories from 1990 to 2017. Worldwide, the age-standardized prevalence rate of HHD in 2017 was 217.9 (95% uncertainty interval [UI], 184.1–254.1) per 100 000 people, an increase of 7.4% (95% UI, 5.0–9.7) from 1990. The global age-standardized mortality and disability-adjusted life year rates of HHD were 12.3 (95% UI, 9.0–13.2) and 209.4 (95% UI, 160.5–226.3) per 100 000 people, a decrease of −19.3% (95% UI, −29.7 to −8.1) and −24.0% (95% UI, −31.0 to −13.7) from 1990, respectively. The global age-standardized prevalence rate of HHD was higher in females and increased with age. Between 1990 and 2017, Bolivia (51.3% [95% UI, 29.6–84.5]) and Maldives (32.3% [95% UI, 22.9–43.8]) showed the greatest increases in age-standardized prevalence rates. Generally, a negative association was found between the age-standardized disability-adjusted life year rates and Sociodemographic index at the regional and national levels. Our results suggest that HHD is a major public health challenge worldwide with an increasing prevalence rate over the past decades. Efforts to improve public awareness and management of high blood pressure and HHD, especially for vulnerable populations, were necessary. (Hypertension. 2021;77:1223-1233. DOI: 10.1161/HYPERTENSIONAHA.120.16483.) • Data Supplement

Key Words: global health◼ heart diseases◼ mortality◼ population◼ prevalence

Hypertensive heart disease (HHD) is a constellation of cardiac modifications induced by hypertension. Development of left ventricular hypertrophy (LVH) and diffuse interstitial fibrosis is the initial responses of the heart in the effort to adapt to longstanding hypertension and represents a major indicator of HHD. Subsequently, the hypertrophied or fibrosed myocardium may be insufficient to maintain normal cardiac output and heart failure occurs. Due to the heterogeneity of HHD, its clinical presentation ranges from absence of symptoms, mild chest tightness, and palpitations to dyspnea or even biventricular failure and sudden death. Therefore, the diagnosis of HHD largely depends on the use of medical instruments like ECG and echocardiography.

The global burden of hypertension in 2010 was estimated at ≈1.4 billion and is likely to surpass 1.6 billion by 2025, however, the blood pressure control rate was only about 32.5% worldwide among patients being treated. Such a high prevalence rate of uncontrolled/poorly controlled blood pressure led to a rise of HHD. It has been estimated that the prevalence of LVH, as assessed by echocardiography, was around 40% in the hypertension...
**Novelty and Significance**

**What Is New?**
- In this analysis of data from the GBD study (Global Burden of Disease) 2017, we provide the first comprehensive assessment of the global burden of hypertensive heart disease (HHD) in terms of its prevalence, mortality, and disability-adjusted life year rates, as well as their temporal trends during 1990 to 2017, stratified by location, age, sex, and development status.

**Method of Estimation**
- The GBD study, conducted by the Institute of Health Metrics and Evaluation, is a systematic effort to provide annual updates on the burden of diseases, injuries, and risk factors at the global, regional, and national levels. In the most up-to-date iteration, GBD 2017, 7 super-regions, 21 regions, and 195 countries and territories have been included; and 359 diseases and injuries, 282 causes of death, and 84 risk factors were systematically analyzed. The general methods used in GBD 2017 have been published previously. Herein, we summarize the methods relevant to the estimation of HHD burden. The GBD 2017 study was reviewed and approved by the University of Washington Institutional Review Board, and informed consent was waived because no identifiable data were used.

**Data Sources**
- HHD was defined using the International Classification of Diseases, Ninth and Tenth Revisions (ICD-9 and -10) codes. Diseases coded as 402-402.91 in ICD-9 or I11-I11.9 in ICD-10 were identified as HHD (Table S1 in the Data Supplement). Detailed information about the strategies of data selection with the ICD codes described above has been published before.

**Summary**
- HHD is a major public health challenge worldwide with an increasing prevalence rate over the past decades. The levels and trends of HHD burden varied substantially by location, age, and sex and were associated with sociodemographic index. Efforts to improve public awareness and management of high blood pressure and HHD, especially for vulnerable populations, were necessary.

**METHODS**

Data and Materials Statement
All data and materials have been made publicly available on the website of the Institute of Health Metrics and Evaluation and can be accessed at http://ghdx.healthdata.org/gbd-2017.

Overview
The GBD study, conducted by the Institute of Health Metrics and Evaluation, is a systematic effort to provide annual updates on the burden of diseases, injuries, and risk factors at the global, regional, and national levels. In the most up-to-date iteration, GBD 2017, 7 super-regions, 21 regions, and 195 countries and territories have been included; and 359 diseases and injuries, 282 causes of death, and 84 risk factors were systematically analyzed. The general methods used in GBD 2017 have been published previously. Herein, we summarize the methods relevant to the estimation of HHD burden. The GBD 2017 study was reviewed and approved by the University of Washington Institutional Review Board, and informed consent was waived because no identifiable data were used.

Data Sources
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A successful response to the challenge of HHD requires an accurate understanding of its current epidemiological characteristics among various countries and populations. However, to the best of our knowledge, no study has been performed so far to comprehensively measure the burden of HHD, including its prevalence, mortality, and disability-adjusted life year (DALY) rates, as well as their temporal trends, stratified by location, age, sex, and development status. The present study aimed to address the gap based on the results of the most recent GBD study (Global Burden of Disease) 2017. This study can provide detailed information to policy- and decision-makers, assisting them in making informed, evidence-based decisions to allocate resources for preventing and managing HHD.
HHD were publicly available via an online query tool on the website of Institute of Health Metrics and Evaluation (https://gbd2017.healthdata.org/gbd-search/).

Estimation of HHD Burden

Deaths due to HHD were estimated using the Cause of Death Ensemble Model. Predictive covariates incorporated in the modeling process were chosen on the basis of a possible causal relationship with HHD-specific mortality. Because of possible multicollinearity, a covariate selection algorithm was developed to further choose covariates. The retained covariates were systolic blood pressure, cholesterol, smoking prevalence, mean body mass index, health care access and quality index, lag-distributed income per capita, sociodemographic index (SDI), alcohol, omega-3, fruits, nuts and seeds, polyunsaturated fatty acid, vegetables, and trans-fatty acid. All models for HHD-specific mortality were assessed using out-of-sample predictive validity tests and combined into an ensemble of models that perform best. The prevalence of HHD for each location, year, age group, and sex was estimated using DisMod-MR 2.1, a Bayesian meta-regression tool developed for the GBD study.

DALYs were a summary measure that can quantify the overall health loss due to HHD and were calculated as the sum of years of life lost and years lived with disabilities. Years of life lost were calculated by multiplying the number of HHD-related deaths in each age group by a standard life expectancy at that age. Years lived with disabilities were calculated by multiplying the prevalence of HHD (in number of cases) by a disability weight that reflects the relative severity of HHD on a scale between 0 and 1. More details on the estimation of fatal and nonfatal outcomes can be obtained in previous publications.

Sociodemographic Index

SDI is a composite indicator developed to provide a comparable metric of overall developmental level for each location-year and is scaled between 0 (less developed) and 1 (most developed). It is calculated using average years of education in the population aged ≥15 years, total fertility rate under 25 years, and lag-distributed income per capita. All 195 countries and territories were grouped into quintiles of low SDI, low-middle SDI, middle SDI, high-middle SDI, and high SDI based on their 2017 values.

Complementary Analyses

Age-standardized rates were calculated by the direct method, using the global age structure as the standard. Uncertainty was propagated through all calculations by sampling 1000 draws at each calculation step. Final estimates were calculated using the mean estimate across 1000 draws, and the 95% uncertainty intervals (UIs) were defined as the 2.5th and 97.5th percentiles of the 1000 draws. For all estimates, a 95% UI excluding zero were considered statistically significant.

RESULTS

Global Level

In 2017, 17.1 million (95% UI, 14.4–19.9) individuals worldwide had HHD (Table), an increase of 121.4% (95% UI, 116.6–126.4) from 1990. However, the age-standardized prevalence rate of HHD only increased by 7.4% (95% UI, 5.0–9.7) from 202.8 (95% UI, 170.3–239.8) per 100,000 people in 1990 to 217.9 (95% UI, 184.1–254.1) per 100,000 people in 2017 (Table S2).

The global numbers of deaths and DALYs attributable to HHD in 2017 were 925.675 (95% UI, 681.438–994.935) and 16.5 million (95% UI, 12.7–17.9), respectively. Overall, 1.7% (95% UI, 1.2–1.8) of all global deaths and 0.7% (95% UI, 0.5–0.7) of all global DALYs in 2017 were constituted by HHD. Between 1990 and 2017, the global numbers of deaths and DALYs attributable to HHD have increased by 71.5% (95% UI, 50.8–96.6) and 49.3% (95% UI, 36.3–70.6), respectively. Despite the increases, the age-standardized mortality and DALY rates of HHD have decreased by −19.3% (95% UI, −29.7 to −8.1) and −24.0% (95% UI, −31.0 to −13.7) from 1990 to 2017, respectively.

Regional Level

At the regional level, the highest age-standardized prevalence rates of HHD in 2017 were seen in North Africa and Middle East (392.1 [95% UI, 335.9–450.2] per 100,000 people) and Central Latin America (320.6 [95% UI, 268.1–375.2] per 100,000 people), whereas the lowest age-standardized prevalence rates were seen in Southern Sub-Saharan Africa (87.9 [95% UI, 68.4–110.4] per 100,000 people) and Australasia (93.0 [95% UI, 78.2–110.4] per 100,000 people; Table).

The highest age-standardized mortality (36.4 [95% UI, 21.0–56.2] per 100,000 people) and DALY (614.6 [95% UI, 362.6–898.1] per 100,000 people) rates of HHD in 2017 were both seen in Central Sub-Saharan Africa. By contrast, the lowest age-standardized mortality (2.4 [95% UI, 2.0–3.2] per 100,000 people) and DALY (36.6 [95% UI, 31.6–47.9] per 100,000 people) rates were both seen in Australasia (Table).

The percentage change in age-standardized prevalence rates of HHD from 1990 to 2017 varied widely by GBD region. East Asia (17.4% [95% UI, 14.9–19.9]) and Central Latin America (12.4% [95% UI, 9.2–16.1]) had the greatest percentage increases in age-standardized prevalence rates, whereas Southern Latin America (−28.1% [95% UI, −33.4 to −22.5]) and Western Europe (−24.4% [95% UI, −28.7 to −19.9]) reported the greatest percentage decreases (Table).

Eastern Europe (89.6% [95% UI, −9.9 to 121.3]) and Central Asia (50.8% [95% UI, 4.8–73.6]) had the greatest percentage increases in age-standardized mortality rates of HHD during 1990 to 2017; they were also the 2 regions with the greatest percentage increases in age-standardized DALY rates: 58.6% (95% UI, −5.5 to 78.5) for Eastern Europe and 28.0% (95% UI, 4.0–41.9) for Central Asia. Conversely, high-income Asia Pacific and East Asia were the 2 regions with the greatest percentage decreases in age-standardized mortality (−70.5%
[95% UI, −75.5 to −26.9] for high-income Asia Pacific and −45.0% [95% UI, −53.2 to −34.8] for East Asia) and DALY (−65.1% [95% UI, −71.0 to −27.6] for high-income Asia Pacific and −48.2% [95% UI, −53.2 to −39.4] for East Asia) rates (Table).

### National Level

The age-standardized prevalence rate of HHD varied by 23.7 times across all countries and territories in 2017. Kuwait (637.5 [95% UI, 544.0–743.1] per 100 000 people) and Jordan (632.5 [95% UI, 535.5–732.8] per 100 000 people) had the highest age-standardized prevalence rates, whereas Ukraine (269 [95% UI, 215.5–330.0] per 100 000 people) and Netherlands (46.8 [95% UI, 38.5–56.5] per 100 000 people) had the lowest age-standardized prevalence rates (Figure 1 and Table S2). Between 1990 and 2017, the greatest percentage increases in age-standardized prevalence rates were observed in Bolivia (51.3% [95% UI, 29.6–84.5]) and Maldives (32.3% [95% UI, 22.9–43.8]), whereas the greatest percentage decreases were observed in Portugal (−35.8% [95% UI, −41.4 to −29.2]) and Spain (−35.3% [95% UI, −40.7 to −29.6]). Notably, China (36.5%) and India (11.0%) accounted for nearly half of the increase in global number of HHD prevalent cases during 1990 to 2017.
The age-standardized mortality rate of HHD ranged from 1.6 to 59.9 cases per 100 000 people in 2017. Seychelles (59.9 [95% UI, 49.3–72.2] per 100 000 people) and Estonia (5.1 [95% UI, 9.8–64.9] per 100 000 people) had the highest age-standardized mortality rates, whereas Canada (1.6 [95% UI, 1.0–1.8] per 100 000 people) and Norway (1.6 [95% UI, 1.1–1.8] per 100 000 people) reported the lowest age-standardized mortality rates (Figure 1 and Table S3). Between 1990 and 2017, the greatest percentage increases in age-standardized mortality rates were seen in Qatar (−81.7% [95% UI, −87.2 to −58.4]) and Israel (−75.0% [95% UI, −81.1 to −21.2]). Seychelles (1082.0 [95% UI, 876.2–1290.9] per 100 000 people) also reported the highest age-standardized DALY rate of HHD in 2017, followed by the Bahamas (918.4 [95% UI, 727.7–1045.3] per 100 000 people; Figure S2 and Table S4). Conversely, Norway (22.5 [95% UI, 19.4–29.7] per 100 000 people) and Denmark (27.2 [95% UI, 23.3–34.0] per 100 000 people) had the lowest age-standardized DALY rate. The greatest percentage increases in age-standardized DALY rates from 1990 to 2017 were seen in Latvia (421.6% [95% UI, −13.4 to 680.5]) and Estonia (401.0% [95% UI, −15.8 to 894.5]), while the greatest percentage decreases were in Qatar (−81.7% [95% UI, −87.2 to −58.4]) and Israel (−75.0% [95% UI, −81.1 to −21.2]).
Figure 1. Age-standardized prevalence and mortality rates of hypertensive heart disease across 195 countries and territories in both sexes, 2017.

A, Prevalence. B, Mortality. ATG indicates Antigua and Barbuda; FSM, Federated States of Micronesia; Isl, Islands; LCA, Saint Lucia; TLS, Timor-Leste; TTO, Trinidad and Tobago; and VCT, Saint Vincent and the Grenadines.
to 598.3), whereas the greatest percentage decreases were seen in Qatar (−78.2% [95% UI, −84.1 to −52.7]) and Israel (−73.2% [95% UI, −79.3 to −26.0]).

Age and Sex Patterns
Globally, the age-specific prevalence, mortality, and DALY rates of HHD tended to increase with increasing age in both sexes in 2017 (Figure 2). The numbers of prevalent cases were higher in females than in males across all age groups (although with overlapping uncertainty in age groups younger than 75 years), peaking at the ages of 65 to 69 years in males and 75 to 79 years in females. The numbers of deaths and DALYs were both higher in males younger than 70 years than in females in the same age group (although with overlapping uncertainty), whereas the numbers were lower in males than in females in age groups of ≥70 years. Additionally, the number of deaths peaked at the ages of 80 to 84 years in both sexes, and the numbers of DALYs peaked at the ages of 65 to 69 years in males and 75 to 79 years in females.

Burden of HHD by SDI
Generally, the age-standardized DALY rates of HHD by the 21 GBD regions decreased with increasing SDI (Figure 3). Oceania, Central, and Southern Sub-Saharan Africa had much higher age-standardized DALY rates than expected based on SDI for all years from 1990 to 2017. Despite gains in SDI over time, several regions, including Western Sub-Saharan Africa, Eastern Europe, Central Asia, and high-income North America, showed an increase in age-standardized DALY rate during 1990 to 2017. Figure 4 demonstrated the relation between age-standardized DALY rates and SDI across 195 countries and territories in 2017. Similar to regional trends, there was a downward trend at the national level of age-standardized DALY rates as SDI increases. Seychelles, the Bahamas, Estonia, and many other countries had much higher age-standardized DALY rates than expected based on SDI.

DISCUSSION
The present investigation is a comprehensive picture of worldwide epidemiology of HHD in terms of its prevalence, mortality, and DALY rates, making comparisons across different locations, age groups, sexes, and social development. More specifically, our findings showed that the number of HHD cases doubled from 7.7 million in 1990 to 17.1 million in 2017, and the numbers of HHD deaths and DALYs surged to 925,675 and 16.5 million cases, respectively. Considering further that most individuals are not aware of their hypertension status,6 HHD remains an important public health challenge that should receive proper attention and high priority.

When HHD-related burden data were age-standardized, they tended to increase only slowly or even slightly decreased, suggesting that the substantial increases in the numbers are mainly driven by aging and population growth. In addition, although there was an increase of 7.4% in age-standardized prevalence rate of HHD from 1990 to 2017, the age-standardized mortality (−19.3%) and DALY (−24.0%) rates of HHD have significantly decreased, suggesting an improvement in the treatment and management of HHD over the past decades. Nevertheless, given the considerable number of HHD cases worldwide, more targeted approaches, such as preventative interventions aimed at reaching senior subjects, are warranted.

Hypertension-related disparities were found to be large around the world,7 and our results demonstrated relatively analogous epidemiological patterns, with the burden imposed by HHD significantly varying among regions and nations. For instance, the age-standardized prevalence rate of HHD was highest in North Africa and Middle East where hypertension prevalence was also the highest in the world between 1975 and 2015.17 Besides, the regional prevalence rate of HHD might be partly determined by blood pressure control. For instance, the age-standardized prevalence rates of hypertension in South Asia and Middle East and North Africa were very close, but the blood pressure control rate in most Middle East and North Africa countries was lower than that in South Asia, which might partly explain the higher HHD prevalence in Middle East and North Africa.218

Our findings indicated that the age-standardized prevalence rate of HHD had a upward trend in low- or middle-income regions like East Asia and Central Latin America, along with the temporal trend of high blood pressure in the past 40 years.19 The reasons behind this epidemiological transition were largely due to the adoption of unhealthy lifestyles and habits, including westernized diet, smoking, obesity, and physical inactivity.19 On the contrary, the age-standardized prevalence rate of HHD largely decreased in high-income regions where exposures to cardiovascular risk behaviors have been declined, resulting in decreasing rates of high blood pressure.15,19 Additionally, we found paradoxically low age-standardized DALY rates of HHD in Latin American regions compared with high prevalence in these regions. Racial disparity might play an important role in this phenomenon as the adverse health outcomes of LVH varied significantly by race.20 High treatment rates of hypertension in Latin American regions could also protect patients from HHD-related disease burden.21

The reasons behind were partly because the ethnically disparity of HHD. It was reported that the hazard ratio of 10-year total mortality was lowest in Latin American LVH patients (1.19 versus 1.41 versus 1.15 for White, Black, and Latino, respectively). Another

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reason may be the good BP control rate (15.9% for males and 33.2% for female).

With regard to the sex difference in HHD, our results indicated that the number of cases and the prevalence rate were higher in females across all age groups, implying that females were more vulnerable to HHD. Generally, from the literature, it is known that the prevalence of hypertension in males was higher than in females in the age groups under 60 years but reversed after 60 years. The reasons behind these patterns may be due to the insurgence of postmenopausal hypertension and a higher life expectancy as well as a higher risk of developing LVH among females (43.4 versus 32.1%, \( P<0.001 \)) and a lower response to treatments. However, females tended to be more aware of their hypertensive status, achieving a better control rate of high blood pressure, thus, at least partially, compensating for their disadvantages.
Generally, a negative association was found between the age-standardized DALY rates and SDI at the regional and national levels; this has not been previously reported. During the past 3 decades, the age-standardized DALY rates tended to be higher in low SDI regions and lower in high SDI regions. However, the relationship between SDI and HHD-related DALYs was not that simplistic and linear, revealing a more complex and subtle interplay between the variables under study. Actually, our findings indicated that the relatively high burden imposed by...
HHD was not limited to low SDI countries but was also seen in countries with a middle or high SDI level, such as Bulgaria and Estonia. Also, there were several regions and countries characterized by a burden much heavier than that expected. The burden of HHD observed could be compared with the expected burden based on the SDI when considering preventive measures.

Our study has several limitations that should be properly acknowledged. First, elevated blood pressure is a common risk factor shared by many diseases, therefore, HHD patients often suffer from comorbidities, including cardiovascular disorders, such as coronary heart disease, atrial fibrillation, and stroke. This may challenge the precise quantitative assessment of HHD as a single contributor to the global burden of disease. Second, the comparability of HHD data is at least partly hindered by different collection methods, sources, and reporting standards across different countries. In addition, the capacity of HHD diagnosis may increase with the growth of social development, which could affect the baseline report of HHD prevalence in 1990 and its change from 1990 to 2017. Actually, high-quality data have been selected in GBD 2017 to minimize diagnostic bias. Third, due to unavailable or unaffordable access to health care facilities and instrumental inspections, high-quality epidemiological data about HHD are scarce in some countries, especially low-income countries, which could lead to an underestimation of results. However, statistically robust approaches have been applied to the GBD 2017 methodology to overcome data scarcity and deal with uncertainty. Fourth, although some factors, including diabetes, impaired kidney function, and blood pressure control, were proved to be associated with risks of cardiovascular mortality, they were not chosen as the predictive covariates in modeling HHD-specific mortality. This selection was based on model performance and the availability of universal high-quality data. In addition, sociocultural and ethnic background differences, which also affect the global burden of HHD, could not be taken into account by the GBD model.

PERSPECTIVES

Our results suggest that HHD is a major public health challenge worldwide with an increasing prevalence rate over the past decades. The levels and trends of HHD burden varied substantially across locations, between age groups, between sexes and were associated with SDI. Efforts to improve public awareness and management of high blood pressure and HHD, especially for vulnerable populations, were necessary to reduce the future burden of this condition.

ARTICLE INFORMATION

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