Current Science
CS 5 (5), 4596-4620 (2025)
**Received** 15 June 2025 | **Revised** 12 July 2025 | **Accepted** 21 August 2025 | **Online Available** 26 September 2025
https://doi.org0/10.52845/CS/2025-5-5-23

**Current Science**
Current Science

**OPEN ACCESS**
**ISSN(O) 2795-8639**

**Research Article**

# Global Burden of Hypertensive Heart Disease and Modifiable Risk Factors: A 30-Year Systematic Analysis of Prevalence, Mortality, and Disability-Adjusted Life Years (1990−2021)

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**Abstract:**
**Background:** Hypertensive heart disease (HHD), a leading cause of heart failure, imposes growing global health burdens with significant inequity. Using Global Burden of Disease (GBD) 2021 data, this study assesses spatiotemporal trends, risk factors, and projections across 204 countries.
**Methods:** We analyzed GBD 2021 estimates for HHD prevalence, deaths, and disability-adjusted life years (DALYs) from 1990-2021. Trends were evaluated using age-standardized rates (ASRs) and estimated annual percentage changes (EAPCs). Burden was projected to 2050 using Bayesian age-period-cohort modeling, stratified by age, sex, and sociodemographic index (SDI).
**Results:** In 2021, HHD affected 12.5 million people globally, causing 13.3 million deaths and 2.5 billion DALYs. Age-standardized death rates (ASDR) declined 0.68% annually (95% CI: −0.77 to −0.59), while age-standardized prevalence rates (ASPR) rose 0.56% yearly (95% CI: 0.52–0.60). Low SDI regions had the highest ASPR (208.4 per 100,000), especially sub-Saharan Africa. High systolic blood pressure and metabolic risks accounted for ~99% of burden in 1990 and 2021. High body mass index showed the largest risk increase since 1990 (nearly 11%), particularly in high SDI. By 2050, ASPR is projected to rise 8.5%, with men experiencing greater increases (15.7%) than women (3.6%).
**Conclusions:** HHD burden remains high with stark SDI disparities. Metabolic risks increasingly surpass hypertension in high-income nations. Context-specific interventions—hypertension control in low SDI areas and metabolic risk reduction in high SDI settings—are urgently needed.
**Keywords: Hypertension Heart Disease; GBD2021; Disability-adjusted life years; High mass body mass index; Metabolic risks.**

## 1. Introduction

Hypertensive heart disease (HHD), a sequela of chronic hypertension, is characterized by structural and functional cardiac adaptations to sustained pressure overload, including left ventricular hypertrophy, diastolic dysfunction, and eventual heart failure[1]. Globally, HHD remains the second leading cause of heart failure, trailing only ischemic heart disease, and imposes a disproportionate burden on aging populations and low-resource regions[2, 3]. Despite advancements in hypertension management, the absolute prevalence of HHD continues to rise, driven by demographic shifts, metabolic risk factors, and persistent gaps in blood pressure control[4, 5].

Pathophysiologically, prolonged hypertension induces compensatory cardiac remodeling, initially preserving ejection fraction but progressing to heart failure with preserved (HFpEF) or reduced ejection fraction (HFrEF)[6]. Early-stage HHD often manifests asymptomatically, yet advanced disease precipitates debilitating outcomes such as arrhythmias, myocardial infarction, and mortality[7, 8]. While hypertension is the primary driver, emerging evidence underscores the synergistic roles of obesity, insulin resistance, and aging in accelerating HHD progression[9, 10]. Alarmingly, fewer than 50% of treated hypertensive patients achieve adequate blood pressure control, exacerbating global disparities in cardiovascular outcomes[11].

Recent epidemiological analyses from the Global Burden of Disease (GBD) study highlight declining age-standardized mortality rates for HHD, yet absolute case numbers and disability-adjusted life years (DALYs) have surged, particularly in sub-Saharan Africa and South Asia[12, 13]. These disparities reflect inequities in healthcare access, socioeconomic determinants, and differential exposure to modifiable risks such as salt intake, physical inactivity, and air pollution[14, 15]. For instance, hypertension awareness and control rates in low-income countries remain below 20%, starkly contrasting with high-income nations where metabolic risks now dominate HHD etiology[16, 17].

Despite these insights, critical gaps persist. Prior GBD analyses (1990–2019) lack integration of post-pandemic health trends and updated risk factor [18]. Furthermore, the differential impact of sociodemographic indices (SDI) on HHD burden—particularly sex- and age-specific trends—remains underexplored. This study leverages GBD 2021 data to provide a comprehensive, contemporary assessment of HHD prevalence, mortality, and DALYs across 204 nations from 1990 to 2021. By stratifying analyses by age, sex, and SDI, we aim to identify high-risk populations, evaluate evolving risk factor contributions, and project disease trajectories to 2050. These findings will inform targeted interventions to mitigate the growing yet inequitable burden of HHD worldwide.

## Method

### Data Sources and Processing

This study utilized data from the Global Burden of Disease (GBD) 2021 study, accessible via the Global Health Data Exchange (GHDx, https://vizhub.healthdata.org/gbd-results/). The GBD 2021 dataset provides standardized estimates for 369 diseases and 88 risk factors across 204 countries and territories, with methodologies extensively documented in prior publications[18, 19]. We extracted annual metrics for HHD prevalence, deaths, and disability-adjusted life years (DALYs) from 1990 to 2021, including age-standardized rates (ASRs) and risk factor attributions. All estimates were reported with 95% uncertainty intervals (UIs) derived from 500 posterior draws of the modeling distribution[20]. Demographic projections for 2022–2050 were obtained from the GBD Population Forecast (https://vizhub.healthdata.org/population-forecast/).

### Statistical Analysis

### Temporal Trends

Age-standardized rates (ASRs) for prevalence, mortality, and DALYs were calculated using the GBD reference population[21]. Trends were quantified via estimated annual percentage changes (EAPCs) using log-linear regression:

$$\text{Ln}\ (\text{ASR}) = \alpha + \beta(\text{Year}) + \epsilon$$

where β represents the annual rate of change, and EAPC was computed as $100\times(e^{\beta}-1)$. Trends were classified as increasing (EAPC and 95% CI >0), decreasing (EAPC and 95% CI <0), or stable[20].

### Projection Modeling

A Bayesian age-period-cohort (BAPC) model with integrated nested Laplace approximation (INLA) was employed to forecast ASRs to 2050[22]. This model accounts for age-specific effects, temporal trends, and cohort influences using:

$$\text{Log}\ (\text{ASR}_{age,period}) = \mu + \alpha_{\text{age}} + \beta_{\text{period}} + \gamma_{\text{cohort}} + \epsilon$$

where α, β, and γ represent age, period, and cohort effects, respectively. Projections incorporated demographic changes but assumed constant risk factor exposure post-2021. Analyses were conducted in R (version 4.2.0) with the *BAPC* (0.036) and *INLA* (24.05.10) packages

[23].

**Ethical Considerations**

The GBD study received ethical approval from the University of Washington Institutional Review Board with waived consent. This study adheres to the STROCSS guidelines for observational research[24].

**Result**

**Global Level**

In global, the prevalence of HHD reached at 12,505,435.7 in 2021, marking a substantial 170.3% rise since 1990 (95% UI: 9,866,065.7~15,827,877.6). In age-standardized rate of prevalence (ASPR), there similar showed notable increase from 125.4 per 100,000 individuals in 1990 (95% UI: 99~117.3) to 148.3 per 100,000 in 2021 (95% UI: 117.3~186.3). The EAPC for ASPR is 0.56 (95% CI: 0.52~0.6) (Table1, Figure1). The Deaths of HHD amounted to 133,200,999.2 in 2021 (95% UI: 112,113,1~146,885,2), representing an 84.7% increase from 1990. Conversely, the age-standardized rate of deaths (ASDR) declined from 20.9 per 100,000 people in 1990 (95% UI: 17.1~23.2) to 16.3 per 100,000 in 2021 (95% UI: 13.8~18). The EAPC is -0.68 (95% CI: -0.77~-0.59) (Table1, Figure1). The DALYs of HHD totaled 25,462,184.7 in 2021 (95% UI: 21,493,311.5~28,047,521), which is a 64.5% increase compared to 1990. The age-standardized rate of DALYs have also decreased from 406.5 per 100,000 in 1990 (95% UI: 328.9~452.2) to 301.6 per 100,000 in 2021 (95% UI: 255.1~332.1). The EAPC for age-standardized rate of DALYs is -0.9 (95% CI: -0.99~-0.81) (Table1 Figure1).

**Table 1: The prevalence, deaths, disability-adjusted life years and their age-standardized rate of hypertension heart disease in global and reginal from1990 to 2021.**

| **Location** | **1990** | | **2021** | | **EAPC_95%CI** |
|---|---|---|---|---|---|
| | **Number** | **ASR** | **Number** | **ASR** | |
| **Prevalence** | | | | | |
| Global | 4626598.4 (3672198.1, 5826591.7) | 125.4(99,158) | 12505435.7 (9866065.7, 15827876.6) | 148.3(117.3, 186.3) | 0.56(0.52,0.6) |
| High SDI | 845598 (645690.6, 1085375.5) | 77.2(59.9,98.1) | 2436472.9 (1878839.4, 3082797.5) | 113.4(88.4,139.9) | 1.58(1.47,1.7) |
| High-middle SDI | 992322.9 (766889.9, 1275711.3) | 107.7(83.5,137.2) | 2740903.4 (2119691.6, 3504372.6) | 139.8(108.6, 177.8) | 0.87(0.82,0.92) |
| Middle SDI | 1666506.2 (1322120.7, 2075893.6) | 189.9(150.6,235.4) | 4456763.4 (3493911.9, 5664363.9) | 178.1(140.4, 225.7) | -0.35(-0.47, -0.24) |
| Low-middle SDI | 741968.4 (598364.9, 921355.3) | 145.5(115.2,181.7) | 1943002.7 (1538778.6, 2439288) | 151.5(119,192.4) | 0.08(0.07,0.1) |
| Low SDI | 375324.2 (290235.5, 477935.3) | 202.3(158.3,263.1) | 915834.8 (705715, 1160391.6) | 208.4(162.5, 268.8) | 0.12(0.09,0.14) |
| High-income North America | 316482.2 (237495.5, 410999.6) | 91.8(70.3,118.4) | 949322 (738427.5, 1167270.7) | 150.7(119.5, 181.9) | 1.94(1.8,2.08) |
| High-income Asia | 105137.2 (75815.2, 138635.3) | 57.4(41.7,75) | 297204.1 (219640.8, 391369) | 57.6(43.8,72.4) | -0.21(-0.4, -0.02) |

| | | | | | |
|---|---|---|---|---|---|
| Pacific | | | | | |
| North Africa and Middle East | 365066.2 (297760.7, 449144) | 239.5(192.8,299.2) | 1027630.6 (814739.4, 1265655.5) | 243.3(192.1, 303.6) | 0.13(0.1,0.16) |
| Central Sub-Saharan Africa | 38769.5 (28041.6, 51326) | 221.6(161.5,300.5) | 106345.9 (78304.8, 139741.5) | 239.1(176.9, 320.4) | 0.28(0.22,0.33) |
| Eastern Sub-Saharan Africa | 175065.6 (131636.8, 224238) | 282.2(216.1,371.2) | 425630 (324247.6, 532350) | 291.8(224,375.4) | 0.08(0.06,0.09) |
| Western Sub-Saharan Africa | 196107.7 (151200.3, 249117.3) | 257.4(201.8,331.6) | 450800.9 (347733.5, 569919.5) | 266.3(206.7, 342.2) | 0.15(0.11,0.19) |
| Southern Sub-Saharan Africa | 48002.4 (35809.5, 61790.2) | 196.8(147.1,256.1) | 108005.9 (80827.6, 139595.1) | 210.6(157.4, 272.2) | 0.25(0.19,0.3) |
| East Asia | 1550299.7 (1198536.3, 1971216.9) | 216.7(168.4,272) | 4066467.9 (3120124.7,5242373.8) | 193.2(147.4, 245.9) | -0.63(-0.85,-0.4) |
| Central Asia | 35124.1 (25707.9, 46385.6) | 80.1(57.8,107.6) | 69365 (48393.5, 95010.8) | 95.6(64.6,132.6) | 0.96(0.75,1.17) |
| South Asia | 470748.4 (374963.8, 589000.2) | 104.1(82.7,129.6) | 1432787.7 (1119541.5,1828056.9) | 111.1(86.6,142.7) | 0.19(0.17,0.2) |
| Southeast Asia | 370474.1 (301792.3, 452815.3) | 168.1(135.9,207.4) | 960247.1 (767865.2, 1203975.6) | 163.3(131.2, 205.2) | -0.19(-0.23, -0.14) |
| Oceania | 2766.6 (2166.7, 3496.4) | 115.7(90.2,148) | 6738 (5278.6, 8527.2) | 106.9(83.7,136.8) | -0.37(-0.42, -0.31) |
| Central Europe | 142712.2 (104116.6, 188157.8) | 100.3(73.7,131.3) | 339147.3 (247045.1, 439436.9) | 146(107.1,186.7) | 1.7(1.56,1.84) |
| Eastern Europe | 77818.9 (57321.6, 105778.5) | 28.7(21.3,38.8) | 154963.1 (107121.7, 212912.7) | 42.8(29.8,58.3) | 1.74(1.56,1.91) |
| Western Europe | 394304.4 (293759.7, 522421.7) | 65.8(49.5,86.4) | 1094894.9 (830591.9, 1423768.4) | 100.8(78,128.1) | 2.03(1.73,2.33) |
| Australasia | 7289.9 (5725.4, 9401.1) | 31.4(24.6,40.1) | 30057.5 (24138.3, 37342.5) | 52.4(42,64.4) | 1.95(1.84,2.06) |
| Caribbean | 36018.1 (28468.9, 45489.5) | 141.5(112.5,179.6) | 105243.3 (81142, 136189.5) | 195.5(151.1, 253.3) | 1.24(1.18,1.3) |

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|---|---|---|---|---|---|
| Southern Latin America | 39028.9 (28709, 52164.1) | 88.1(64.9,117.8) | 98818.6 (70049.2, 130976.4) | 110.1(78.3,145.8) | 0.98(0.93,1.04) |
| Andean Latin America | 29498.9 (23627.5, 36700.6) | 150.2(118.6,191.6) | 85962.3 (65683, 110960.7) | 148.4(112.9, 192.7) | 0.18(0.08,0.28) |
| Tropical Latin America | 122755.4 (95999.2, 153966.8) | 149.9(118.5,187.4) | 411264.2 (317929.8, 527720.4) | 166(129.1,213.6) | 0.32(0.29,0.36) |
| Central Latin America | 103128.1 (82807.5, 129101.2) | 136.8(108,171.6) | 284539.3 (222180.4, 367455.7) | 119(92.2,154) | -0.66(-0.72, -0.6) |
| Deaths | | | | | |
| Global | 713935.2 (577534, 795258.1) | 20.9(17.1,23.2) | 1332099.2 (1121131, 1468852) | 16.3(13.8,18) | -0.68(-0.77, -0.59) |
| High SDI | 93389.7 (85035.9, 98125.2) | 8.6(7.7,9) | 189009.8 (157234.2, 209886.2) | 7.7(6.5,8.5) | 0.1(-0.08,0.28) |
| High-middle SDI | 145582.2 (128528, 161926.8) | 17.8(15.6,19.7) | 275365.3 (237571, 312977.9) | 14.6(12.5,16.5) | -0.41(-0.52, -0.3) |
| Middle SDI | 270962.9 (190726.9, 306788.8) | 35.2(25.5,39.4) | 461729.8 (349647, 546063.3) | 20.3(15.3,24) | -1.76(-1.97, -1.54) |
| Low-middle SDI | 132745.2 (95311.2, 158999.3) | 28(21.1,33.9) | 274886 (225956.2, 315308.9) | 23.1(19.1,26.6) | -0.56(-0.61, -0.51) |
| Low SDI | 70360.6 (46597.6, 89469.1) | 40.5(28.1,50.8) | 129352.3 (90728.4, 159533.1) | 33.6(24.7,40.6) | -0.61(-0.7, -0.52) |
| High-income North America | 24618.3 (22278.1, 25860.9) | 6.9(6.3,7.3) | 70913.5 (60614, 78750.1) | 10.4(9.1,11.5) | 1.51(1.33,1.68) |
| High-income Asia Pacific | 17175.7 (15077.3, 18444.8) | 10.5(9.1,11.4) | 21393.6 (16165.2, 25059.6) | 3(2.3,3.5) | -3.64(-4.36, -2.91) |
| North Africa and Middle East | 71361.3 (54461.7, 85226.7) | 56.9(43.9,68.1) | 138260.7 (109923, 161917.9) | 39.5(31.5,46.2) | -1.04(-1.14, -0.93) |
| Central Sub-Saharan Africa | 10737.4 (5994.3, 15055.5) | 67.5(40.7,91.8) | 24396.1 (15347, 34210.8) | 66.3(42.2,92.9) | -0.09(-0.14, -0.04) |
| Eastern Sub-Saharan Africa | 32510.7 (20661.1, 41346.1) | 58.5(39.6,72.8) | 52210.9 (35806.3, 66306.1) | 42.6(29.4,54.7) | -1.14(-1.21, -1.07) |
| Western | 25023.2 | | 45746.4 | | |

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|---|---|---|---|---|---|
| Sub-Saharan Africa | (18234.2, 31428.2) | 34.6(25.7,43.7) | (28908.7, 56512.4) | 28.8(18.8,34.9) | -0.77(-0.92, -0.62) |
| Southern Sub-Saharan Africa | 8661.6 (7510.6, 10960.1) | 38.2(32.7,49.2) | 21605.1 (19013.5, 25148.3) | 47.4(41.5,55.2) | 0.84(0.41,1.28) |
| East Asia | 238411.3 (161564.7, 281395.9) | 41.9(30,48.6) | 340500.6 (235952.6, 438264.7) | 18.7(13,24.1) | -2.63(-2.99, -2.26) |
| Central Asia | 6687.1 (5814.4, 7780.7) | 16(13.8,18.8) | 13575.2 (11626.1, 15907.5) | 20.6(17.7,23.9) | 1.31(0.72,1.9) |
| South Asia | 76637.9 (49356.5, 103624.1) | 17.9(11.7,24.2) | 196772 (155294.7, 256586.6) | 16.5(13.1,21.4) | -0.17(-0.26, -0.08) |
| Southeast Asia | 62278.4 (43376.4, 75569.9) | 29.6(20.7,35.8) | 128532.1 (93845.4, 148677.6) | 22.9(16.9,26.5) | -0.82(-0.87, -0.77) |
| Oceania | 615.1 (385.4, 836.2) | 26.1(17.3,34.4) | 1215.8 (823.2, 1758.3) | 19(13.1,26.9) | -1.11(-1.16, -1.06) |
| Central Europe | 31130.3 (29587.1, 32630.5) | 23.3(21.9,24.5) | 60801.4 (54777.3, 65338) | 25.4(22.9,27.3) | 0.84(0.59,1.1) |
| Eastern Europe | 11685.5 (11105.2, 12232.1) | 4.5(4.2,4.7) | 26346.4 (23721.6, 28591.2) | 7.4(6.7,8) | 1.72(0.82,2.62) |
| Western Europe | 51680.9 (46518.8, 54541.1) | 8.7(7.8,9.2) | 107186 (85267.3, 119112.3) | 8.2(6.7,9.1) | 0.4(0.21,0.58) |
| Australasia | 742.3 (667.3, 789.8) | 3.4(3,3.7) | 1506.5 (1239.3, 1667) | 2.4(2,2.6) | -1.03(-1.43, -0.63) |
| Caribbean | 4754.5 (4028.2, 5539.2) | 20.2(17.3,23.3) | 10816 (9110, 12603.4) | 19.7(16.6,23) | 0.4(0.19,0.61) |
| Southern Latin America | 6842.3 (6398.9, 7159.1) | 16.3(15.1,17.1) | 12725.1 (11072.4, 13670.7) | 13.8(12,14.8) | -0.17(-0.33,0) |
| Andean Latin America | 2565.6 (2225.4, 2905.7) | 14.5(12.6,16.3) | 4700.6 (3728.2, 5792.3) | 8.4(6.7,10.4) | -1.17(-1.54, -0.8) |
| Tropical Latin America | 17381.7 (16368.4, 18044.1) | 23.1(21.2,24.2) | 30406.2 (26624.8, 33180.7) | 12.4(10.8,13.5) | -1.81(-1.94, -1.68) |
| Central Latin America | 12434.2 (11776.8, 12862.3) | 18.6(17.4,19.4) | 22489.1 (18586.4, 26047.5) | 9.6(8,11.1) | -2.21(-2.4, -2.01) |
| DALYs | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Global | 15473830.1 (12310724.9, 17311822.2) | 406.5(328.9,452.2) | 25462184.7 (21493311.5,28047521) | 301.6(255.1, 332.1) | -0.9(-0.99, -0.81) |
| High SDI | 1695961.8 (1583911.6, 1767114.4) | 155.6(145.3,162.3) | 3098667.2 (2717717.6,3397623.5) | 149.4(134.5, 162.9) | 0.37(0.16,0.57) |
| High-middle SDI | 2891666.6 (2552952.8, 3233034.9) | 315.2(278.3,351) | 4389744.9 (3890114.7,4989433.6) | 228(201.5,258.5) | -0.93(-1.03, -0.83) |
| Middle SDI | 6002936.9 (4223842.6, 6811307.5) | 645.1(459.8,729.1) | 8930493 (6909201.1,10413694.4) | 355.7(273.6, 414.6) | -1.92(-2.14,-1.71) |
| Low-middle SDI | 3111598.6 (2200759.4, 3753608.4) | 545.4(391,652.8) | 5955401.9 (4908448.2,6812461.4) | 438.5(364.1, 503.3) | -0.69(-0.73, -0.66) |
| Low SDI | 1753192.4 (1128631.4, 2257732.4) | 817.3(545.8,1035.7) | 3055862.3 (2148435.8,3826137) | 640.7(451.5, 786.8) | -0.86(-0.93, -0.78) |
| High-income North America | 515673.1 (485610.7, 535499.9) | 152.1(144,157.8) | 1404762.2 (1266197, 1545160.9) | 236.5(214.9, 259.5) | 1.81(1.65,1.97) |
| High-income Asia Pacific | 285967 (256364.8, 304070.1) | 159.1(141.7,169.8) | 271541.7 (221082.7, 316519.1) | 47.1(40.2,56.3) | -3.63(-4.3, -2.95) |
| North Africa and Middle East | 1560227.1 (1166916.3, 1870658) | 1025.9(781.2,1223.5) | 2854429.8 (2223168.1,3367199.2) | 692.1(549,810.5) | -1.18(-1.27, -1.1) |
| Central Sub-Saharan Africa | 271363.2 (146934.9, 388905.8) | 1326.9(764.1,1844.6) | 576693.4 (363693.5, 812009.6) | 1213.1(774,1694.9) | -0.34(-0.39, -0.29) |
| Eastern Sub-Saharan Africa | 813363.1 (498148, 1044829.4) | 1151.6(741.1,1457.2) | 1226566.2 (838033.8, 1554381.5) | 786.2(549.7, 992.2) | -1.39(-1.48, -1.31) |
| Western Sub-Saharan Africa | 614135.7 (448611.6, 771928.2) | 712.7(522.3,889.5) | 1166017.4 (722290.1, 1453815.5) | 590.8(378.8, 726.1) | -0.78(-0.92, -0.63) |
| Southern Sub-Saharan Africa | 202983.9 (179665.2, 249009.5) | 758.9(665,944.8) | 483470.5 (427106.9, 568061.7) | 889.1(785.1, 1034.2) | 0.66(0.22,1.1) |
| East Asia | 5094621.5 (3390116.5, 6059526.2) | 704.8(483.2,825.2) | 5816084.8 (4174234.2,7400720) | 292.6(210.4, 371.8) | -2.9(-3.28, -2.52) |
| Central | 147719.8 (130145.4, | 323.9(284.1,368.1) | 283347.8 (241619.6, | 376.1(320.9, | 0.67(0.07,1.27) |

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|---|---|---|---|---|---|
| Asia | 166387.4) | | 334738.4) | 441.9) | |
| South Asia | 1817085.8 (1179625.3, 2449771.1) | 345.1(226.3,463.8) | 4123050.4 (3221045.8,5404917.5) | 301.7(238.1, 392.3) | -0.4(-0.46, -0.34) |
| Southeast Asia | 1514601.9 (1050905, 1853653.2) | 611.5(426.6,743.7) | 2960770.1 (2139788.6,3454907.8) | 464.8(339.7, 536.9) | -0.89(-0.93, -0.86) |
| Oceania | 17829.3 (10920.9, 24839.1) | 583.6(371.2,789.7) | 35086.2 (23181.1, 51352.8) | 434.6(296.5, 627.6) | -1.02(-1.07, -0.97) |
| Central Europe | 591356.5 (566986.2, 618798.3) | 413.1(394.8,432.6) | 956691.2 (873566.8, 1033374.8) | 418.1(380.5, 451.9) | 0.56(0.32,0.8) |
| Eastern Europe | 278145.1 (263673.3, 291844.7) | 101.6(96.2,106.6) | 486143.9 (446186.3, 530864.3) | 139.7(128.2, 152.8) | 0.86(-0.06,1.78) |
| Western Europe | 800560.1 (740059.2, 838839.7) | 134.9(124.6,141.2) | 1301047.9 (1089765.6,1426439.9) | 111.1(95.1,120.7) | -0.05(-0.21,0.12) |
| Australasia | 12663.5 (11731.6, 13303.5) | 56.3(51.8,59.3) | 22284.5 (19484, 24367.3) | 38.8(34.5,42) | -1.07(-1.5, -0.63) |
| Caribbean | 105057.4 (86186, 124660.1) | 411.5(340.5,485.4) | 220546.5 (183991.2, 262109.7) | 408.8(340.5, 486.4) | 0.36(0.18,0.55) |
| Southern Latin America | 129092.1 (122998.2, 134160.6) | 289.4(274.8,301.4) | 191778.8 (173311.1, 203910.3) | 213.2(193.3, 226.4) | -0.67(-0.81, -0.53) |
| Andean Latin America | 53333.8 (45900.5, 60206.2) | 267.1(230.8,301.8) | 87399.7 (70637.5, 106993.8) | 151(122.1,184.7) | -1.3(-1.69, -0.91) |
| Tropical Latin America | 401303.9 (385288.1, 413173) | 455(431.3,470.2) | 593759.1 (541161.4, 645012) | 234.8(213.3, 255.2) | -2.04(-2.16, -1.92) |
| Central Latin America | 246746.4 (237067.5, 254869.2) | 323.9(308.8,335.8) | 400712.6 (340190.6, 468739.8) | 165.7(141,193.2) | -2.29(-2.52, -2.06) |

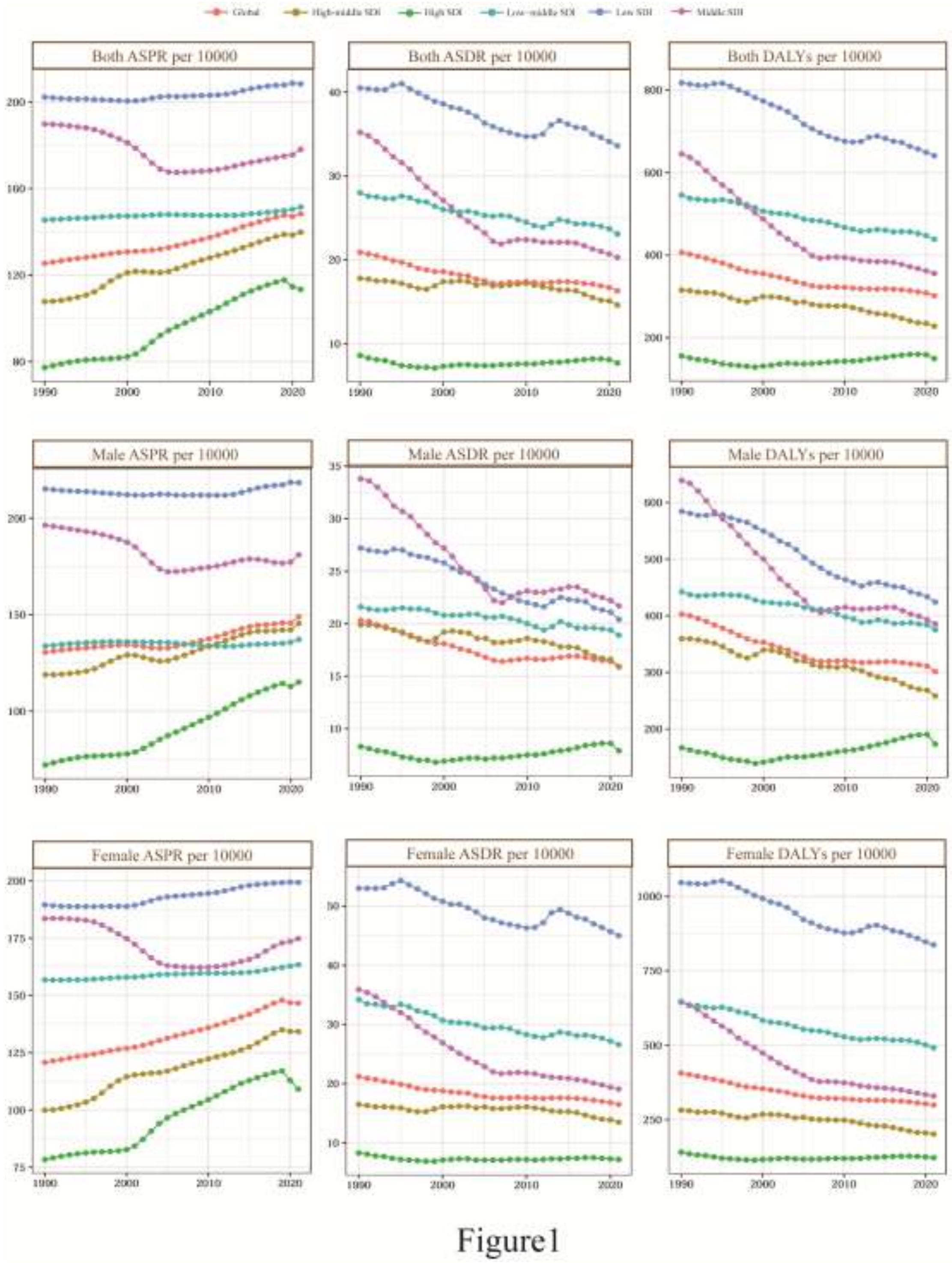


**Figure 1: Trend of Hypertensive Heart Disease in ASPR, ASDR, and age-standard rate of DALYs from 1990-2021 in global and SDI regions.**

### Regional Level

At regional level, the disease burden of HHD varies across different SDI regions. Between 1990 and 2021, the ASPR in lower SDI regions remained the highest and exhibited an upward trajectory, reaching 208.4 per 100,000 people in 2021 (95% UI: 162.5~268.8). While, the ASPR in high SDI region remained the lowest, stood at 113.4 cases per 100,000 people in 2021 (95% UI: 88.4~139.8). The ASPR in these regions generally increased with the exception of middle SDI region, which showed a decline over the 30-year period with an EAPC of 0.35 (95% CI: -0.47 to 0.24). The high SDI regions experienced the most significant rise in ASPR, with an EAPC of 1.58 (95% CI: 1.47 to 1.7) (Table 1, Figure 1). Similarly, the ASDR and age-standardized

DALYs of low SDI region consistently the highest among these regions. In 2021, the ASDR and age-standardized DALYs for HHD in low SDI region were 33.6 per 100,000 people (95% UI: 24.7~40.6) and 640.7 per 100,000 people (95% UI: 451.5~786.8), respectively (Table 1, Figure 1). While these metrics in high SDI were 7.7 per 100,000 for ASDR (95% UI: 6.5~8.5) and 149.4 per 100,000 for age-standardized DALYs (95% UI: 134.5~162.9) in 2021, the lowest level among 5 SDI regions (Table 1, Figure 1). The ASDR and age-standardized DALYs showed decreased trend except for high SDI region, which showed an increasing trend with EAPC of 0.1 (95% CI: -0.08~0.28) and 0.37 (95% CI: -0.16~0.57), respectively. The middle SDI region had the most significant declines, with EAPC of -1.76 (95% CI: -1.97~-1.54) for ASDR and -1.92 (95% CI: -2.14~-1.71) for age-standardized DALYs (Table 1, Figure 1).

ASPR: age-standard rate of prevalence; ASDR age-standard rate of deaths; DALYs: disability-adjusted life years; SDI: sociodemographic index.

In 2021, the ASPR of HHD was notably higher in Africa, the Middle East, the Caribbean, Tropical Latin America, and East Asia. Eastern Sub-Saharan Africa topped the list with the highest ASPR at 291.8 per 100,000 people (95% UI: 224~375.4), closely followed by Western Sub-Saharan Africa with 266.3 per 100,000 people (95% UI: 206.7~342.2), the North Africa and Middle East with 243.3 per 100,000 (95% UI: 192.1~303.6). While the lowest ASPR was Eastern Europe with 42.8 per 100,000 (95% UI: 29.8~58.3) (Table 1, Figure 2A).

The top 3 highest ascending of ASPR from 1990 to 2021 were Western Europe, Australasia, and High-income North America with EAPC of 2.03 (95% CI: 1.73~2.33), 1.95 (95% CI: 1.84~2.06), and 1.94 (95% CI: 1.80~2.08), respectively. While the most decreased of ASPR were Central Latin America, East Asia, and Oceania with EAPC of -0.66 (95% CI: -0.72~-0.60), -0.63 (95% CI: -0.85~-0.40), and -0.37 (95% CI: -0.42~-0.31), respectively (Table 1, Figure 3A).

The ASDR and age-standardized rate of DALYs for HHD were mainly concentrated in sub-Saharan region, particularly Central, Southern, and Eastern Sub-Saharan Africa, with ASDR 66.3 (95% UI:42.2~92.9), 47.4 (95% UI:41.5~55.2), and 42.6 (95% UI:29.4~54.7) per 100,000 people, respectively; and age-standardized DALYs of 1,213.1 (95% UI:774,1~694.9), 889.1 (95% UI:785.1~1034.2), and 786.2 (95% UI:549.7~992.2) per 100,000 people (Table 1, Figure 2B-C).

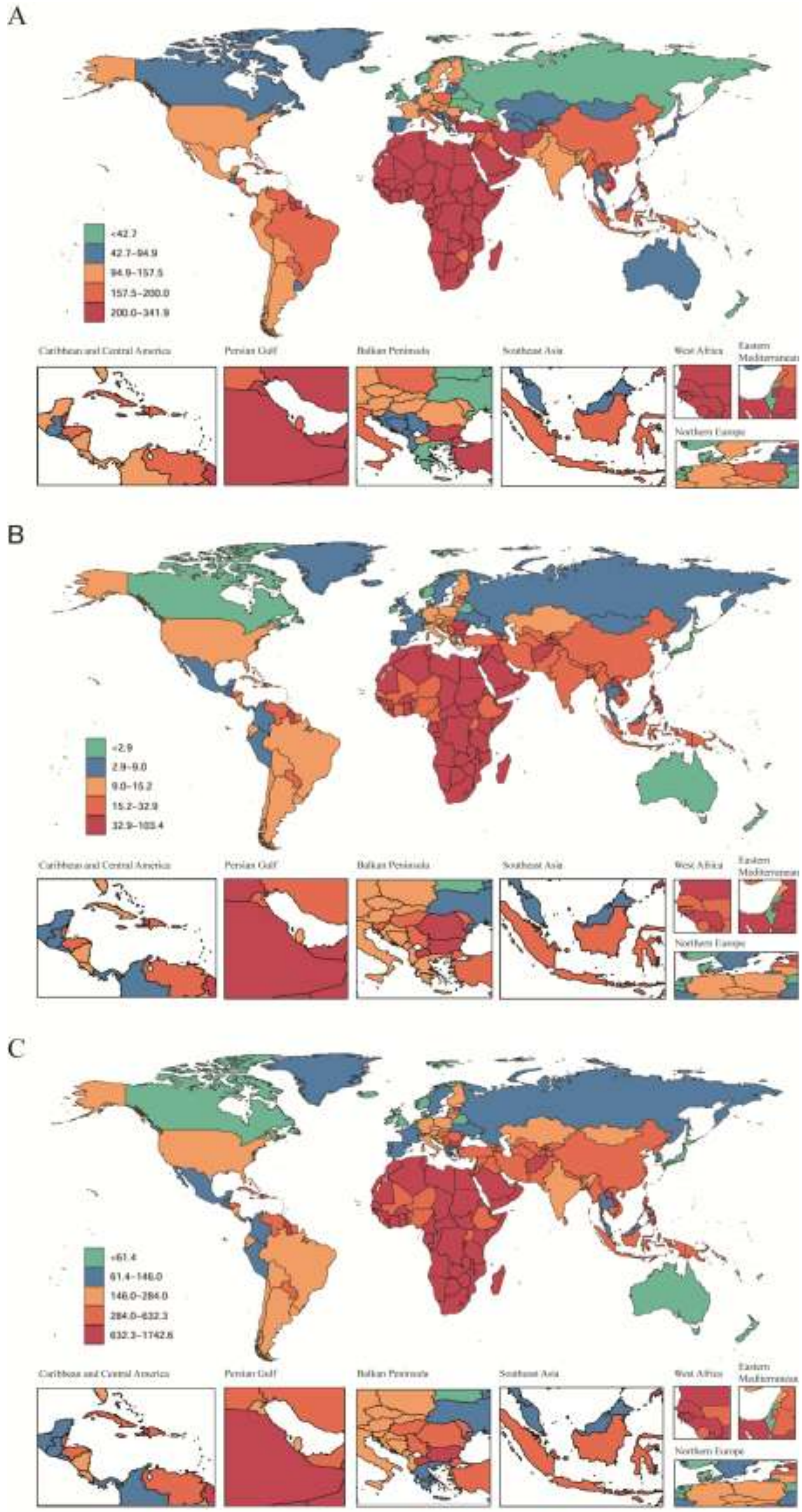


Figure2

**Figure 2: Disease burden of hypertension heart disease in 204 countries and territories in 2021.** (A) **ASPR. (B) ASDR. (C) age-standard rate of DALYs. ASPR: age-standard rate of prevalence; ASDR age-standard rate of deaths; DALYs: disability-adjusted life years.**

From 1990 to 2021, the ASDR for HHD in Eastern Europe experienced the largest rise, with EAPC of 1.72 (95% CI: 0.82~2.62), while, the High-income Asia Pacific experienced the most decreased, with EAPC of -3.64 (95% CI: -4.36 ~-2.91) (Table 1, Figure 3B). The age-standardized rate of HHD DALYs increased most in High-income North America (EAPC 1.81, (95% CI: 1.65~1.97)), while declined most in the High-income Asia Pacific (EAPC -3.63, (95% CI: -4.30~-2.95)) (Table 1, Figure 3C).

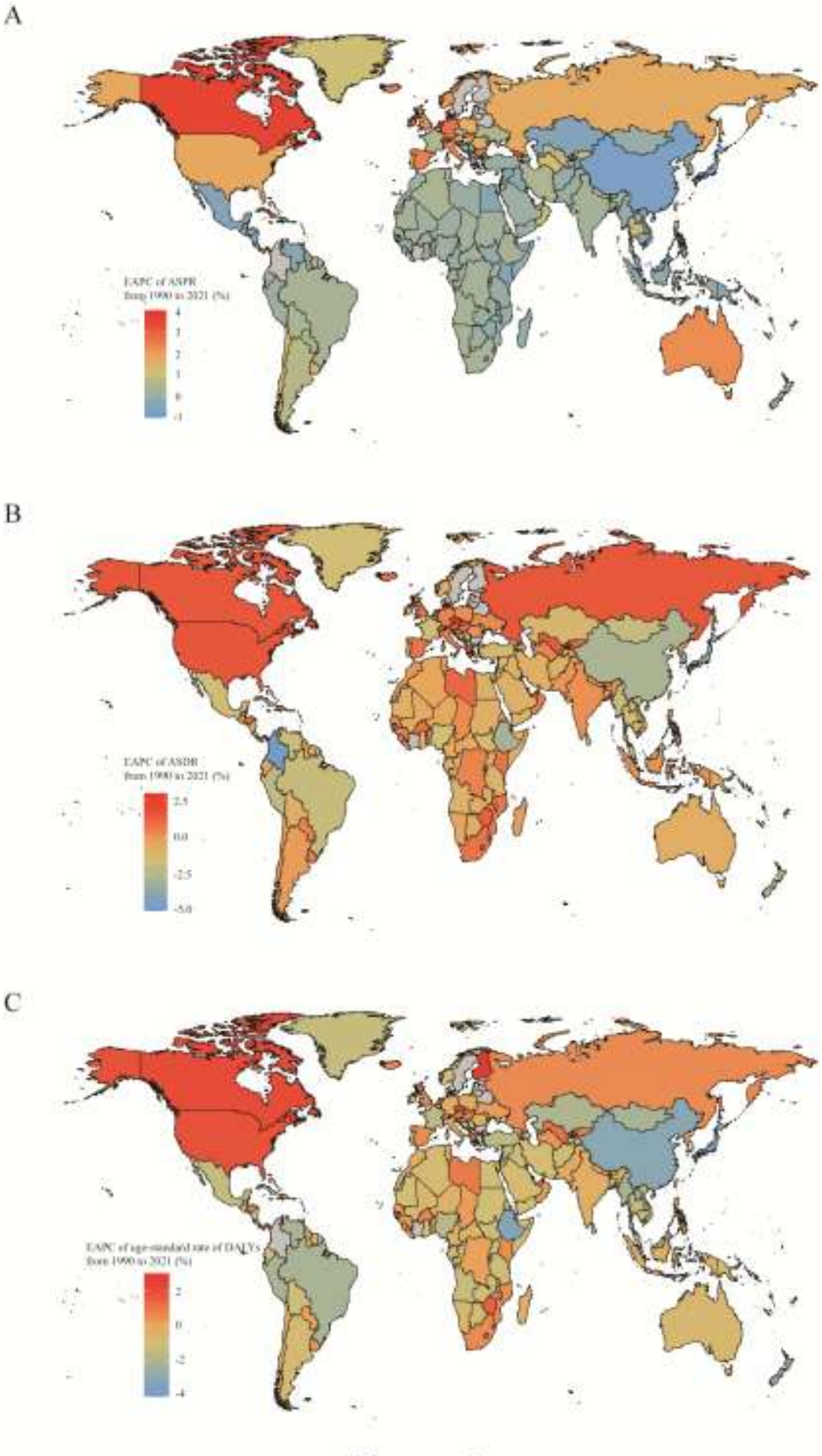


Figure 3

**Figure 3: EAPC of hypertension heart disease in 204 countries and territories from 1990 to 2021. (A) EAPC of ASPR. (B) EAPC of ASDR. (C) EAPC of age-standard rate of DALYs. EAPC: estimated annual percentage change; ASPR: age-standard rate of prevalence; ASDR age-standard rate of deaths; DALYs: disability-adjusted life years.**

### National Level

In 2021, the highest ASPR country for HHD were led by Jordan (Asia) with 341.9 per 100,000 people (95% UI: 268.8~427.8), followed by Bahamas (North America) with 329.9 per 100,000 people (95% UI: 257.4~428.2), and Cook Islands (South Pacific) with 317.5 per 100,000 people (95% UI: 252.2~402.5) (Figure 2A, Table 1), the lowest ASPR country was Belarus at 8.7 per 100,000 people (95% UI: 6~12). The largest change country for ASPR were both in Europe, most increase was Latvia with EAPC of 6.76 (95% CI: 6.16~7.38), most decrease was Belarus with EAPC of -3.77 (95% CI: -4.16~-3.37) (Figure 3A). The highest ASDR was Bulgaria (Europe) with 103.4 per 100,000 people (95% UI: 89.6~116.4), followed by Afghanistan (Asia) with 78.3 per 100,000 people (95% UI: 43.8~115), and Madagascar (Africa) with 77.6 per 100,000 people (95% UI: 50.8~108.5). Belarus had the lowest ASDR at 1.1 per 100,000 people (95% UI: 0.9~1.3). Latvia showed the largest increase in ASDR with EAPC of 8.6 (95% CI: 7.36~9.86), while Belarus had the largest decrease with EAPC of -5.67 (95% CI: -6.74~-4.59) (Figure 3B). The top listed age-standardized DALYs were Bulgaria (Europe) with 739.3 per 100,000 population (95% UI: 1494~1984.7), followed by Lesotho (Africa) with 1524.5 per 100,000 population (95% UI: 835.4~2159.8), and Madagascar (Africa) with 1509 per 100,000 population (95% UI: 999.7~2082.2). Belarus had the lowest age-standardized DALYs at 25 per 100,000 people (95% UI: 20.7~31). Latvia recorded the highest increase in age-standardized DALYs for HHD with EAPC of 6.97 (95% CI: 5.82~8.13), while Belarus had the lowest with an EAPC of -5.8 (95% CI: -6.91 to -4.68) (Figure 3C).

As observed above, the prevalence and ASPR of HHD were on the rise, while deaths, DALYs, ASDR and age-standard rate of DALYs were on the downside. This could be attributed to heightened public awareness and enhanced detection and management strategies of HHD. However, the disease burden exhibits regional disparities, with the most significant impact noted in low SDI region and the least in high SDI region. Over the past three decades, an intriguing pattern has emerged: the burden in high SDI region was increasing while other SDI regions were declined, with the most pronounced decrease in middle SDI region. At the national level, the ASPR, ASDR, and age-standardized DALYs of HHD are predominantly found in regions such as Africa and the Middle East in 2021. Interestingly, the highest values for these metrics are not observed in Africa but in Asia for ASPR, and in Europe for both ASDR and age-standardized DALYs. And the country with highest EAPC also located in Europe.

### Age and Gender Patterns

In 2021, the global ASPR for HHD increasing with age, Sudden increasing at 60-64 years and peaking at 95+ years. Initially, women had a lower ASPR than men, but reversed after the age of 80, with women showing a higher ASPR, women peaking at 95+years, men at 90-94 years (Figure 4A). The ASDR for HHD also increased with age, peaking at 95+ years. At the age of 15-19 years, the ASDR of women exceeded than men, then declined and again higher than men at the age of 90, peaking age at 95+ years for both men and women (Figure 4B). The age-standardized DALYs for HHD followed a pattern similar to the ASDR, with peaks at 95+ years. Females had higher age-standardized DALYs than males in the 15-19 age group, then decreased, and higher again after the age of 65, with a temporary dip in the 85-89 age group. The peak age for both sexes was 95+ years (Figure 4C).

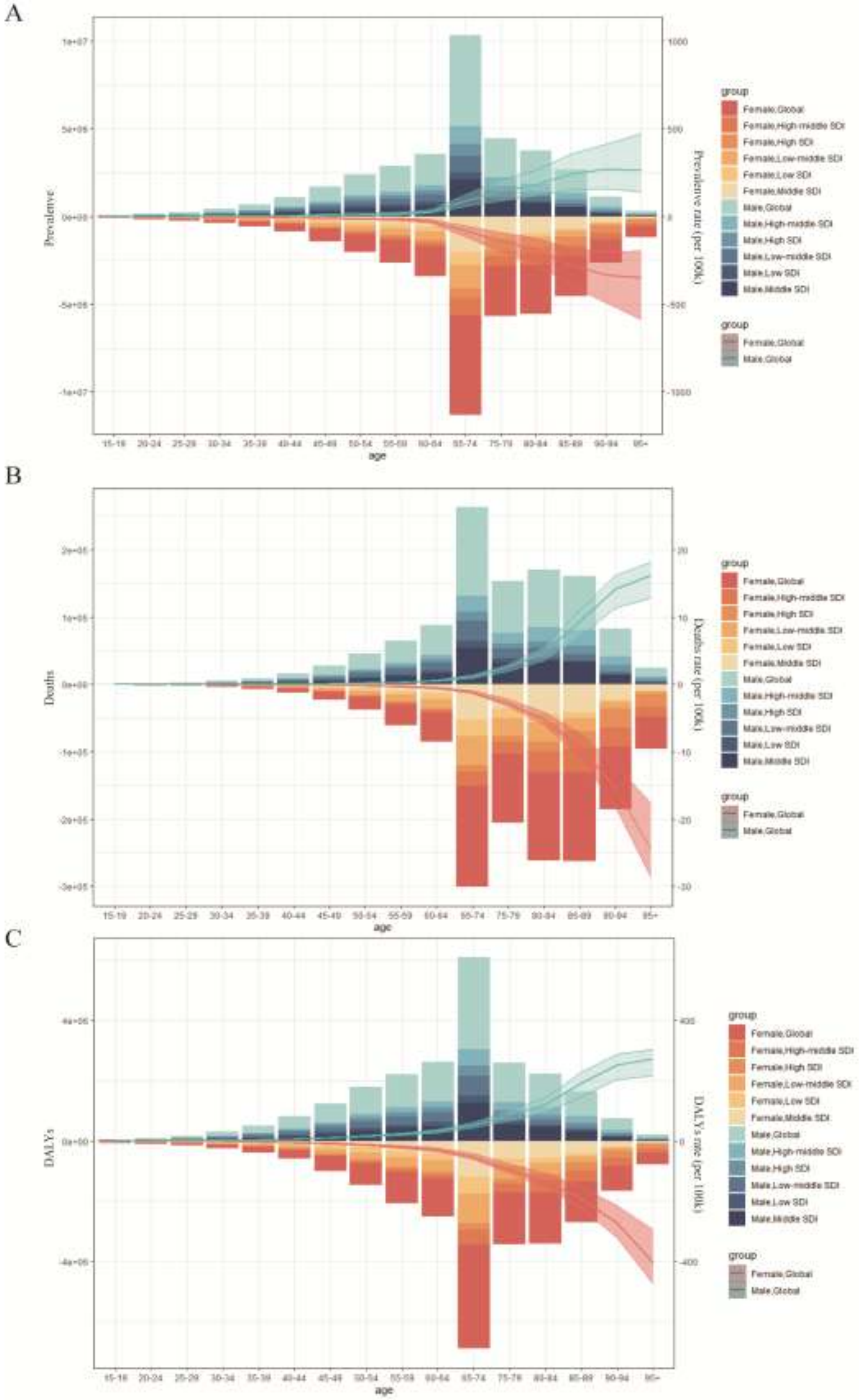


Figure 4

**Figure4：Age-specific cases and rates of hypertension heart disease by sex in global and SDI regions in 2021. (A) Age-specific cases and rates of prevalence. (B) Age-specific cases and rates of deaths. (C) Age-specific cases and rate of DALYs. SDI: sociodemographic index; DALYs: disability-adjusted life years.**

The global ASPR was higher than 1990 both sex at all ages (Figure 5), while the ASDR and age-standardized DALYs rate were higher than 1990 for both sexes over 90 years (Figure S1, Figure S2).

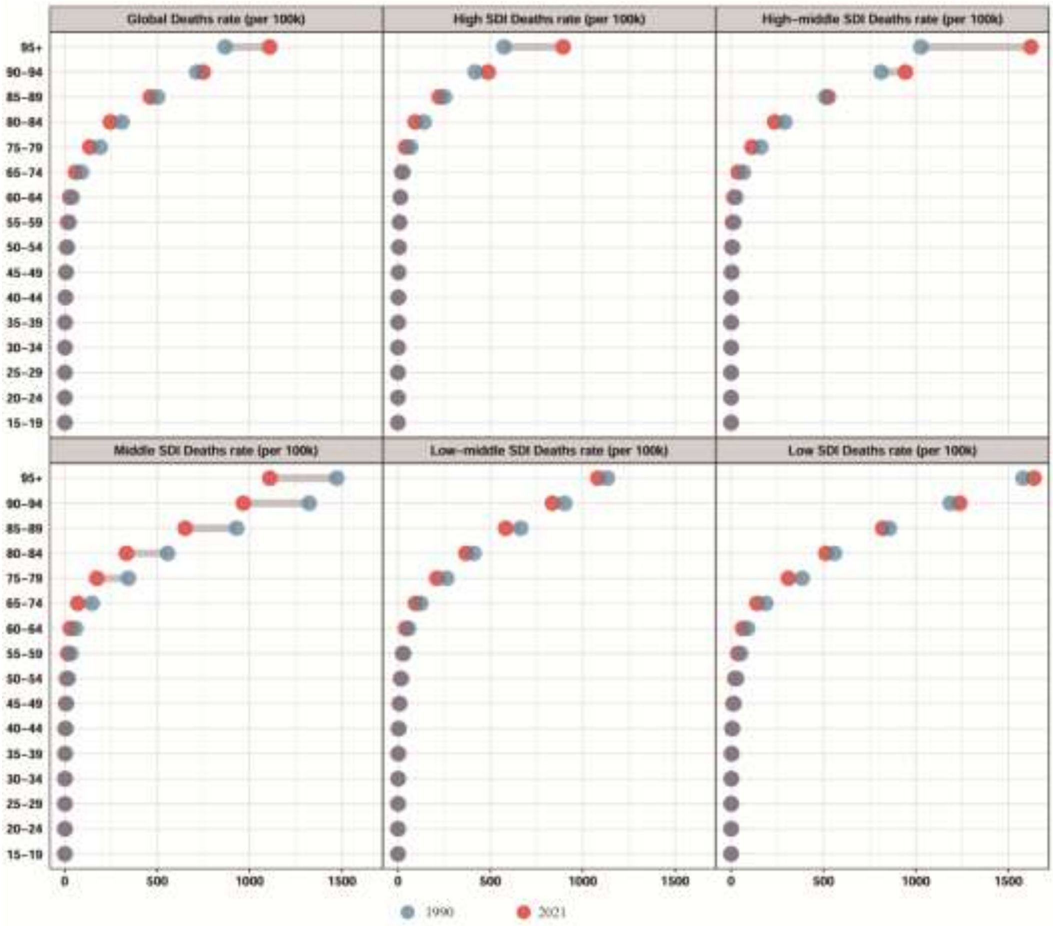


Figure S1

**Figure S1: ASDR of hypertension heart disease by sex, age group in global and SDI regions in 1990 and 2021.**
**ASDR: age-standard rate of deaths; SDI: sociodemographic index.**

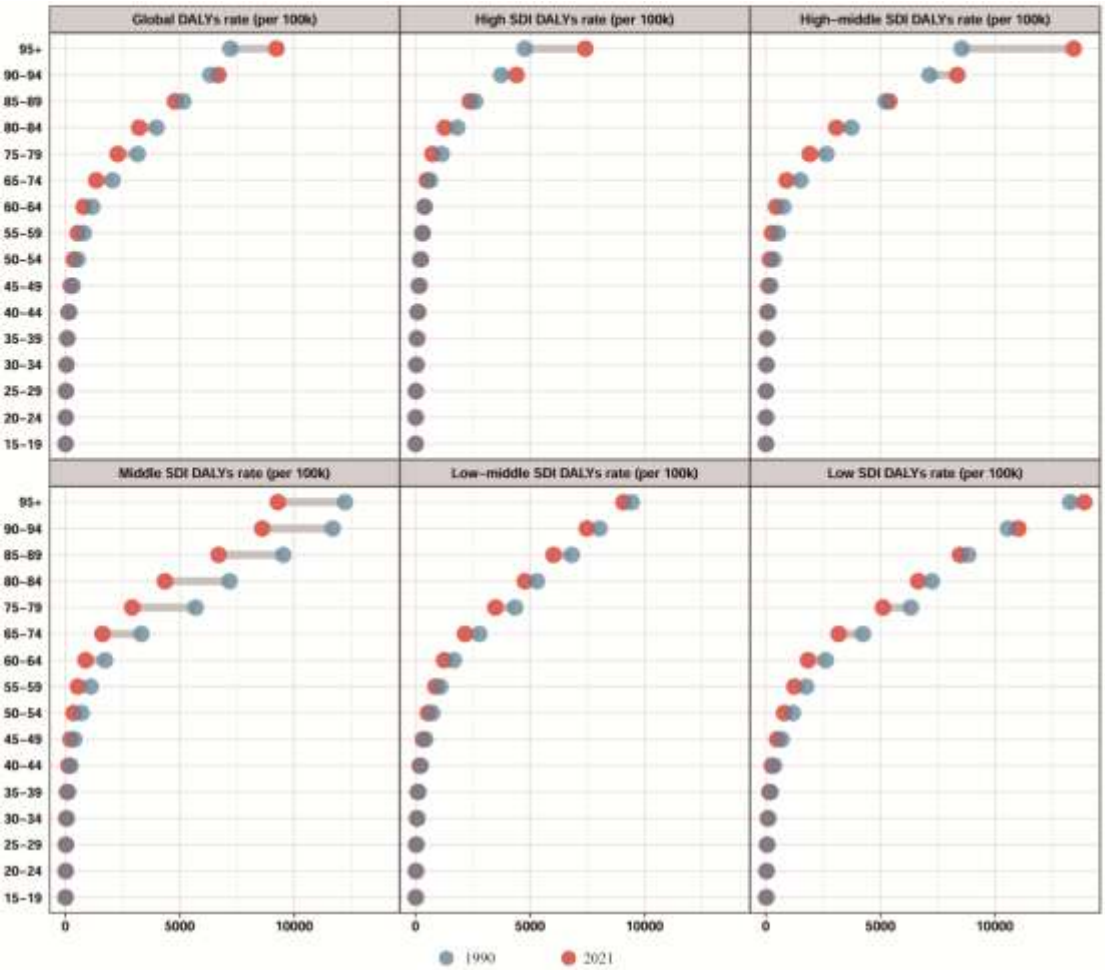


Figure S2

**Figure S2: age-standard rate of DALYs of hypertension heart disease by sex, age group in global and SDI regions in 1990 and 2021.**
**DALYs: disability-adjusted life years; SDI: sociodemographic index.**

For different SDI regions, expect the ASPR peaking at 90-94 years in middle SDI region, other SDI regions all peaking at ages 95 (Figure 4A). The ASDR and age-standard rate of DALYs rate peak age at 95+ years in all SDI regions (Figure 4B-C). The ASPR at all age groups in low-middle SDI region, high-middle SDI region and high SDI region has increased compared to 1990, While except the 60-89 years in middle SDI region and 65-79 years in low SDI region, the ASPR of other age group has rising compared to 1990 (Figure 5).

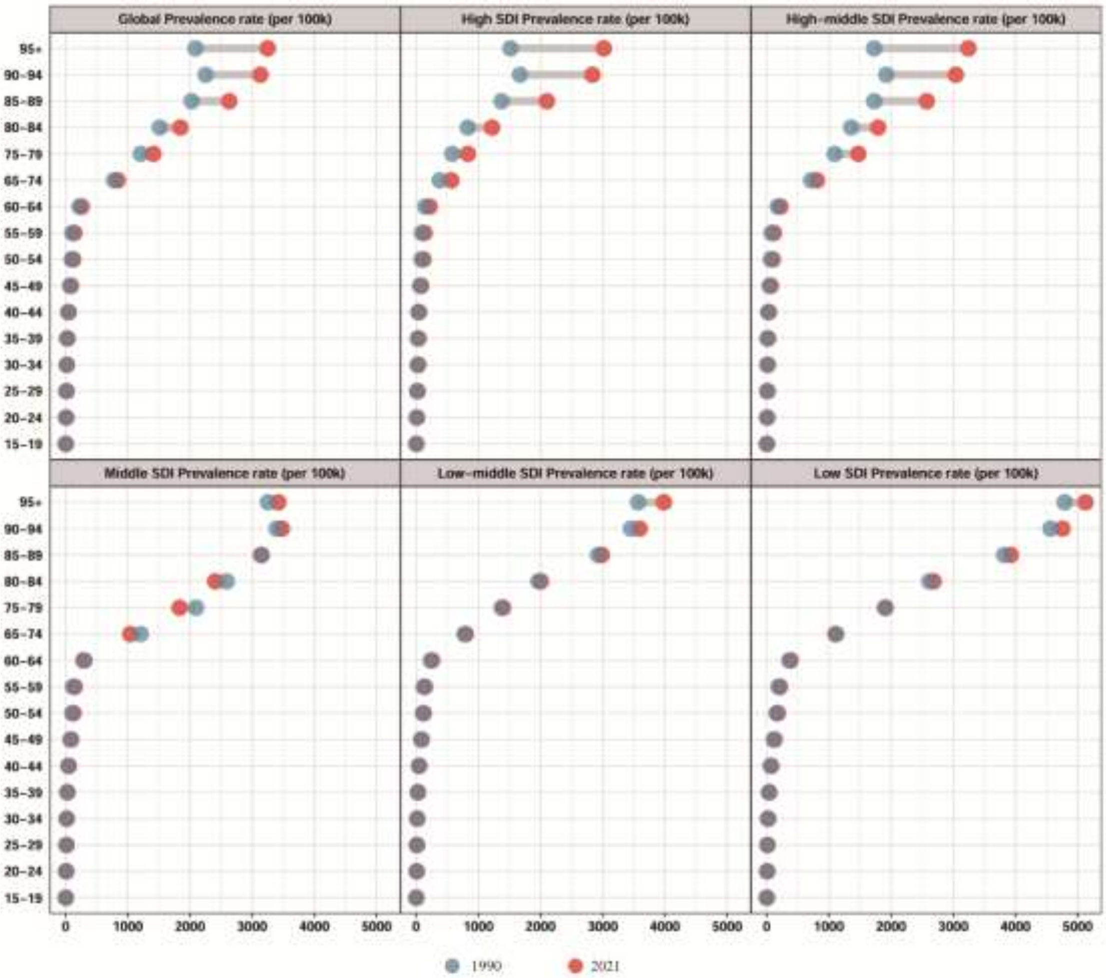


Figure 5

**Figure5: ASPR of hypertension heart disease by sex, age group in global and SDI regions in 1990 and 2021.**
**ASPR: age-standard rate of prevalence; SDI: sociodemographic index.**

The age of 65-89 years in high SDI, 15-84 years in high-middle SDI region, 15-89 years in low SDI, all age group in middle and low-middle SDI region of ASDR and age-standard rate of DALYs rate showed a downward trend when comparing to 1990 (Figure S1, Figure S2).

### Risk Factors for HHD

Our research analyzed 14 distinct risk factors of deaths and DALYs associated with HHD classified by the GBD 2021 study and further divided by divided by geographical region (Figure 6).

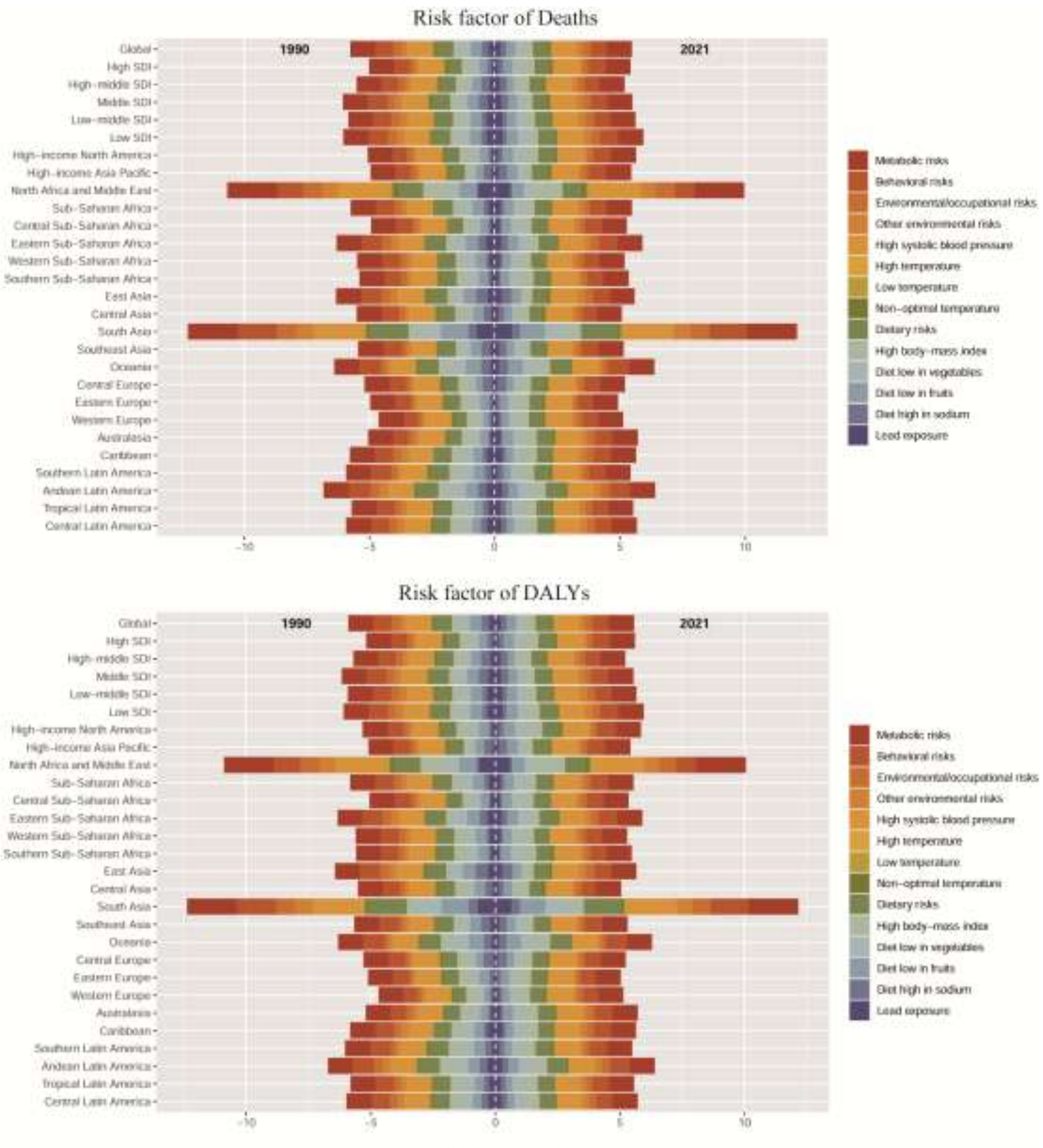


Figure 6

**Figure 6: Risk factors in deaths and DALYs of hypertension heart disease in global and regional in 2021. (A) risk factors in deaths. (B) risk factors in DALYs. DALYs: disability-adjusted life years.**

In 2021, high systolic blood pressure and metabolic risks were the predominant contributors to deaths and DALYs of HHD, responsible for over 99% of the total burden, whereas behavioral risk and dietary risk accounted for approximately more than 60%. For different gender, the proportion of deaths and DALYs for risk factors in men had a slight preponderance compared to women. For different age, Certain risk factors, such as behavioral risk, low fruit and vegetable consumption, and high body mass index, were more common in younger individuals in 25-49 years（Figure S3）.

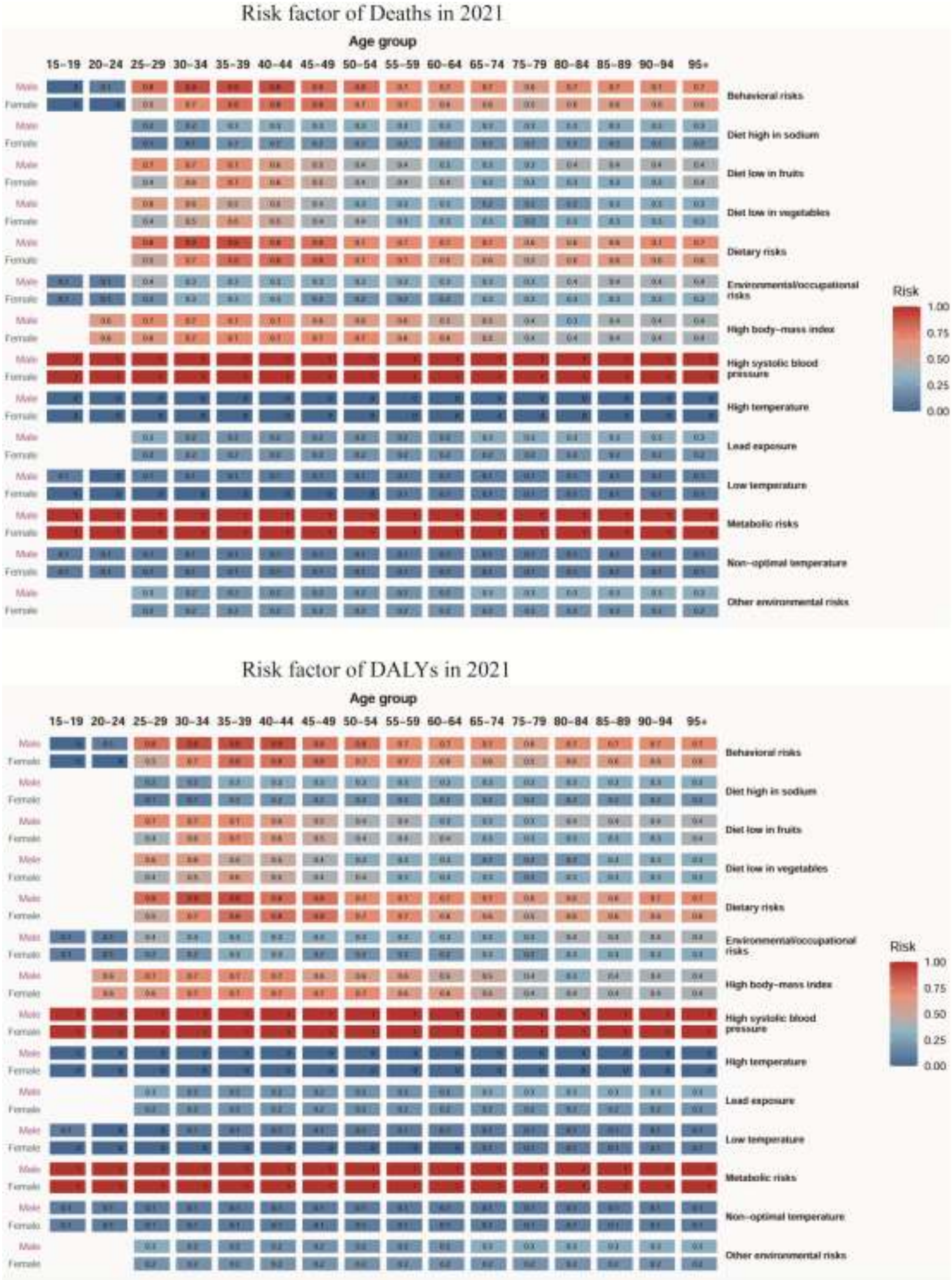


Figure S3

**Figure S3: Risk factors in deaths and DALYs of hypertension heart disease by sex and age group in global in 2021.**
**DALYs: disability-adjusted life years.**

Comparing to 1990, the risk factors for deaths and DALYs of HHD increased were high temperature and high body mass index, with high body mass index showing the most significant rise at both around 11%. While the steepest declined of risk factor was low vegetable intake, dropping by 11% and 16.9% respectively.

For different SDI regions, most of the risk factors accounted for highest percentage in the low SDI region than in the other SDI regions, such as

Behavioral risks, Dietary risks, Diet low in vegetables, Diet low in fruits, while the risk factors of high body mass index and high temperature occupied the first place in the high SDI. Compared to 1990, the most increased of deaths and DALYs of risk factors was High body-mass index among theses regions. The most risk factors of HHD showed a decreasing trend in Low SDI region, Low-middle SDI region, and middle SDI region, while showed an increasing trend in High SDI region and High-middle SDI region (Figure 6).

In national level, some risk factors of HHD in deaths and DALYs ranked first in Oceania, such as Diet low in vegetables, Diet low in fruits, Dietary risks, behavioral risks; Environmental/ occupational risks、Lead exposure、other environmental risks were top first in South Asia; high body mass index in High-income North America reached top list. Compared to 1990, high body mass index was the most increased in many regions, while the risk factors of some areas showed increased such as Australasia、Central Sub-Saharan Africa、High-income Asia Pacific 、High-income North America, while risk factors in areas such as Andean Latin America、Eastern Europe、Sub-Saharan Africa、Western Sub-Saharan Africa showed decreased(Figure 6).

**Future Projection for Global HHD**

We projected future disease burden of global HHD from 2022 to 2050 to foreseen future trend of the disease. The ASPR in global of HHD is expected to rise, increasing from 148.3 per 100,000 in 2021 to 160.9 per 100,000 by 2050, marking an approximate 8.5% growth. While the ASPR among females is expected to remain stable, with a modest rise from 146.6 to 151.9 per 100,000 (3.6% increase), males are projected to experience a more pronounced increase, from 148.9 to 172.3 per 100,000 (15.7% increase) (Figure 7A). The ASDR and age-standard DALYs for HHD are forecasted to decline over the next three decades. The ASDR is predicted to drop from 16.3 per 100,000 in 2021 to 12.4 per 100,000 by 2052, a reduction of 23.9%. For females, this decline is slightly less pronounced, decreasing from 16.5 to 12.8 per 100,000 (22.4% reduction), while for males, the rate is expected to fall more significantly, from 15.9 to 11.8 per 100,000 (25.7% decrease) (Figure 7B). The age-standardized DALYs for HHD will decrease from 301.6 per 100,000 in 2021 to 235.8 per 100,000 by 2050, a 21.8% reduction. For females, this decrease is slightly less at 19.8%, from 299.3 to 240.1 per 100,000, and for males, it is slightly more at 23.5%, from 301.4 to 230.5 per 100,000 by 2050 (Figure 7C). The projected data suggest that while the ASPR of HHD is expected to rise, the growth rate will be considerably slower than in the past three decades, and there will be a notable decrease in both ASDR and age-standardized DALYs, indicating a significant improvement in the management and outcomes of HHD in the future.

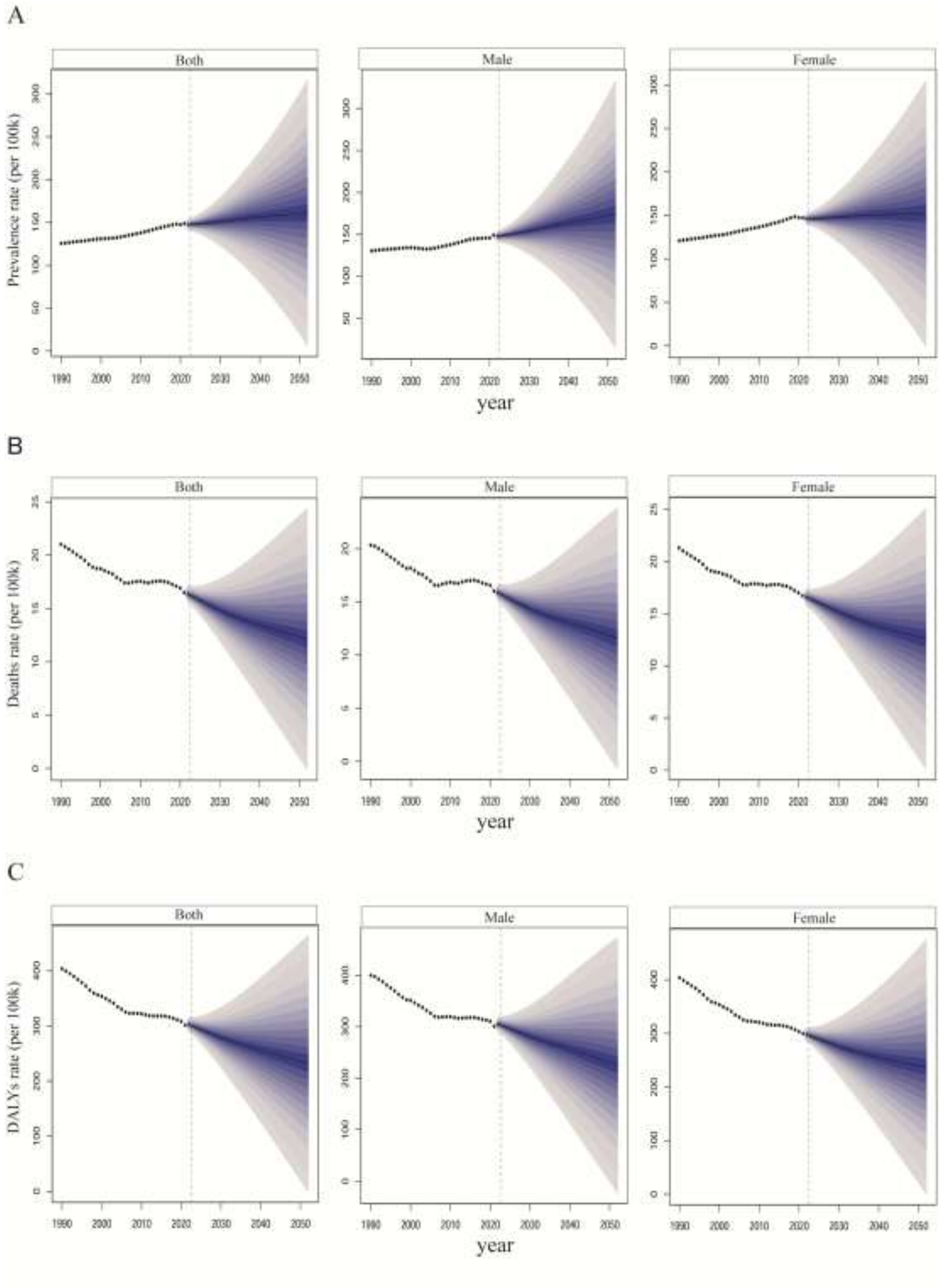


Figure 7

**Figure7: Future forecasts for hypertension heart disease in global from 2022 to 2050. (A) Future forecasts for ASPR. (B) Future forecasts for ASDR. (C) age-standard rate of DALYs. ASPR: age-standard rate of prevalence; ASDR age-standard rate of deaths; DALYs: disability-adjusted life years.**

**Discussion**

Our analysis of the global HHD burden from 1990–2021 reveals a paradoxical trend: while ASDR and DALY rates declined, absolute prevalence surged by 170%, underscoring the complex interplay of aging populations, metabolic risks, and persistent healthcare inequities. These findings align with recent GBD reports but extend prior insights by integrating post-pandemic data and forecasting trajectories to 2050[12, 25]. Three critical themes emerge from our results.

First, the shifting risk factor landscape demands region-specific interventions. High systolic blood pressure and metabolic risks remain the dominant contributor to HHD (99% attributable risk), yet high body mass index's role has escalated globally of death and DALYs, particularly in high SDI region, nearly 11% increase since 1990[9, 14]. This mirrors recent cohort studies demonstrating that obesity-mediated endothelial dysfunction and insulin resistance amplify cardiac remodeling independent of hypertension severity[10]. In contrast, low-SDI regions face compounded burdens from underdiagnosed hypertension and environmental risks (e.g., air pollution, limited greenspace), with fewer than 15% achieving blood pressure control—a disparity exacerbated by COVID-19 healthcare disruptions[13, 17]. These findings emphasize the urgency of tailored strategies: metabolic risk mitigation in high-SDI settings versus hypertension screening and salt-reduction policies in low-resource areas[11].

Second, aging populations drive irreversible burdens. The ASPR peak at ≥95 years reflects cumulative exposure to hypertension and age-related arterial stiffening—a phenomenon exacerbated by rising global life expectancy[26]. Notably, women surpass men in HHD prevalence after age 80, likely due to postmenopausal vascular dysfunction and longevity bias[27]. Recent proteomic studies suggest that aging-associated biomarkers (e.g., galectin-3, GDF-15) may accelerate hypertensive cardiomyopathy, presenting novel therapeutic targets[23, 28]. However, our projections indicate a 15.7% ASPR rise in males by 2050, possibly linked to younger-onset obesity and delayed healthcare-seeking behavior—a trend corroborated by sex-stratified analyses in the EURObservational Research Programme[29].

Third, SDI stratification reveals stark inequities. Low-SDI regions bear 2.5-fold higher ASPR than high-SDI nations, yet paradoxically exhibit declining ASDR due to competing mortality from infectious diseases and limited diagnostic capacity[15]. Eastern Sub-Saharan Africa's disproportionate burden (ASPR 291.8/100,000) reflects systemic underinvestment: hypertension treatment coverage remains below 25% in 18 African nations, versus >70% in high-income countries[16, 30]. Conversely, high-SDI regions face rising burdens from obesogenic environments and sedentary lifestyles, with the U.S. and Australia showing the steepest ASPR increases (EAPC >1.9) [31, 32]. These disparities mirror 2023 WHO reports highlighting that <10% of low-income countries have functional HHD registries versus 90% of high-income nations[33].

Our projections to 2050 suggest cautious optimism: ASDR may decline by 23.9% globally, reflecting improved antihypertensive therapies and heart failure management[34]. However, the 8.5% ASPR rise—particularly among men—signals an impending wave of HFpEF cases, demanding proactive measures. Recent trials (e.g., EMPEROR-Preserved, DELIVER) demonstrate SGLT2 inhibitors' efficacy in HHD-related HFpEF, advocating for broader access[35]. Additionally, AI-driven telehealth platforms show promise for hypertension control in rural areas, achieving 40% BP control rates in pilot African studies[36].

## Limitation

While this study provides a comprehensive analysis of HHD burden using GBD 2021 data, several limitations warrant consideration. First, the accuracy of estimates relies on the quality and representativeness of underlying data, which vary substantially across regions. For example, 23% of sub-Saharan African countries lacked recent population-level cardiovascular surveys, necessitating heavy reliance on modeling imputation—a limitation highlighted in recent critiques of GBD methods[25]. Conflict-affected regions (e.g., Yemen, Syria) and small island nations (e.g., Pacific Island states) exhibited wider uncertainty intervals (>40% UI range), potentially underestimating true burdens due to fragmented health systems[37, 38].

Second, risk factor projections assumed static post-2021 exposures, overlooking emerging threats like climate change-induced heat stress and pandemic-related physical inactivity—factors shown to elevate hypertension risk in recent cohort studies[39, 40]. Similarly, our analysis excluded genetic predispositions (e.g., APOL1 variants prevalent in African populations), which account for 15–20% of early-onset HHD in low-SDI regions[41, 42].

**Conclusion**

This 30-year global analysis reveals a dual reality in hypertensive heart disease (HHD): declining age-standardized mortality (-0.68% annually) contrasts sharply with a 170% surge in absolute prevalence, fueled by aging populations and metabolic risks. Stark disparities persist, with low-SDI regions bearing the highest burden (ASPR 208.4/100,000) due to underdiagnosed hypertension, while high-SDI nations face escalating obesity-driven HHD (11% rise since 1990). Projections to 2050 signal cautious optimism—ASDR and DALYs may decline by 23.9% and 21.8%, respectively—but an 8.5% ASPR rise, particularly among men, heralds a growing HFpEF epidemic.

Urgent action requires context-specific strategies: scaling hypertension screening and salt-reduction policies in low-resource settings, and combating obesogenic environments in affluent nations. Integrating SGLT2 inhibitors and AI-driven telehealth could mitigate disparities. Addressing data gaps in conflict zones and genetic risks remains critical. These multidimensional efforts are essential to align global progress with equitable cardiovascular health outcomes.

**Funding**

This work was supported by the National Natural Science Foundation of China (No. 82272602 to H Lin), the National Natural Science Foundation Youth Program of China
(No. 82100407 to H Lin), GuangDong Basic and Applied Basic Research Foundation (No.2024A1515010366 to H Lin), the National China Postdoctoral Science Foundation (No.2021M690074, 2022T150297 to H Lin)

**Conflicts of Interest**

None.

**Data Availability Statements**

The data underlying this article are available in Global Burden of Disease (GBD) 2021, at https://vizhub.healthdata.org/gbd-results/.

**References**

1. Nwabuo CC, Vasan RS: Pathophysiology of Hypertensive Heart Disease: Beyond Left Ventricular Hypertrophy. Curr Hypertens Rep 2020, 22(2):11.
2. Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, Barengo NC, Beaton AZ, Benjamin EJ, Benziger CP et al: Global Burden of Cardiovascular Diseases and Risk Factors, 1990-2019: Update From the GBD 2019 Study. J Am Coll Cardiol 2020, 76(25):2982-3021.
3. Bragazzi NL, Zhong W, Shu J, Abu Much A, Lotan D, Grupper A, Younis A, Dai H: Burden of heart failure and underlying causes in 195 countries and territories from 1990 to 2017. Eur J Prev Cardiol 2021, 28(15):1682-1690.
4. Lawson CA, Zaccardi F, Squire I, Okhai H, Davies M, Huang W, Mamas M, Lam CSP, Khunti K, Kadam UT: Risk Factors for Heart Failure: 20-Year Population-Based Trends by Sex, Socioeconomic Status, and Ethnicity. Circ Heart Fail 2020, 13(2):e006472.
5. Lu M, Li D, Hu Y, Zhang L, Li Y, Zhang Z, Li C: Persistence of severe global inequalities in the burden of Hypertension Heart Disease from 1990 to 2019: findings from the global burden of disease study 2019. BMC Public Health 2024, 24(1):110.
6. Diez J, Butler J: Growing Heart Failure Burden of Hypertensive Heart Disease: A Call to Action. Hypertension 2023, 80(1):13-21.
7. Tadic M, Cuspidi C, Plein S, Milivojevic IG, Wang DW, Grassi G, Mancia G: Comprehensive assessment of hypertensive heart disease: cardiac magnetic resonance in focus. Heart Fail Rev 2021, 26(6):1383-1390.
8. Rossi VA, Laptseva N, Nebunu D, Haider T, Nagele MP, Ruschitzka F, Sudano I, Flammer AJ: Impaired retinal micro-vascular function in patients with atrial fibrillation. Int J Cardiol 2024, 398:131592.
9. Faulkner JL: Obesity-associated cardiovascular risk in women: hypertension and heart failure. Clin Sci (Lond) 2021, 135(12):1523-1544.
10. Masenga SK, Kirabo A: Hypertensive heart disease: risk factors, complications and mechanisms. Front Cardiovasc Med 2023, 10:1205475.
11. Carey RM, Muntner P, Bosworth HB, Whelton PK: Prevention and Control of Hypertension: JACC Health Promotion Series. J Am Coll Cardiol 2018, 72(11):1278-1293.
12. Liu AB, Lin YX, Meng TT, Tian P, Chen JL, Zhang XH, Xu WH, Zhang Y, Zhang D,

Zheng Y et al: Global prevalence and disability-adjusted life years of hypertensive heart disease: A trend analysis from the Global Burden of Disease Study 2019. J Glob Health 2024, 14:04172.
13. Ouma PO, Maina J, Thuranira PN, Macharia PM, Alegana VA, English M, Okiro EA, Snow RW: Access to emergency hospital care provided by the public sector in sub-Saharan Africa in 2015: a geocoded inventory and spatial analysis. Lancet Glob Health 2018, 6(3):e342-e350.
14. Schutte AE, Jafar TH, Poulter NR, Damasceno A, Khan NA, Nilsson PM, Alsaid J, Neupane D, Kario K, Beheiry H et al: Addressing global disparities in blood pressure control: perspectives of the International Society of Hypertension. Cardiovasc Res 2023, 119(2):381-409.
15. Yang R, Zhang X, Bai J, Wang L, Wang W, Cai J: Global, regional, and national burden of hypertensive heart disease among older adults in 204 countries and territories between 1990 and 2019: a trend analysis. Chin Med J (Engl) 2023, 136(20):2421-2430.
16. Mills KT, Bundy JD, Kelly TN, Reed JE, Kearney PM, Reynolds K, Chen J, He J: Global Disparities of Hypertension Prevalence and Control: A Systematic Analysis of Population-Based Studies From 90 Countries. Circulation 2016, 134(6):441-450.
17. Collaboration NCDRF: Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019: a pooled analysis of 1201 population-representative studies with 104 million participants. Lancet 2021, 398(10304):957-980.
18. Tuo Y, Li Y, Li Y, Ma J, Yang X, Wu S, Jin J, He Z: Global, regional, and national burden of thalassemia, 1990-2021: a systematic analysis for the global burden of disease study 2021. EClinicalMedicine 2024, 72:102619.
19. Collaborators GBDRF: Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet 2024, 403(10440):2162-2203.
20. Li XY, Kong XM, Yang CH, Cheng ZF, Lv JJ, Guo H, Liu XH: Global, regional, and national burden of ischemic stroke, 1990-2021: an analysis of data from the global burden of disease study 2021. EClinicalMedicine 2024, 75:102758.
21. Stevens GA, Paciorek CJ, Flores-Urrutia MC, Borghi E, Namaste S, Wirth JP, Suchdev PS, Ezzati M, Rohner F, Flaxman SR et al: National, regional, and global estimates of anaemia by severity in women and children for 2000-19: a pooled analysis of population-representative data. Lancet Glob Health 2022, 10(5):e627-e639.
22. Senn S: Mastering variation: variance components and personalised medicine. Stat Med 2016, 35(7):966-977.
23. Guo J, Riebler A, Rue H: Bayesian bivariate meta-analysis of diagnostic test studies with interpretable priors. Stat Med 2017, 36(19):3039-3058.
24. Mathew G, Agha R, Albrecht J, Goel P, Mukherjee I, Pai P, D'Cruz AK, Nixon IJ, Roberto K, Enam SA et al: STROCSS 2021: Strengthening the reporting of cohort, cross-sectional and case-control studies in surgery. Int J Surg 2021, 96:106165.
25. Diseases GBD, Injuries C: Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet 2024, 403(10440):2133-2161.
26. Pajewski NM, Donohue MC, Raman R, Espeland MA: Ascertainment and Statistical Issues for Randomized Trials of Cardiovascular Interventions for Cognitive Impairment and Dementia. Hypertension 2024, 81(1):45-53.
27. Ghazi L, Annabathula RV, Bello NA, Zhou L, Stacey RB, Upadhya B: Hypertension Across a Woman's Life Cycle. Curr Hypertens Rep 2022, 24(12):723-733.
28. de Boer RA, van der Velde AR, Mueller C, van Veldhuisen DJ, Anker SD, Peacock WF, Adams KF, Maisel A: Galectin-3: a modifiable risk factor in heart failure. Cardiovasc Drugs Ther 2014, 28(3):237-246.
29. Corrigendum to 'Weight change and clinical outcomes in heart failure with reduced ejection fraction: Insights from EMPEROR-Reduced' [Eur J Heart Fail 2023;25:117-127].

Eur J Heart Fail 2023, 25(6):924.
30. Ataklte F, Erqou S, Kaptoge S, Taye B, Echouffo-Tcheugui JB, Kengne AP: Burden of undiagnosed hypertension in sub-saharan Africa: a systematic review and meta-analysis. Hypertension 2015, 65(2):291-298.
31. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, Mullany EC, Biryukov S, Abbafati C, Abera SF et al: Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2014, 384(9945):766-781.
32. Collaborators GBDO, Afshin A, Forouzanfar MH, Reitsma MB, Sur P, Estep K, Lee A, Marczak L, Mokdad AH, Moradi-Lakeh M et al: Health Effects of Overweight and Obesity in 195 Countries over 25 Years. N Engl J Med 2017, 377(1):13-27.
33. Kario K, Okura A, Hoshide S, Mogi M: The WHO Global report 2023 on hypertension warning the emerging hypertension burden in globe and its treatment strategy. Hypertens Res 2024, 47(5):1099-1102.
34. Ostrominski JW, Hirji S, Bhatt AS, Butler J, Fiuzat M, Fonarow GC, Heidenreich PA, Januzzi JL, Jr., Lam CSP, Maddox TM et al: Cost and Value in Contemporary Heart Failure Clinical Guidance Documents. JACC Heart Fail 2022, 10(1):1-11.
35. Anker SD, Butler J, Filippatos G, Ferreira JP, Bocchi E, Bohm M, Brunner-La Rocca HP, Choi DJ, Chopra V, Chuquiure-Valenzuela E et al: Empagliflozin in Heart Failure with a Preserved Ejection Fraction. N Engl J Med 2021, 385(16):1451-1461.
36. Muiruri C, Manavalan P, Jazowski SA, Knettel BA, Vilme H, Zullig LL: Opportunities to Leverage Telehealth Approaches Along the Hypertension Control Cascade in Sub-Saharan Africa. Curr Hypertens Rep 2019, 21(10):75.
37. Negin J, Martiniuk A: Sector wide approaches for health in small island states: lessons learned from the Solomon Islands. Glob Public Health 2012, 7(2):137-148.
38. Ugalde A, Selva-Sutter E, Castillo C, Paz C, Canas S: Conflict and health: The health costs of war: can they be measured? Lessons from El Salvador. BMJ 2000, 321(7254):169-172.
39. Ebi KL, Capon A, Berry P, Broderick C, de Dear R, Havenith G, Honda Y, Kovats RS, Ma W, Malik A et al: Hot weather and heat extremes: health risks. Lancet 2021, 398(10301):698-708.
40. Stockwell S, Trott M, Tully M, Shin J, Barnett Y, Butler L, McDermott D, Schuch F, Smith L: Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: a systematic review. BMJ Open Sport Exerc Med 2021, 7(1):e000960.
41. Genovese G, Friedman DJ, Ross MD, Lecordier L, Uzureau P, Freedman BI, Bowden DW, Langefeld CD, Oleksyk TK, Uscinski Knob AL et al: Association of trypanolytic ApoL1 variants with kidney disease in African Americans. Science 2010, 329(5993):841-845.
42. Freedman BI, Limou S, Ma L, Kopp JB: APOL1-Associated Nephropathy: A Key Contributor to Racial Disparities in CKD. Am J Kidney Dis 2018, 72(5 Suppl 1):S8-S16.