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ORIGINAL RESEARCH

Rheumatic Heart Disease Is a Neglected Disease Relative to Its Burden Worldwide: Findings From Global Burden of Disease 2019

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BACKGROUND: Rheumatic heart disease (RHD) takes a heavy toll in low- and middle-income countries. We aimed to present worldwide estimates for the burden of the RHD during 1990 to 2019 using the GBD (Global Burden of Disease) study.

METHODS AND RESULTS: Sociodemographic index (SDI) and age-period-cohort analysis were used to assess inequity. The age-standardized death, disability-adjusted life years, incidence, and prevalence rates of RHD were 3.9 (95% uncertainty interval, 3.3–4.3), 132.9 (95% uncertainty interval, 115.0–150.3), 37.4 (28.6–46.7), and 513.7 (405.0–636.3) per 100 000 in 2019, respectively. The age-standardized incidence and prevalence rates increased by 14.4% and 13.8%, respectively. However, disability-adjusted life years and death rates decreased by 53.1% and 56.9%, respectively. South Asia superregion had the highest age-standardized disability-adjusted life years and deaths. Sub-Saharan Africa had the highest age-standardized incidence and prevalence rates. There was a steep decline in RHD burden among higher-SDI countries. However, only age-standardized deaths and disability-adjusted life years rates decreased in lower-SDI countries. The age-standardized years of life lost and years lived with disability rates for RHD significantly declined as countries' SDI increased. The coefficients of birth cohort effect on the incidence of RHD showed an increasing trend from 1960 to 1964 to 2015 to 2019; however, the birth cohort effect on deaths attributable to RHD showed unfailingly decreasing trends from 1910 to 1914 to 2015 to 2019.

CONCLUSIONS: There was a divergence in the burden of RHD among countries based on SDI levels, which calls for including RHD in global assistance and funding. Indeed, many countries are still dealing with an unfinished infectious disease agenda, and there is an urgency to act now to prevent an increase in future RHD burden.

Key Words: disability-adjusted life years ■ global burden of disease ■ heart ■ rheumatic fever ■ rheumatic heart disease

Rheumatic heart disease (RHD), a known complication following acute rheumatic fever,[1] remains to be the most acquired heart disease among people aged <25 years.[2] RHD is usually associated with overcrowding, poor housing conditions, and improper health literacy.[3] High sociodemographic index (SDI) countries have managed to reduce RHD incidence via significant elimination of acute rheumatic fever occurrence[4] and its recurrence.[5] Nevertheless, RHD still affects older adults, immigrants, marginalized, and underprivileged populations in high-SDI countries. The achievements in lowering RHD incidence are known to be attributable to improvements in socioeconomic status,[4] better performance of health care systems,

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CLINICAL PERSPECTIVE

What Is New?

- The incidence and prevalence rates of rheumatic heart disease (RHD) increased globally, whereas death rates showed declining trend during the study period; RHD continues to take a heavy toll on far too many people in lower-income countries.
- Quantifying the burden of RHD with epidemiologic measures in this study, we provided a clearer picture of the inequity patterns in the RHD status by age, sex, country, and socioeconomic status, which have mainly been underestimated by the health authorities.
- There are fundamental disparities among countries and territories with disparate socioeconomic status on RHD, making it among the most neglected diseases relative to burden worldwide.

What Are the Clinical Implications?

- Until there is an effective vaccine for RHD, a multilevel approach is suggested, which includes primordial prevention via improving the socioeconomic status of populations at risk, primary prevention via treating patients with strep throat using benzathine–penicillin-G, secondary prevention via antibiotic prophylaxis among patients with previous rheumatic fever or RHD, and tertiary prevention via medical/surgical treatment of RHD complications.
- In settings with limited resources, the physicians' task for an antibiotic prescription could be shifted to community health workers, who could play a key role in delivering preventive medications via practical clinical algorithms, diagnostic tools, availability of appropriate antibiotics, and supportive supervision.

Nonstandard Abbreviations and Acronyms

ASDR	age-standardized death rate
ASIR	age-standardized incidence rate
ASPR	age-standardized prevalence rate
GBD	Global Burden of Disease
RHD	rheumatic heart disease
SDI	sociodemographic index
WHO	World Health Organization
YLDs	years lived with disability
YLLs	years of life lost

implementation of control programs,[6] and the widespread use of penicillin G benzathine to treat streptococcal pharyngitis.[7] Despite improvements in high-SDI countries, low and low-middle SDI countries have been less successful in lowering the burden of RHD.[8]

The World Health Organization (WHO) proposed prevention and treatment guidelines for RHD >6 decades ago.[9] Previous calls for advocacy, action, and investment to reduce the RHD burden have been neglected.[3] Moreover, there was a sharp decrease in focus on RHD after apparent RHD elimination in high-SDI countries,[10] and even the Global Rheumatic Heart Disease Control Program, coordinated by WHO since 1984, ended in the early 2000s.[11] Nevertheless, novel regional and international initiatives against RHD have emerged. The World Heart Federation has set a 2025 RHD reduction target, some low- and middle-SDI countries implemented national programs for RHD prevention and control,[12,13] and the World Health Assembly endorsed a global resolution on RHD in 2018.[14]

Prioritizing investment and providing proper action plans require accurate global, regional, and national burden estimates. The objective of this study was to present worldwide estimates of RHD prevalence, incidence, death, years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs) from 1990 to 2019 by age groups and SDI quintiles using GBD (Global Burden of Disease) 2019.[15]

METHODS

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

Data Source

The data of GBD were used in the study, which includes high-quality estimations on vital epidemiological measures, including prevalence, incidence, death, YLLs, YLDs, and DALYs for 286 causes of death, 369 diseases and injuries, and 87 risk factors in 204 countries and territories. GBD classified countries and territories into 7 superregions and 21 regions. The 7 superregions are high income; Latin America and Caribbean; Sub-Saharan Africa; North Africa and Middle East; Southeast Asia, East Asia, and Oceania; South Asia; and Central Europe, Eastern Europe, and Central Asia.[16] RHD data were extracted from GBD 2019: GBD code: B.2.1; *International Classification of Diseases, Tenth Revision* (*ICD-10*), codes I01 to I01.9, I02.0, and I05 to I09.9 were used for mapping mortality and new cases.[17] Sources used in the study are presented in Table S1.

Fatal Estimates

The vital registration system and surveillance data were transformed and modeled to provide the cause-specific death estimates. Furthermore, data were mapped to

the GBD list of disease causes. To enhance the comparability of death data sources, reclassification and redistribution of codes that are nonspecific or unspecific were performed. In addition, a regression analysis using Bayesian geospatial regression software (Cause of Death ensemble model) was considered to model deaths from RHD. Eight selected covariates for Cause of Death ensemble models of RHD were defined, including RHD summary exposure value scalar (+1 direction), improved water (–1 direction), malnutrition (+1 direction), sanitation (–1 direction), health care access and quality index (–1 direction), lag-distributed income per capita (–1 direction), SDI (–1 direction), and education via years per capita (–1 direction). Finally, the single cause death estimates were adjusted by applying CoDCorrect algorithm. YLLs were calculated using normative global life expectancy and the number of deaths by age.

Nonfatal Estimates

To provide estimates on the incidence and prevalence of RHD, data were collected using the existing scientific reports on cohorts, registries, population surveys, health system administrative data, and inpatient/outpatient claims data. RHD was defined by clinical diagnosis, and estimates of RHD included cases identified by clinical history and physical examination, including auscultation or standard echocardiographic criteria. Consistent disease estimates were produced by using epidemiologic state-transition disease modeling software, DisMod-MR, and Bayesian meta-regression software, MR-BRT. Two covariates were selected, including RHD summary exposure value scalar and lag-distributed income per capita. The survival of RHD was modeled using death/incidence ratios across various geographical locations and age groups. The 10-year prevalence was then calculated for each incidence cohort. YLDs were calculated by multiplying each sequela's prevalence by its disability weight (0.049; 95% CI, 0.031–0.072) and by adding the procedure-related morbidity associated with RHD treatment. RHD DALYs were calculated by summing YLDs and YLLs.

Decomposition Investigation

The contribution of population growth, aging, and variations in age-specific incidence rates to the witnessed new cases changes was investigated. In the first step, the age structure and age-specific incidence rate of RHD in 1990 were applied to the population size of 2019. In the second step, the age structure and age-specific incidence rate of RHD in 2019 were applied to the population size of 1990. The difference between the new cases, as calculated in the first and second steps, was considered the contribution of age structure changes from 1990 to 2019. The difference between the new cases in the first step and the actual new cases in 1990 was attributed to the population growth. The differences between the value of the second step and the actual new cases in 2019 were attributed to the changes in age-specific incidence rates.[18]

Inequity Pattern

Countries were categorized using SDI to investigate the burden of RHD based on development status.[19] SDI of countries was basically calculated using 3 factors: (1) average income per person, (2) educational attainment, and (3) total fertility rate. SDI scores were categorized into 5 quintiles, including high SDI, high-middle SDI, middle SDI, low-middle SDI, and low SDI.

Age-period-cohort analysis with the intrinsic estimator method was performed to decompose the effects of 3 collinear factors named age, period, and cohort. Data were stratified in 22 birth cohorts starting from 1910 to 1914, 6 5-year calendar periods starting from 1990, and 17 5-year age groups starting from age <5 years to age ≥80 years.[20]

Statistical Analysis

Age standardization was conducted using the direct method, applying a global age structure from the year 2019. Age-standardized rates of RHD for countries were calculated using the GBD world population standard and reported per 100 000 individuals. The 95% uncertainty intervals (95% UIs) were reported for each metric using 2.5% and 97.5% quintiles across 1000 draws. The comparison for the differences in values of each metric from 1990 to 2019 was computed to calculate the total and percentage of change. All essential data analysis, tables, and illustrations were performed using R statistical package v3.4.3 (http://www.r-project.org, RRID: SCR_001905). The "apc-ie" command in STATA software was used for age-period-cohort effect analysis.

Ethical Approval and Consent to Participate

Not applicable.

RESULTS

Global and Superregional Burden of RHD

On global scale, RHD caused 305 651 (95% UI, 259 220–340 486) deaths in 2019: 173 933 (140 652–208 089) among women and 131 717 (113 445–159 904) among men. Between 1990 and 2019, there was a 15.6% (–30.5% to –2.1%) decrease in the number of deaths attributable to RHD: 17.2% (–34.2% to 3.1%) decrease among women and 13.4% (–30.9% to 8.0%) among men (Table 1). The age-standardized death rate (ASDR) of RHD at the global level decreased

Table 1. Global Burden of RHD in 1990 and 2019

Measure	Age (metric)	Year						% Change (1990–2019)		
		1990			2019					
		Both	Women	Men	Both	Women	Men	Both	Women	Men
Incidence	All ages, n	1 863 318 (1 438 465 to 2 308 707)	1 000 723 (778 585 to 1 235 154)	862 595 (663 211 to 1 075 583)	2 789 443 (2 153 319 to 3 454 256)	1 490 770 (1 159 323 to 1 837 879)	1 298 673 (995 189 to 1 617 204)	49.7 (47.1 to 52.2)	49.0 (46.1 to 52.0)	50.6 (47.9 to 53.2)
	Age-standardized, rate per 100 000	32.7 (25.8 to 40.0)	35.5 (28.2 to 43.4)	29.8 (23.4 to 36.7)	37.4 (28.6 to 46.7)	40.6 (31.1 to 50.4)	34.3 (26.3 to 42.9)	14.4 (11.2 to 17.0)	14.1 (10.6 to 17.1)	15.1 (12.1 to 17.7)
Prevalence	All ages, n	23 756 847 (18 791 683 to 29 295 709)	13 099 934 (10 421 455 to 16 035 909)	10 656 912 (8 363 711 to 13 199 602)	40 502 345 (32 052 904 to 50 062 426)	22 519 239 (17 895 086 to 27 713 122)	17 983 106 (14 198 981 to 22 406 039)	70.5 (66.6 to 74.2)	71.9 (67.5 to 76.1)	68.7 (65.1 to 72.7)
	Age-standardized, rate per 100 000)	451.6 (363.3 to 552.5)	501.6 (405.5 to 609.7)	400.5 (321.4 to 492.4)	513.7 (405.0 to 636.3)	572.2 (450.7 to 705.5)	455.2 (359.2 to 566.2)	13.8 (11.0 to 16.0)	14.1 (10.9 to 16.7)	13.7 (11.2 to 15.8)
Deaths	All ages, n	362 160 (326 259 to 408 222)	210 057 (185 677 to 238 266)	152 103 (125 111 to 184 940)	305 651 (259 220 to 340 486)	173 933 (140 652 to 208 089)	131 717 (113 445 to 159 904)	−15.6 (−30.5 to −2.1)	−17.2 (−34.2 to 3.1)	−13.4 (−30.9 to 8.0)
	Age-standardized, rate per 100 000	8.9 (8.0 to 10.1)	9.7 (8.5 to 11.0)	8.2 (6.7 to 10.0)	3.9 (3.3 to 4.3)	4.1 (3.3 to 4.8)	3.6 (3.1 to 4.4)	−56.9 (−64.7 to −49.8)	−58 (−67.1 to −47.5)	−55.8 (−65 to −44.9)
DALYs	All ages, n	13 168 339 (11 896 460 to 14 634 663)	7 420 707 (6 565 305 to 8 275 336)	5 747 632 (4 827 059 to 6 847 812)	10 673 882 (9 207 379 to 12 121 608)	5 840 425 (4 813 977 to 6 963 022)	4 833 457 (4 121 949 to 5 729 105)	−18.9 (−30.6 to −7.7)	−21.3 (−34.3 to −5.2)	−15.9 (−29.9 to 0.2)
	Age-standardized, rate per 100 000	283.3 (255.9 to 315.2)	312.7 (276.9 to 349.8)	253.7 (211.8 to 304)	132.9 (115.0 to 150.3)	142.0 (117.5 to 168.6)	123.5 (105.8 to 145.9)	−53.1 (−60.0 to −46.4)	−54.6 (−62.2 to −45.3)	−51.3 (−59.8 to −41.8)
YLLs	All ages, n	12 010 791 (10 869 595 to 13 434 295)	6 783 119 (5 961 779 to 7 613 484)	5 227 672 (4 260 508 to 6 297 315)	8 683 950 (7 431 179 to 9 774 672)	4 733 750 (3 803 664 to 5 787 570)	3 950 201 (3 400 008 to 4 706 404)	−27.7 (−39.4 to −16.8)	−30.2 (−43.8 to −13.7)	−24.4 (−37.8 to −7.2)
	Age-standardized, rate per 100 000	261.2 (235.9 to 292.9)	288.1 (253.9 to 323.4)	234.0 (190.1 to 284.8)	107.7 (92.7 to 120.9)	113.9 (92.1 to 138.8)	101.1 (87.4 to 120.1)	−58.8 (−65.6 to −52.5)	−60.5 (−68.3 to −51.1)	−56.8 (−64.7 to −46.9)
YLDs	All ages, n	1 157 548 (692 048 to 1 779 160)	637 587 (385 648 to 979 760)	519 960 (309 324 to 802 264)	1 989 931 (1 200 919 to 3 044 823)	1 106 675 (671 449 to 1 687 184)	883 256 (528 946 to 1 359 110)	71.9 (67.9 to 76.0)	73.6 (69.1 to 78.0)	69.9 (66.1 to 74.0)
	Age-standardized, rate per 100 000	22.1 (13.3 to 33.7)	24.5 (14.9 to 37.2)	19.7 (11.8 to 30.0)	25.2 (15.2 to 38.7)	28 (17 to 42.9)	22.4 (13.4 to 34.6)	13.9 (11.1 to 16.0)	14.4 (11.1 to 16.9)	13.7 (11.2 to 15.9)

DALYs indicates disability-adjusted life year; RHD, rhematic heart disease; YLDs, years lived with disability; and YLLs, years of life lost.

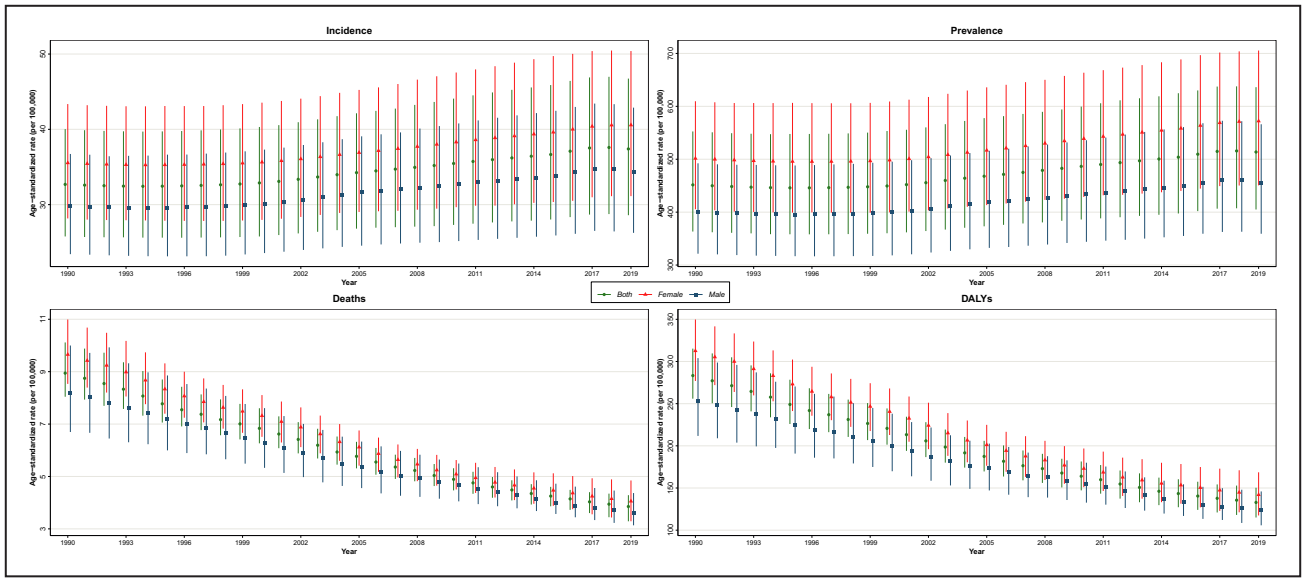

Figure 1. Age-standardized epidemiological measures (incidence, prevalence, deaths, and disability-adjusted life years [DALYs] of rheumatic heart disease at global scale across years from 1990 to 2019 by sex).

from 8.9 (8.0–10.1) per 100 000 population in 1990 to 3.9 (3.3–4.3) per 100 000 population in 2019. Although the trend of ASDRs of RHD from 1990 to 2019 was decreasing among both men and women, the rates were slightly higher among women than men (Figure 1 and Table 1). Considering the GBD superregions, the ASDRs of RHD were unfailingly highest among countries in South Asia superregion with 11.2 (8.6–13.4) in 100 000 population in 2019, and lowest among countries in Latin America and Caribbean, with 1.1 (1.0–1.2) in 100 000 population in 2019 (Table 2).

RHD led to nearly 10.7 million (9.2–12.1) DALYs in 2019 globally, which showed a decrease from just over 13.2 million (11.9–14.6) in 1990. Compatible with total trend in all-age DALYs, the age-standardized DALYs showed 54.6% (−62.2% to −45.3%) and 51.3% (−59.8% to −41.8%) decrease among women and men, respectively (Figure 1). Considering the age-standardized rates in 2019, RHD contributed to 132.9 (115.0–150.3) DALYs in 100 000 population, which was almost half of the age-standardized rate in 1990 (Table 1). During the past 30 years, the age-standardized DALY rate of RHD was consistently lowest among the high-income superregion, with 24.6 (22.3–27.0) in 100 000 population in 2019, and highest among South Asia superregion, with 348.5 (272.4–412.2) in 100 000 population in 2019 (Table 2). Consistent with the ASDRs, the age-standardized DALY rate decreased during the past 30 years; however, the rates were higher among women (Figure 1). Although the declining trend in age-standardized DALYs of RHD was consistent with trends in YLLs, with 58.8% (−65.6% to −52.5%) decrease since 1990, the age-standardized YLD rate increased by 13.9% (11.1%–16.0%) in the study period. In addition, YLDs contributed to 7.8% and 19.0% of rates in DALYs in 1990 and 2019, respectively. However, the contribution of YLLs decreased from 91.2% in 1990 to 81.4% in 2019 (Table 1).

Nearly 2.8 (2.2–3.5) million new cases and 40.5 (32.1–50.1) million prevalent cases of RHD were identified in 2019, worldwide, showing a 1.5- and 1.7-fold increase since 1990, respectively (Figure 1). The increase in the absolute values of new cases since 1990 was mainly attributable to population growth (44.6%), and 17.9% of the current trend was attributable to an increase in incidence rate of RHD (Table S2).

The global age-standardized incidence rate (ASIR) and age-standardized prevalence rate (ASPR) of RHD were 37.4 (28.6–46.7) and 513.7 (405.0–636.3) per 100 000 population in 2019, respectively. The corresponding rates in 1990 were 32.7 (25.8–40.0) and 451.6 (363.3–552.5) in 100 000 population for ASIR and ASPR, respectively. The ASIRs and ASPRs among women increased by 14.1% (10.6%–17.1%) and 14.1% (10.9%–16.7%) from 1990 to 2019, respectively (Table 1 and Figure 1). Among men, the corresponding rate increased by 15.1% (12.1%–17.7%) and 13.7% (11.2%–15.8%) from 1990 to 2019. Considering the GBD superregions, Sub-Saharan Africa and the high-income superregion showed the highest and lowest ASIRs and ASPRs for all the years from 1990 to 2019 (Tables 1 and 2).

Regional and National Burden of RHD

At the regional level, Oceania had the highest ASDRs attributable to RHD in 2019 among women (15.5

Table 2. Age-Standardized Rates (95% Uncertainty Intervals) Attributable to RHD in 1990 and 2019

GBD superregion	Measure	Age-standardized rate (per 100 000)						% Change (1990 to 2019)		
		1990			2019					
		Both	Women	Men	Both	Women	Men	Both	Women	Men
Central Europe, Eastern Europe, and Central Asia	Incidence	19.3 (17.2 to 21.7)	20.7 (18.4 to 23.3)	17.7 (15.6 to 20.1)	17.4 (14.4 to 20.7)	18.5 (15.4 to 21.8)	16.1 (13.2 to 19.4)	−9.9 (−17.1 to −3.3)	−10.7 (−17.6 to −4.1)	−8.6 (−16.3 to −1.2)
	Prevalence	264.1 (235.3 to 297.4)	292.1 (260.6 to 329.1)	224.2 (198.4 to 255.6)	254.2 (217.1 to 299.7)	279.8 (239.4 to 329.5)	222.6 (187.9 to 263.6)	−3.7 (−10.8 to 3.3)	−4.2 (−11 to 2.8)	−0.7 (−8.8 to 6.9)
	Deaths	5.6 (5.4 to 5.9)	5.8 (5.6 to 6.1)	5.3 (5 to 5.7)	1.8 (1.6 to 1.9)	1.9 (1.7 to 2)	1.6 (1.5 to 1.8)	−68.4 (−71.6 to −65.4)	−68.1 (−71.1 to −64.5)	−69.4 (−73.3 to −65.9)
	DALYs	198 (188.2 to 207.1)	201.3 (191.9 to 211.1)	191.1 (178 to 203.2)	66.3 (59.2 to 74.1)	68.4 (60.1 to 77.4)	62.9 (56.5 to 71)	−66.5 (−69.7 to −62.9)	−66 (−69.6 to −62.3)	−67.1 (−71 to −62.9)
	YLLs	185.4 (177 to 193.1)	187.4 (179.4 to 195.7)	180.4 (167.8 to 192)	54 (48.4 to 59.5)	54.9 (48.6 to 61.1)	52.2 (46.7 to 58)	−70.9 (−73.9 to −67.9)	−70.7 (−73.8 to −67.2)	−71.1 (−74.8 to −67.4)
	YLDs	12.6 (8 to 18.1)	13.9 (8.9 to 20)	10.7 (6.7 to 15.5)	12.3 (7.5 to 18.3)	13.5 (8.2 to 20)	10.8 (6.6 to 16.1)	−2.4 (−9.5 to 4.3)	−3 (−9.9 to 4)	0.8 (−7.6 to 8.6)
High-income	Incidence	8.1 (7.2 to 9.1)	8.9 (8 to 10)	7.2 (6.4 to 8)	7.2 (6.5 to 8)	7.6 (6.9 to 8.4)	6.8 (6.1 to 7.6)	−11.1 (−15.3 to −6.7)	−14.9 (−19.3 to −10.3)	−5 (−9.6 to 0.2)
	Prevalence	98.1 (86.8 to 109.4)	108.5 (96.3 to 120.7)	85.6 (75.4 to 95.9)	93.1 (83.7 to 103.5)	100.4 (90.1 to 111.1)	85.4 (76.8 to 95.1)	−5.1 (−10.5 to 0.4)	−7.5 (−12.9 to −1.6)	−0.2 (−6.2 to 5.9)
	Deaths	2.7 (2.5 to 2.8)	3 (2.8 to 3.2)	2.2 (2.1 to 2.3)	1.2 (1.1 to 1.3)	1.3 (1.1 to 1.5)	1.1 (1 to 1.1)	−55 (−58.6 to −51.7)	−56.6 (−60.9 to −52.8)	−52.2 (−55.1 to −49.3)
	DALYs	61.4 (58.8 to 64)	68.9 (65.7 to 71.9)	51.6 (49.4 to 54.1)	24.6 (22.3 to 27)	26.2 (23.5 to 28.9)	22.4 (20.6 to 24.6)	−60 (−62.3 to −57.5)	−61.9 (−64.5 to −59.3)	−56.6 (−59 to −53.8)
	YLLs	56.2 (54 to 57.9)	63 (60.4 to 65.2)	47.1 (45.6 to 48.9)	19.7 (18 to 21.1)	20.9 (18.8 to 22.8)	18 (16.9 to 19.1)	−64.9 (−67 to −62.8)	−66.8 (−69.2 to −64.5)	−61.8 (−63.8 to −59.7)
	YLDs	5.2 (3.5 to 7.5)	5.8 (3.9 to 8.4)	4.5 (2.9 to 6.5)	4.9 (3.2 to 6.9)	5.3 (3.5 to 7.6)	4.4 (2.8 to 6.3)	−6.6 (−11.6 to −1.4)	−8.8 (−13.8 to −3.3)	−1.8 (−7.4 to 4.4)
Latin America and Caribbean	Incidence	39.2 (29.9 to 49)	41.5 (31.6 to 51.7)	36.9 (28 to 46.4)	39 (29.5 to 48.9)	41.5 (31.6 to 52.2)	36.5 (27.7 to 45.9)	−0.6 (−1.8 to 0.5)	0 (−1.7 to 1.7)	−1.1 (−2.8 to 0.4)
	Prevalence	652.9 (511.1 to 807.9)	731.1 (574.6 to 900.2)	571 (446.6 to 715.1)	654.9 (511.5 to 812.1)	738.8 (580.1 to 910.7)	566.5 (441.6 to 708.4)	0.3 (−0.9 to 1.6)	1.1 (−0.8 to 2.8)	−0.8 (−2.3 to 0.9)
	Deaths	3.1 (2.9 to 3.3)	3.7 (3.4 to 4)	2.4 (2.2 to 2.6)	1.1 (1 to 1.2)	1.3 (1.1 to 1.4)	0.8 (0.8 to 0.9)	−65 (−69.3 to −61.6)	−65.6 (−70.2 to −61.4)	−64.8 (−69.7 to −60.3)
	DALYs	135.1 (121.4 to 152.1)	161.8 (144.9 to 181.3)	107 (94.2 to 122.5)	64.7 (51.3 to 81)	75.3 (59.7 to 93.9)	53.2 (41.7 to 68.2)	−52.1 (−58.3 to −45.9)	−53.4 (−59.8 to −46.9)	−50.2 (−57.3 to −43.2)
	YLLs	104.1 (99.1 to 110.4)	127.2 (117.5 to 136.5)	79.7 (74.7 to 86.3)	33.6 (29.7 to 38)	40.3 (34.7 to 47)	26.2 (23.2 to 29.6)	−67.8 (−71.7 to −63.9)	−68.3 (−72.5 to −63.7)	−67.2 (−71.5 to −62.4)
	YLDs	31 (18.4 to 47.7)	34.6 (20.6 to 52.7)	27.2 (16.1 to 42.2)	31.2 (18.4 to 48.2)	35 (20.8 to 54)	27.1 (15.9 to 42.3)	0.6 (−0.8 to 2)	1.3 (−0.8 to 3.4)	−0.5 (−2.5 to 1.4)

(*Continued*)

Table 2. Continued

GBD superregion	Measure	Age-standardized rate (per 100 000)						% Change (1990 to 2019)		
		1990			2019					
		Both	Women	Men	Both	Women	Men	Both	Women	Men
North Africa and Middle East	Incidence	23.8 (18.6 to 29.6)	24.5 (19.2 to 30.4)	23 (17.9 to 28.8)	25.6 (19.7 to 31.9)	26.5 (20.4 to 32.9)	24.8 (19 to 31)	7.8 (3.5 to 11.6)	8.3 (3.8 to 12.3)	7.5 (3 to 11.7)
	Prevalence	368.8 (293.2 to 455.9)	395.7 (313.7 to 488.5)	343.2 (271.8 to 429.3)	388.9 (304.7 to 483.5)	420 (328.6 to 521)	360.4 (282.5 to 449)	5.4 (1.3 to 8.5)	6.1 (1.6 to 9.8)	5 (0.9 to 8.8)
	Deaths	4.5 (3.4 to 6.7)	5.3 (3.8 to 7.5)	3.7 (2.3 to 6.3)	1.6 (1.4 to 2)	1.9 (1.5 to 2.3)	1.4 (1 to 1.8)	−63.4 (−74.6 to −52.5)	−63.5 (−74 to −46.8)	−62.9 (−77.5 to −43.9)
	DALYs	173.1 (139.6 to 223.6)	209.4 (157.4 to 256.5)	138.2 (94.4 to 205.2)	67.1 (54.2 to 82.4)	77.1 (60.9 to 94.4)	57.7 (42.2 to 74.8)	−61.3 (−70.2 to −52.1)	−63.2 (−71 to −48.7)	−58.2 (−71.4 to −40.2)
	YLLs	155.2 (123.3 to 205)	190.4 (139.9 to 235.6)	121.5 (76.7 to 184.8)	48.2 (38 to 60.8)	56.9 (43.2 to 71.3)	40.2 (27 to 54.2)	−68.9 (−77.1 to −59.4)	−70.1 (−77 to −55.6)	−66.9 (−78.4 to −49.5)
	YLDs	17.9 (10.5 to 27.4)	19 (11.3 to 29)	16.7 (9.8 to 25.8)	18.8 (11.1 to 29.2)	20.2 (12 to 31.3)	17.6 (10.3 to 27.1)	5.5 (1.1 to 9.1)	6.1 (1.2 to 10.7)	5 (0.3 to 9.5)
South Asia	Incidence	42.4 (31.9 to 53.2)	49.2 (36.7 to 61.3)	36.1 (27.3 to 45.6)	43 (32.2 to 54.2)	49.2 (36.6 to 62)	37.1 (27.9 to 47.1)	1.3 (−1.7 to 4.3)	0 (−4.1 to 3.9)	2.7 (−0.6 to 5.6)
	Prevalence	623.9 (481.5 to 781.4)	737.2 (565.6 to 923.1)	519.5 (404.4 to 659.7)	645.1 (498.2 to 811.7)	752.7 (579.1 to 945.3)	540.7 (415.8 to 684.7)	3.4 (0.5 to 6.2)	2.1 (−1.6 to 5.8)	4.1 (1.3 to 6.9)
	Deaths	20.7 (16.9 to 26.4)	20.7 (16.2 to 25.4)	20.7 (14.6 to 30.7)	11.2 (8.6 to 13.4)	12.2 (8.6 to 16.4)	10.1 (7.7 to 14.5)	−45.9 (−59.6 to −30.6)	−41 (−59.1 to −17.5)	−51 (−64.9 to −35.3)
	DALYs	630.7 (525.2 to 772.2)	650 (519.8 to 782.7)	613.1 (456.2 to 852.3)	348.5 (272.4 to 412.2)	382.2 (278.6 to 511.1)	314.9 (246.9 to 417.6)	−44.7 (−56.5 to −32.2)	−41.2 (−55.4 to −23.3)	−48.6 (−60.3 to −33.7)
	YLLs	600.4 (495.2 to 739.6)	614.4 (483.9 to 743.1)	587.6 (431.3 to 824.7)	317 (243.6 to 381)	345.7 (243.6 to 470)	288.3 (222.1 to 388.9)	−47.2 (−58.9 to −34.1)	−43.7 (−58.9 to −24.9)	−50.9 (−62.8 to −35.7)
	YLDs	30.3 (18.4 to 46.3)	35.5 (21.8 to 54)	25.5 (15.4 to 39)	31.5 (19 to 48)	36.5 (22.2 to 55.5)	26.6 (15.9 to 40.8)	3.9 (1 to 6.5)	2.7 (−1 to 6.4)	4.4 (1.1 to 7.5)
Southeast Asia, East Asia, and Oceania	Incidence	26 (20.5 to 32.2)	27.4 (21.6 to 33.7)	24.7 (19.4 to 30.6)	21.9 (17.2 to 27.1)	23.3 (18.3 to 28.9)	20.6 (16.1 to 25.7)	−15.9 (−17.7 to −14.3)	−15 (−17 to −13.1)	−16.3 (−18.3 to −14.3)
	Prevalence	397.1 (316 to 491.9)	431 (345.5 to 533.1)	364.1 (288.5 to 452)	355.3 (283.6 to 436.6)	394.4 (316.3 to 484.5)	317.2 (253.7 to 391.2)	−10.5 (−12.4 to −8.6)	−8.5 (−10.7 to −6.4)	−12.9 (−15.2 to −10.3)
	Deaths	14.3 (12.4 to 16.8)	16.8 (13.9 to 20.4)	11.6 (9.4 to 13.8)	3.5 (3 to 4)	3.6 (2.9 to 4.3)	3.5 (2.8 to 4.3)	−75.4 (−81.2 to −69.1)	−78.8 (−84.1 to −72)	−69.9 (−78.5 to −57.3)
	DALYs	356 (310.9 to 405.9)	430.5 (361.4 to 514.7)	280.1 (231 to 329.1)	91.8 (79.6 to 103.9)	96.4 (81.9 to 112.3)	87.5 (72 to 103.8)	−74.2 (−79.2 to −69)	−77.6 (−82.7 to −71.6)	−68.8 (−76.6 to −58.1)
	YLLs	335.9 (293.2 to 385.1)	408.5 (340.3 to 491.5)	261.8 (213.4 to 309)	73.5 (62.9 to 83.4)	75.8 (62.7 to 89.7)	71.3 (57.8 to 86)	−78.1 (−82.7 to −73)	−81.4 (−85.8 to −75.8)	−72.8 (−80.2 to −62)
	YLDs	20.2 (12.1 to 30.9)	22 (13.4 to 33.4)	18.4 (11.1 to 28.4)	18.3 (11 to 27.8)	20.5 (12.4 to 31)	16.2 (9.7 to 24.9)	−9 (−11.2 to −6.6)	−6.6 (−9.2 to −3.8)	−11.9 (−14.6 to −8.9)

(*Continued*)

Table 2. Continued

GBD superregion	Measure	Age-standardized rate (per 100 000)						% Change (1990 to 2019)		
		1990			2019					
		Both	Women	Men	Both	Women	Men	Both	Women	Men
Sub-Saharan Africa	Incidence	67.3 (50.6 to 85.6)	69.4 (52 to 88.2)	65.1 (48.9 to 82.4)	70 (52.4 to 88.8)	72.4 (54 to 91.9)	67.6 (50.4 to 85.9)	4.1 (2.6 to 5.8)	4.4 (2.6 to 6.3)	3.7 (2 to 5.8)
	Prevalence	984.2 (766.4 to 1237.4)	1028.3 (799.3 to 1287.9)	938.7 (730.1 to 1179.7)	1030.9 (799 to 1297.8)	1080 (833.7 to 1349.2)	978.4 (757.7 to 1232.7)	4.8 (3.4 to 6.3)	5 (3.3 to 6.8)	4.2 (2.5 to 6.2)
	Deaths	5.7 (4.6 to 6.8)	6 (4.4 to 7.4)	5.3 (3.7 to 7.6)	2.6 (2.1 to 3)	2.5 (2 to 3.2)	2.6 (2.1 to 3.3)	−54.9 (−63.8 to −44.7)	−58.1 (−66.4 to −47.1)	−50.8 (−64.3 to −32.4)
	DALYs	216.8 (178.4 to 259.6)	233.6 (180.6 to 281.5)	199.5 (151 to 258.7)	119.8 (94.9 to 148.8)	121.3 (94.6 to 151.7)	118.2 (91.5 to 149.4)	−44.7 (−54.6 to −34.7)	−48.1 (−56.9 to −36.6)	−40.8 (−54.9 to −25.2)
	YLLs	169.8 (138.2 to 205.9)	184.7 (136.7 to 226.4)	154.4 (111.1 to 216.4)	70.4 (58 to 85.3)	69.8 (54.3 to 88.1)	71.1 (56.2 to 90.7)	−58.5 (−67.5 to −48.8)	−62.2 (−69.4 to −51.5)	−54 (−67.4 to −37.1)
	YLDs	47 (27.9 to 73.5)	48.9 (29 to 76.4)	45 (26.6 to 70.7)	49.4 (29.4 to 76.9)	51.5 (30.8 to 80.2)	47.1 (27.8 to 73.8)	5.1 (3.7 to 6.8)	5.3 (3.3 to 7.2)	4.7 (2.7 to 6.7)

DALY indicates disability-adjusted life year; GBD, Global Burden of Disease; RHD, rheumatic heart disease; YLDs, years lived with disability; and YLLs, years of life lost.

[9.5– 23.4] in 100 000 population), men (16.7 [7.8–31.1] per 100 000 population), and both sexes combined (16.1 [10.1–24.6] in 100 000 population). Concurrently, Oceania had the highest age-standardized DALY rate for women, men, and both sexes combined, with the rates of 639.8 (403.5–976.8), 615.5 (321.9–1065.4), and 627.4 (404.1–918.1) per 100 000 population, respectively. South, Central, and East Asia were the regions with the next highest ASDRs attributable to RHD for both women and men in 2019, with rates of 11.2 (8.6–13.4), 4.2 (3.6–4.7), and 4.0 (3.3–4.6) per 100 000 population, respectively.

South Asia, Central Sub-Saharan Africa, and Central Asia ranked the next highest age-standardized DALY rate in 2019. Central Sub-Saharan Africa had the fifth-highest ASDRs (4.0 [2.4–6.0] per 100 000 population in 2019) attributable to RHD; however, it was consistently the top region in terms of ASIRs (81.7 [60.6–104.2] per 100 000 population in 2019) and ASPRs (1195.6 [918.2–1511.3] per 100 000 population in 2019) in all years from 1990 to 2019.

The lowest ASDRs attributable to RHD were among the countries in Central Latin America region, with the rate of 0.7 (0.6–0.8) per 100 000 population in 2019. High-income Asia Pacific had the second lowest ASDRs (0.8 [0.6–0.9] per 100 000 population), whereas the lowest ASIR (2.5 [2.1–2.8] per 100 000 population), ASPR (34.2 [29.6–39.0] per 100 000 population), and age-standardized DALY (13.2 [11.5–14.5] per 100 000 population) were in this region in 2019.

From 1990 to 2019, the trends of ASDR and age-standardized DALY rate attributable to RHD were decreasing for all regions, with the highest decrease for Central Europe, followed by East Asia. The lowest decrease in ASDRs and DALYs during the study period was for Oceania, with 21.5% (–38.2% to –1.4%) and 17.6% (–35.4% to –4.6%) decrease, respectively.

The trends in ASIRs and ASPRs attributable to RHD varied markedly among various regions from 1990 to 2019. The ASIRs and ASPRs of 13 of 21 regions increased from 1990 to 2019, with the most increase in Oceania, with 8.1% (3.6%–12.7%) increase in ASIR and 8.1% (3.3%–13.0%) increase in ASPR. The most decrease in ASIRs and ASPRs was among countries of Central Europe and Eastern Europe, with 47.0% (–49.6% to –44.3%) and 37.1% (–40.4% to –33.8%) decrease in rates, respectively (Figure 2). Considering the trends in the absolute numbers of new cases of RHD, the overall changes of absolute numbers in all regions were increasing, except for Central Europe, East Asia, and Eastern Europe regions, which showed 39.8%, 26.5%, and 38.0% decrease in the number of new cases from 1990 to 2019. Table S2 presents the contribution of population growth, aging, and variations in age-specific incidence rates of RHD in the witnessed trends.

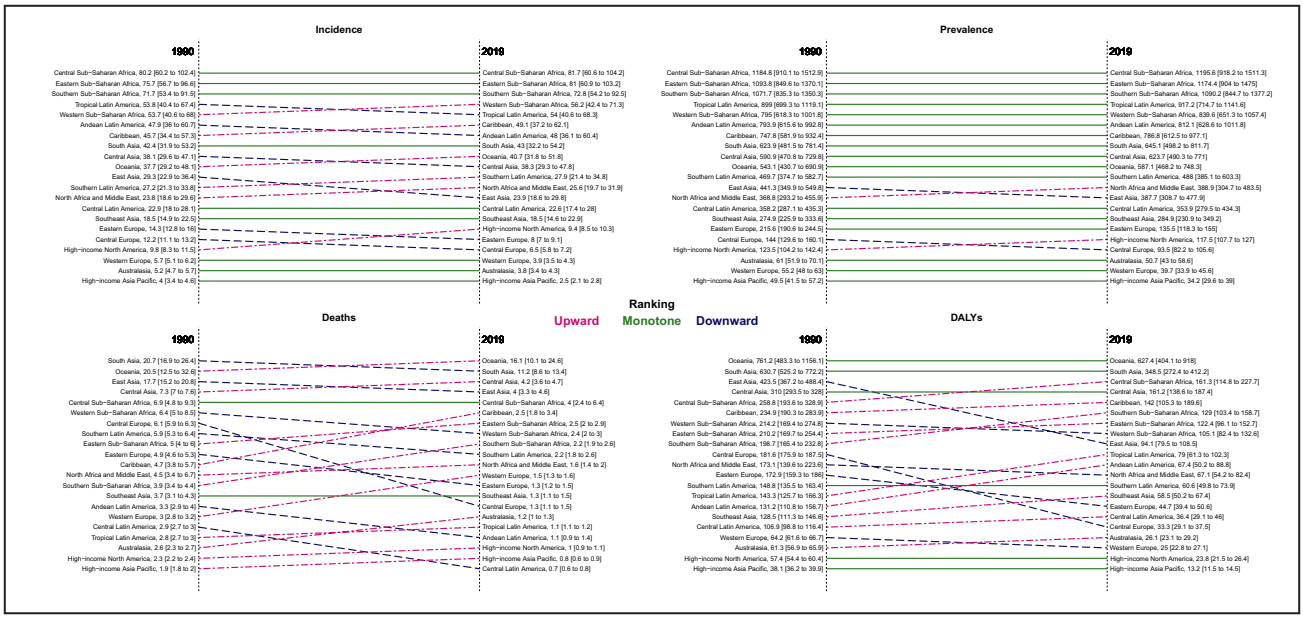

Figure 2. Regional age-standardized incidence, prevalence, deaths, and disability-adjusted life years (DALYs) of rheumatic heart disease in 1990 and 2019.

Across countries, Solomon Islands had the highest ASDR of RHD in all years from 1990 (30.9 [18.1–46.1] per 100 000 population) to 2019 (21.1 [10.9–31.2] per 100 000 population), despite a 31.8% (–54.2% to –4.6%) decrease in ASDRs since 1990. The second highest ASDR attributable to RHD was in Kiribati in 1990 and 2019 (Figure 3A). Commensurate with the ASDRs, the highest age-standardized DALY rate in 2019 was at the Solomon Islands, followed by Kiribati (Figure 3B). Finland and the Republic of Korea had the lowest ASDRs and age-standardized DALY rate for RHD in 2019.

The highest and lowest ASIR of RHD were in Uganda and Finland in 2019, with rates of 94.0 (68.4–128.3) and 1.5 (1.3–1.7) per 100 000 population, respectively (Figure 3C). The highest and lowest ASPR of RHD were among Eritrea (1370.1 [1054.6–1735.7] per 100 000 population) and Finland (18.0 [14.7–21.7] per 100 000 population) in 2019 (Figure 3D).

From 1990 to 2019, the ASDRs and age-standardized DALY rate of RHD decreased among all countries, except for 3 countries. The most decrease for ASDRs and age-standardized DALYs during the study period has been among Thailand (89.8% [–93.0% to –86.1%]) and Poland (86.7% [–88.7% to –84.6%]), respectively. The difference between the highest and lowest age-standardized rates for deaths and DALYs attributable to RHD decreased from 30.1 and 1177.2 in 1990 to 20.7 and 801.8 in 2019, respectively (Data S1).

Inequity Pattern in RHD Burden

In 2019, the age-standardized rates of RHD were higher among lower SDI countries. The low-SDI countries had ASIR, ASDR, and age-standardized DALY rates of 58.9 (44.4–74.2), 8.5 (7.0–10.2), and 275.5 (22.8–324.6) per 100 000 population, respectively, which were 10.0-, 7.7-, and 12.1-fold more than corresponding rates among high-SDI region. From 1990 to 2019, all age-standardized rates of RHD have shown a steep decline among countries of high-SDI, high-middle-SDI, and middle-SDI regions; however, only ASDRs and age-standardized DALY rate of RHD showed decreases in low-middle-SDI and low-SDI regions (Figure S1).

Considering the composition of DALYs attributable to RHD, expected age-standardized YLL rates for RHD declined profoundly as SDI increased. At the same time, age-standardized YLD rates for RHD demonstrate relatively little changes by SDI. At higher SDIs, the composition of disease burden shifted toward YLDs (Figure 4).

The analysis results on the age-period-cohort effect on incidence and deaths attributable to RHD worldwide are presented in Figure 5. The coefficient of age group effect on the incidence of RHD peaked in the age group of 15 to 19 years, with the rate of 0.98 (0.95–1.00), and started to decrease to the values as low as –1.06 (–1.14 to –0.97) in the age group of 50 to 54 years. The coefficient of age effect on deaths attributable to RHD showed increasing trends from the age group of 5 to 9 years (–1.83 [–1.92 to –1.75]) to the age

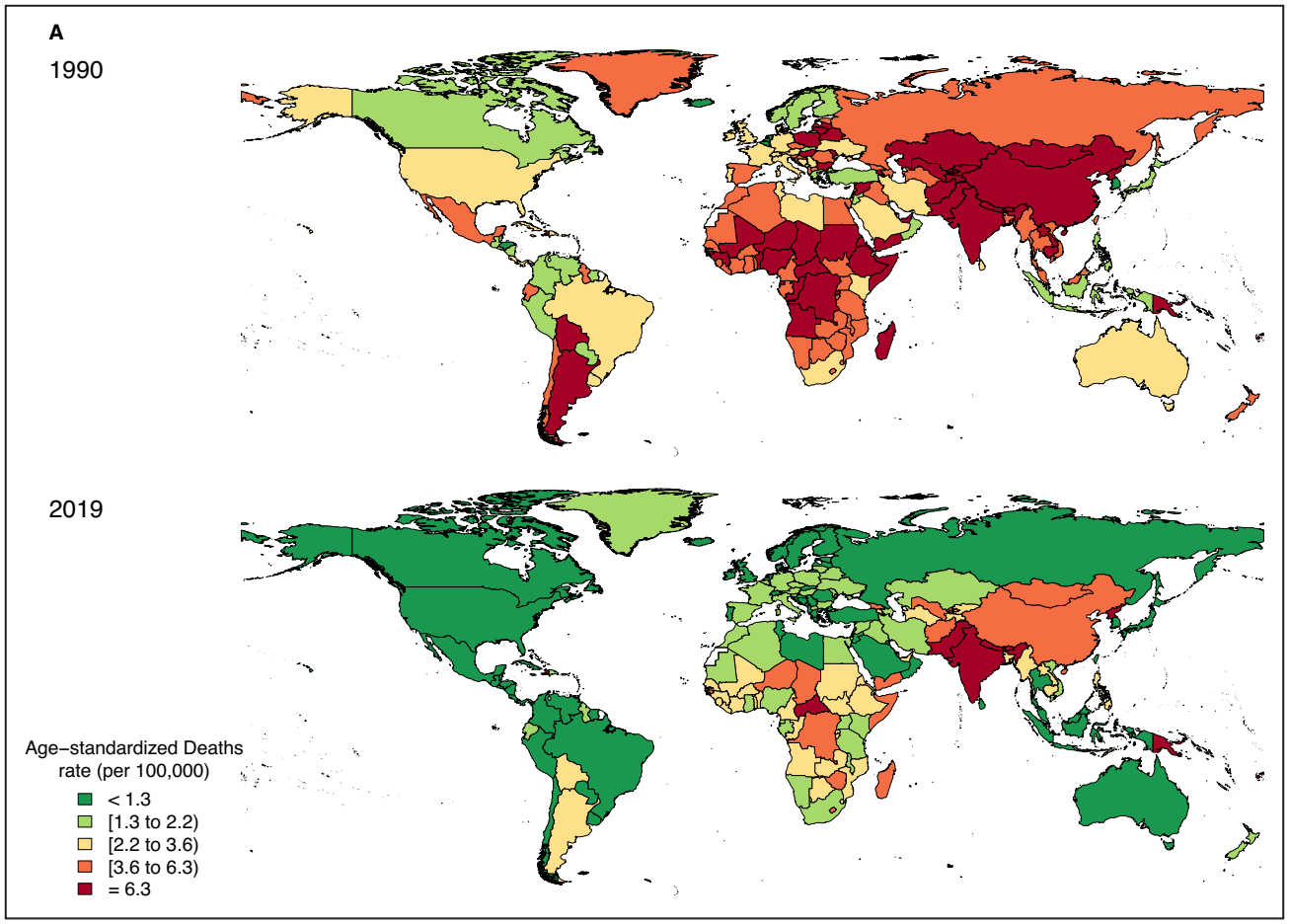

Figure 3. Age-standardized rheumatic heart disease epidemiological rates in both sexes in 204 countries or territories in 1990 and 2019: death (A), disability-adjusted life years (DALYs) (B), incidence (C), and prevalence (D).

group of ≥80 years (1.94 [1.91–1.97]). RHD had incessantly increasing trends in coefficients of period effect on incidence and mortality from 1990 to 1994 to 2015 to 2019. The coefficients of birth cohort effect on incidence of RHD showed a significantly increasing trend from 1960 to 1964 to 2015 to 2019; however, the birth cohort effect on deaths attributable to RHD showed unfailingly decreasing trends from 0.81 (0.75–0.86) in 1910 to 1914 to –1.23 (–1.48 to –0.98) in 2015 to 2019 (Table S3).

Age Pattern of RHD

Patterns in global rates of RHD by age were similar between men and women and across years from 1990 to 2019 and were consistently higher among women than rates among men. From 1990 to 2019, the death rate of RHD showed an increasing pattern by age and peaked at >85 years in both sexes. The DALY rate of RHD showed the current increasing trend by age at both 1990 and 2019. However, the DALY rate peaked at 75 to 79 years among women and 80 to 84 years in 1990. The age of the peaked DALY rate was at >85 years at both sexes. The global peak of incidence rate among women and men was 15 to 19 and 10 to 14 years, respectively. Nevertheless, the trends in the incidence rate of RHD rocketed up from the age group of 45 to 49 years at both sexes and peaked at the age group of ≥85 years again. The current dual trend was observed at age patterns of ASPRs of RHD for men and women in 1990 and 2019.

Age patterns in various rates of RHD showed an increasing trend by age in the high-SDI region and peaked at ≥85 years in all years from 1990 to 2019. Although the increasing trend by age is also witnessed at the death rate of all SDI regions and the peak age group of death rate was at ≥85 years for both sexes, and in both 1990 and 2019, the trend of disparate measures varies markedly across various SDI regions. The age trend of DALY rate among various SDI regions is similar to the death rate trend; however, the age pyramid base is wider than the death rate. Considering the pattern of incidence and prevalence rates of RHD by age, the lower the SDI, the wider the age pyramid base in both men and women in both 1990 and 2019,

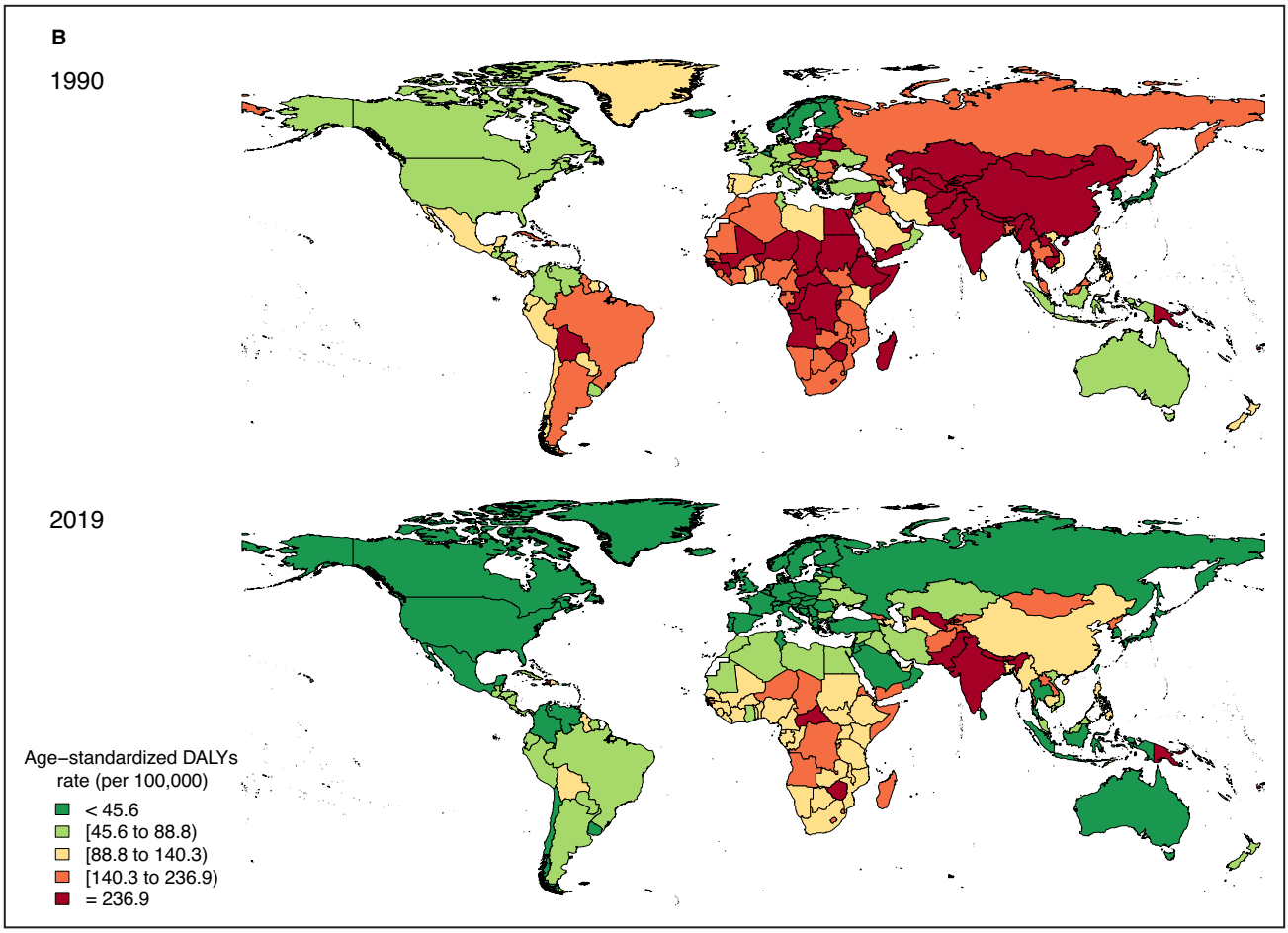

Figure 3. Continued

as the peak of incidence rate in the low-SDI region was at the age group of 10 to 14 years among men and women in 2019 (Figure S2).

DISCUSSION

In this study, multiple data sources and epidemiologic modeling techniques were used to estimate the global burden of RHD over the past 3 decades. The health-related burden of RHD has dramatically declined in affluent countries. Nevertheless, RHD continues to take a heavy toll on far too many people in lower-income countries, making it among the most neglected diseases relative to its burden worldwide. In this sense, the study results could be used by health care authorities in countries for resources allocation and hopefully drive efforts to reduce the disease burden further worldwide.

Globally, the ASIR and ASPR of RHD increased; however, the ASDR decreased during the study period. The increase in the new cases of RHD was majorly attributable to population growth and an increase in the incidence rate. Although YLLs and DALYs of RHD dramatically decreased, YLDs increased from 1990 to 2019. The burden of RHD was much higher among lower SDI countries. The age-standardized YLL and YLD rates for RHD significantly declined as countries' SDI increased.

The age-standardized DALY rate, although decreasing, has been higher among women than men. Although acute rheumatic fever is equally common among men and women, RHD occurs more commonly among women than men.[21] The reasons for this inequity in burden are yet to be understood; however, the roles of greater autoimmune susceptibility, exposure to infection, unequal access to primary and secondary acute rheumatic fever prophylaxis, and hemodynamic changes during pregnancy have been underscored.[22]

The burden of RHD varied significantly among countries. The age-standardized DALY, ASIR, and ASPR were lowest among the high-income superregion and highest among Southeast Asia, East Asia, and Oceania superregion, which also had the highest age-standardized death rates attributable to RHD. Central Sub-Saharan Africa was the first region regarding age-standardized incidence rate during the study period, consistent with other studies.[23]

Looking closer at Southeast Asia, East Asia, and Oceania superregion, the Oceania region had the

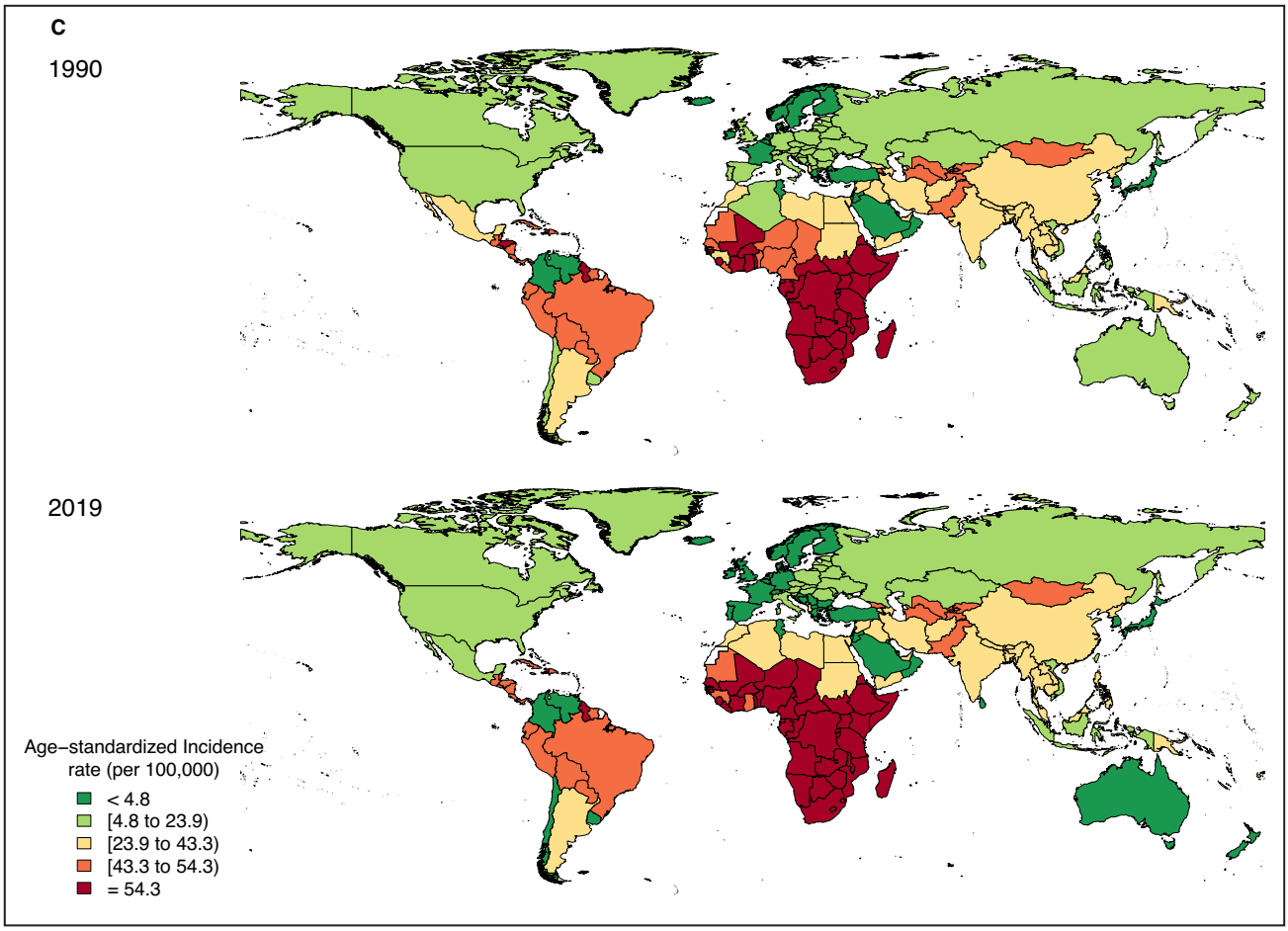

Figure 3. Continued

highest age-standardized DALYs and death rates attributable to RHD, which could be fueled by overcrowding, poor housing conditions, and improper health literacy. There is evidence that the actual number of deaths attributable to RHD could even be up to twice the records in vital registration systems, which could impose a burden much more than estimated.[24] Eradication of RHD calls for a centrally planned approach with a particular focus on prevention, early detection, and follow-up. Australia and New Zealand have spent millions to eliminate the burden of RHD among indigenous families and immigrants. Although there may be some evidence that genetic susceptibility may have a role in the significantly higher burden of RHD among Indigenous populations in the Oceania region,[25] socioeconomic and environmental conditions are the overwhelming significant modifiable determinants of RHD prevention.[26] The New Zealand government launched a program for the primordial and primary prevention of RHD in 2011, spending >$13 per capita, to increase awareness of rheumatic fever, reduce household crowding, and improve access to timely and effective treatment for strep throat infections.[27] The Australian government has invested $2 per capita in Rheumatic Fever Strategy during 2009 to 2021, resulting in no measurable reductions in the rates of rheumatic fever and RHD. Thus, they have recently launched RHD Endgame Strategy with a larger investment targeting all areas of control from primordial prevention to tertiary prevention to eliminate RHD in Australia by 2031.[28]

Improvements in housing and hygiene education have lessened the burden of RHD worldwide. Nevertheless, RHD remains the most acquired heart disease among people aged <25 years.[29] Given that the age group 15 to 19 years had the highest coefficient for age effect on RHD incidence, prompt medical interventions could substantially alleviate RHD mortality.[29] The burden of RHD was related to the socioeconomic development status of countries. Although both YLLs and YLDs attributable to RHD decreased as countries' SDI improved, the heterogeneities across countries based on SDI was more evident in YLLs. Higher YLLs attributable to RHD in low-SDI countries could be inadequate health infrastructure and poor health care services and management. The gaps between high-SDI countries and low-SDI countries were also reflected in the burden of RHD across various age groups. The DALYs attributable to RHD had an increasing trend by

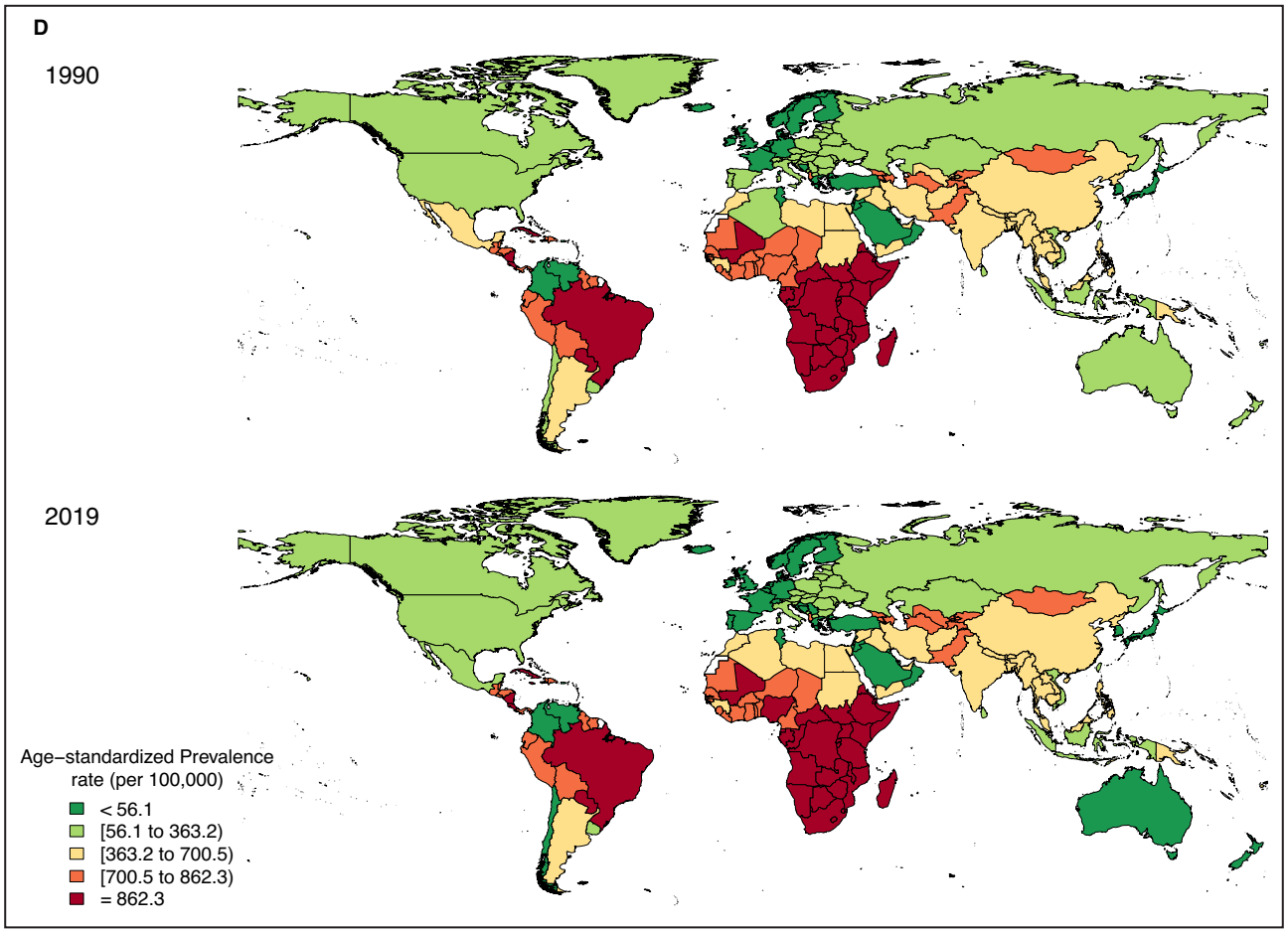

Figure 3. **Continued**

age in the high-SDI region and peaked at ≥85 years, which could show the cohort effect,[2] as reflected in the age-period-cohort effect in this study. Nevertheless, the incidence rate of RHD for the low-SDI region was at the age group of 10 to 14 years among men and women in 2019.

RHD, a complex consequence of acute rheumatic fever, is a febrile illness caused by group A streptococcus infection. The antibodies against the infection slowly damage the heart valves in RHD pathogenesis. The rheumatic fever per se is not likely to be fatal; however, untreated RHD could result in mortality.[30] RHD diagnosis still relies on a clinical diagnostic algorithm with no gold standard confirmatory test, which leaves the potential for imperfect specificity and sensitivity. This calls for further research to improve case detection, especially for use in moderate-/high-risk settings with limited resources.[31] Improvements in diagnosis in low-SDI countries could help policy makers better understand the problem severity, as there are many undiagnosed cases in such countries.[24]

The witnessed gaps and inequities call for concerted efforts to lessen the burden of RHD in areas with limited resources. Although low-SDI countries are witnessing a global shift of disease burden from communicable diseases to noncommunicable diseases,[32,33] they are still dealing with RHD, a neglected consequence of a communicable disease, which could add to their existing challenges.

Thus, there is an urgent need for investment and resource allocation to lessen RHD's burden. Given the level of technology, expenses, and the expertise required for tertiary prevention of RHD, the prevention of rheumatic fever recurrence among patients with previous rheumatic fever or RHD seems to be the most feasible measure among the mentioned prevention levels. In 2018, the World Health Assembly launched a coordinated global response to RHD and acute rheumatic fever and called for concerted efforts in prevention, treatment, and care,[14] the work plan of which is being developed. In the meantime, the WHO Benzathine Penicillin Technical Working Group endeavors to address global supply and demand issues for benzathine penicillin G for rheumatic fever prevention.[34] However, the disruptive effect of the COVID-19 pandemic on any progress is concerning.

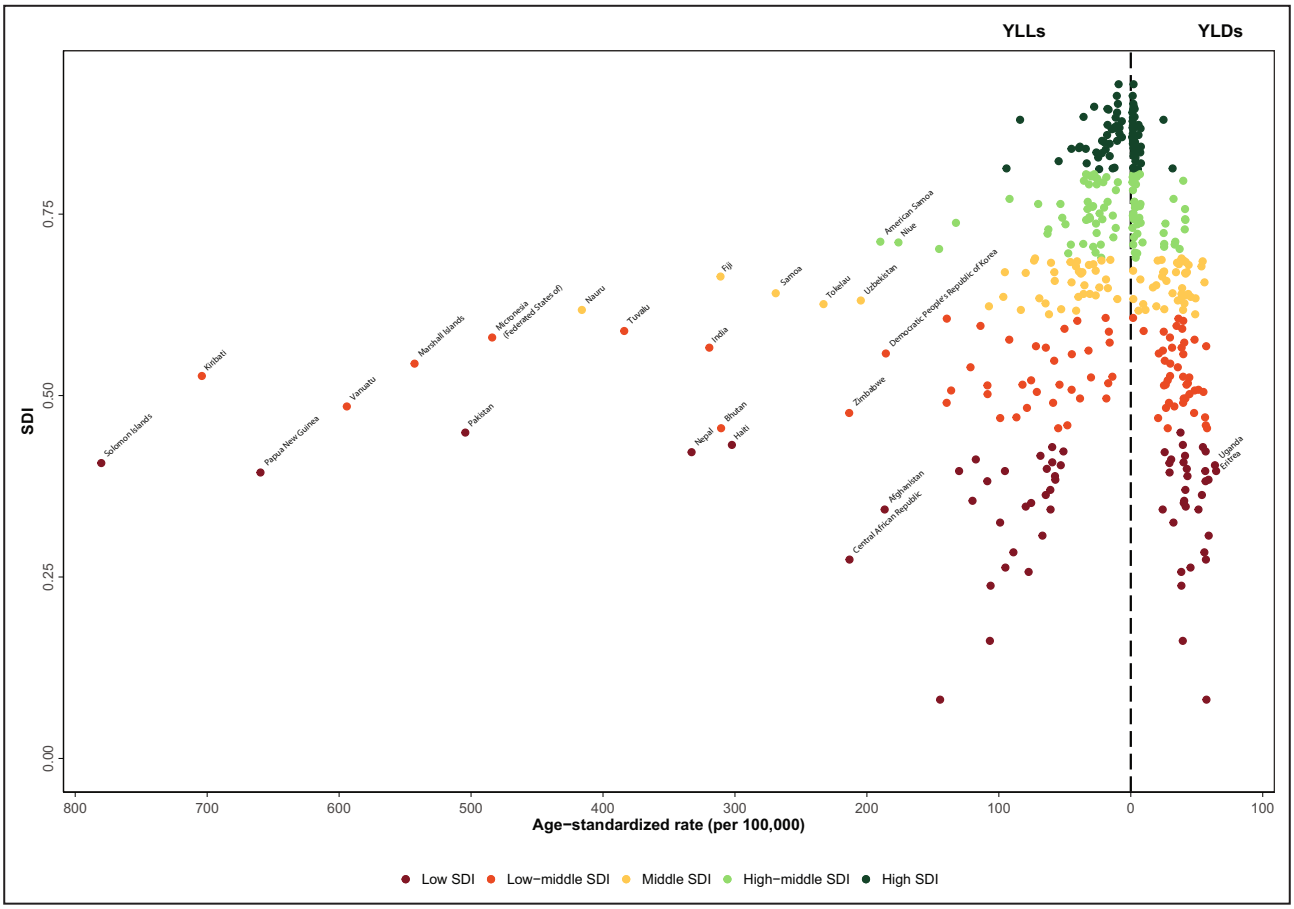

Figure 4. Expected relationship between age-standardized years of life lost (YLLs) and years lived with disability (YLDs) rates and sociodemographic index (SDI) for 204 countries.

The WHO emphasizes improved access to primary health care and extensive investment in a community and primary health care workforce trained in the prevention, diagnosis, and evidence-based management of group A β-hemolytic streptococcal pharyngitis and acute rhematic fever.[14] In this sense, public health authorities and donors need to use the existing evidence to allocate resources proportionate to disease burden and witnessed inequalities and support countries through exchange of expertise and training. As the required expertise and training are also currently lacking in low-SDI countries, the physicians' task for an antibiotic prescription could be shifted to community health workers, who could play a key role in delivering preventive medications via practical clinical algorithms, diagnostic tools, availability of appropriate antibiotics, and supportive supervision.[35]

Until there is an effective vaccine for RHD prevention, the WHO suggests following a multilevel approach against RHD: primordial prevention, including improving the socioeconomic status of populations at risk; primary prevention, including treating patients with strep throat using benzathine penicillin G; secondary prevention, including antibiotic prophylaxis among patients with previous rheumatic fever or RHD; and tertiary prevention, including medical/surgical treatment of RHD complications.[23,29]

Strengths and Limitations

This study presents estimates for incidence, prevalence, deaths, YLLs, YLDs, and DALYs attributable to RHD based on GBD 2019. It provides the opportunity to investigate the current situation and time trends of health metrics and measures worldwide during the past 3 decades to fill information gaps and implement action to address this avoidable disease. Nevertheless, the overall quality of GBD estimates fundamentally relies on the accuracy of data sources used in the modeling. The availability and reliability of registry data and the paucity of other RHD-specific data among countries with limited resources could be questionable, resulting in a need for modeling and data extrapolation. In this sense, the GBD study includes various modeling processes to overcome this limitation and presents

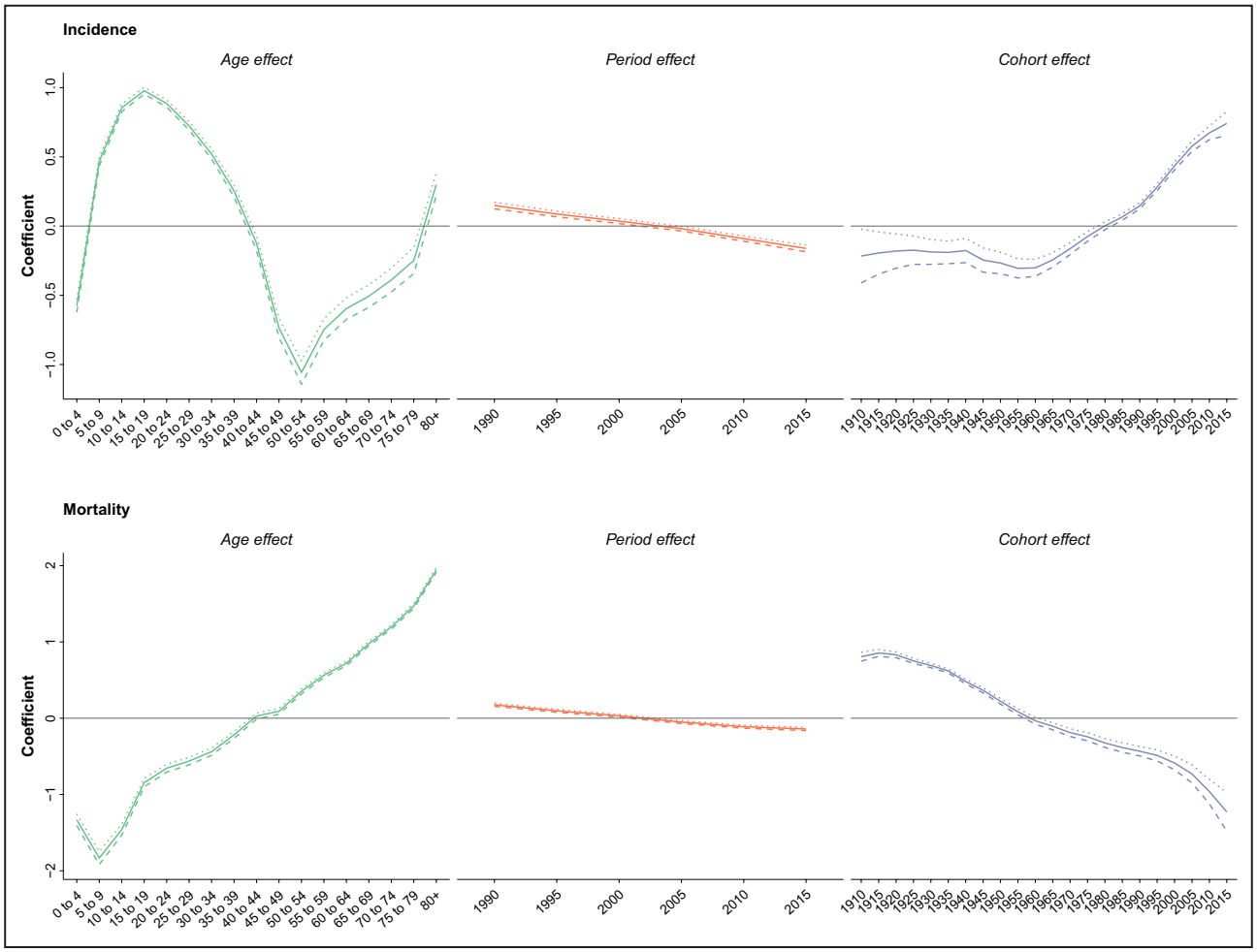

Figure 5. **Age-period-cohort effect on rheumatic heart disease incidence and death.**

metrics with 95% UIs. Moreover, the GBD does not provide subnational data estimates for all countries and thus makes it unfeasible to pick up within-country inequities by location and subpopulations.

CONCLUSIONS

Our study shows a divergence in the burden of RHD among countries based on SDI levels, which calls for including RHD in global assistance and funding. Indeed, many countries are still dealing with an unfinished infectious disease agenda, and there is an urgency to act now to prevent an increase in future burden from RHD.

ARTICLE INFORMATION

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Supplemental Material

Tables S1–S3
Figures S1–S2
Data S1

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SUPPLEMENTAL MATERIAL

Table S1. Data sources used by global burden of disease to estimate the burden of rheum

Nid	Title	Original or	Time period	Coverage ty	Geography	Data type	Secondary	Provider
140208	A Study on Rheumatic		10/1997 to	Subnationa	Yemen, Åžá	Survey		
124013	Algeria Epi	La situatior	01/1990 to	Country	Algeria	Report		National In
375935	American Samoa Statis		01/1997 to	Subnationa	United Stat	Report	Facility (no	American S
375937	American Samoa Statis		01/1998 to	Subnationa	United Stat	Report	Facility (no	American S
375939	American Samoa Statis		01/1999 to	Subnationa	United Stat	Report	Facility (no	Departmer
375941	American Samoa Statis		01/2000 to	Subnationa	United Stat	Report	Facility (no	Departmer
375943	American Samoa Statis		01/2001 to	Subnationa	United Stat	Report	Facility (no	Departmer
375945	American Samoa Statis		01/2002 to	Subnationa	United Stat	Report	Facility (no	Departmer
375947	American Samoa Statis		01/2003 to	Subnationa	United Stat	Report	Facility (no	Departmer
375949	American Samoa Statis		01/2004 to	Subnationa	United Stat	Report	Facility (no	Departmer
375951	American Samoa Statis		01/2005 to	Subnationa	United Stat	Report	Facility (no	Departmer
375953	American Samoa Statis		01/2006 to	Subnationa	United Stat	Report	Facility (no	Departmer
124029	An epidemiologic inve		01/1993 to	12/1994	China	Scientific literature		
22998	Argentina - Salud, Bien		10/1999 to	Subnationa	Argentina,	Survey	Household	Inter-unive
265349	Australia National Hea		07/2014 to	Country	Australia	Survey	Cross-secti	Australian
471395	Australia National Hea		07/2017 to	Country	Australia	Survey	Cross-secti	Australian
121841	Austria Hospital Inpati		01/1990 to	Country	Austria	Administra	Discharge,	Statistics A
121842	Austria Hospital Inpati		01/1991 to	Country	Austria	Administra	Discharge,	Statistics A
121843	Austria Hospital Inpati		01/1992 to	Country	Austria	Administra	Discharge,	Statistics A
121844	Austria Hospital Inpati		01/1993 to	Country	Austria	Administra	Discharge,	Statistics A
121845	Austria Hospital Inpati		01/1994 to	Country	Austria	Administra	Discharge,	Statistics A
121846	Austria Hospital Inpati		01/1995 to	Country	Austria	Administra	Discharge,	Statistics A
121847	Austria Hospital Inpati		01/1996 to	Country	Austria	Administra	Discharge,	Statistics A
121848	Austria Hospital Inpati		01/1997 to	Country	Austria	Administra	Discharge,	Statistics A
121849	Austria Hospital Inpati		01/1998 to	Country	Austria	Administra	Discharge,	Statistics A
121850	Austria Hospital Inpati		01/1999 to	Country	Austria	Administra	Discharge,	Statistics A
121851	Austria Hospital Inpati		01/2000 to	Country	Austria	Administra	Discharge,	Statistics A
121831	Austria Hospital Inpati		01/2001 to	Country	Austria	Administra	Discharge,	Statistics A
121854	Austria Hospital Inpati		01/2002 to	Country	Austria	Administra	Discharge,	Statistics A
121855	Austria Hospital Inpati		01/2003 to	Country	Austria	Administra	Discharge,	Statistics A
121856	Austria Hospital Inpati		01/2004 to	Country	Austria	Administra	Discharge,	Statistics A
121857	Austria Hospital Inpati		01/2005 to	Country	Austria	Administra	Discharge,	Statistics A
121858	Austria Hospital Inpati		01/2006 to	Country	Austria	Administra	Discharge,	Statistics A
121859	Austria Hospital Inpati		01/2007 to	Country	Austria	Administra	Discharge,	Statistics A
121860	Austria Hospital Inpati		01/2008 to	Country	Austria	Administra	Discharge,	Statistics A
121862	Austria Hospital Inpati		01/2009 to	Country	Austria	Administra	Discharge,	Statistics A
121863	Austria Hospital Inpati		01/2010 to	Country	Austria	Administra	Discharge,	Statistics A
121832	Austria Hospital Inpati		01/2011 to	Country	Austria	Administra	Discharge,	Statistics A
128781	Austria Hospital Inpati		01/2012 to	Country	Austria	Administra	Discharge,	Statistics A
205019	Austria Hospital Inpati		01/2013 to	Country	Austria	Administra	Discharge,	Statistics A
239353	Austria Hospital Inpati		01/2014 to	Country	Austria	Administra	Discharge,	Statistics A
264938	Bangladesh Health Bul		01/2015 to	Country	Bangladesh	Report	Epi surveill	Directorate
57735	Bangladesh Statistical Y		01/2010 to	Country	Bangladesh	Report		Bangladesh

31754	Barbados - Salud, Bien	10/1999 to	Subnationa	Barbados, S	Survey	Household	Inter-unive
265001	Bhutan Ani à½£à½¼à¼	01/1994 to	Country	Bhutan	Report	Epi surveill	Ministry of
401324	Botswana Health Stati	01/1995 to	Country	Botswana	Report	Discharge,	Statistics B
151848	Botswana I Health Stat	01/1996 to	Country	Botswana	Report	Discharge,	Epi surveilla
151849	Botswana I Republic of	01/1997 to	Country	Botswana	Report	Discharge,	Epi surveilla
401325	Botswana Health Stati	01/1998 to	Country	Botswana	Report	Discharge,	Statistics B
151850	Botswana I Republic of	01/1999 to	Country	Botswana	Report	Discharge,	Epi surveilla
401326	Botswana I Republic of	01/2000 to	Country	Botswana	Report	Discharge,	Statistics B
401327	Botswana Health Stati	01/1997 to	Country	Botswana	Report	Discharge,	Statistics B
401328	Botswana Health Stati	01/1999 to	Country	Botswana	Report	Discharge,	Statistics B
401329	Botswana Health Stati	01/2001 to	Country	Botswana	Report	Discharge,	Statistics B
108916	Botswana Health Stati	01/2001 to	Country	Botswana	Report	Subnationa	Central Sta
109203	Botswana Health Stati	01/2001 to	Country	Botswana	Report	Subnationa	Central Sta
336687	Botswana Health Stati	01/2002 to	Country	Botswana	Report	Discharge,	Statistics B
31758	Brazil - SÃ£	Salud, Bien	10/1999 to	Subnationa	Brazil, SÃ£	Survey	Household	Inter-unive
104247	Brazil Hosp	Sistema de	01/1998 to	Country	Brazil	Administra	Discharge,	Ministry of
104248	Brazil Hosp	Sistema de	01/1999 to	Country	Brazil	Administra	Discharge,	Ministry of
104249	Brazil Hosp	Sistema de	01/2000 to	Country	Brazil	Administra	Discharge,	Ministry of
104250	Brazil Hosp	Sistema de	01/2001 to	Country	Brazil	Administra	Discharge,	Ministry of
104251	Brazil Hosp	Sistema de	01/2002 to	Country	Brazil	Administra	Discharge,	Ministry of
104252	Brazil Hosp	Sistema de	01/2003 to	Country	Brazil	Administra	Discharge,	Ministry of
104253	Brazil Hosp	Sistema de	01/2004 to	Country	Brazil	Administra	Discharge,	Ministry of
104254	Brazil Hosp	Sistema de	01/2005 to	Country	Brazil	Administra	Discharge,	Ministry of
87014	Brazil Hosp	Sistema de	01/2006 to	Country	Brazil	Administra	Discharge,	Ministry of
87013	Brazil Hosp	Sistema de	01/2007 to	Country	Brazil	Administra	Discharge,	Ministry of
87012	Brazil Hosp	Sistema de	01/2008 to	Country	Brazil	Administra	Discharge,	Ministry of
26333	Brazil Hosp	Sistema de	01/2009 to	Country	Brazil	Administra	Discharge,	Ministry of
104255	Brazil Hosp	Sistema de	01/2010 to	Country	Brazil	Administra	Discharge,	Ministry of
104256	Brazil Hosp	Sistema de	01/2011 to	Country	Brazil	Administra	Discharge,	Ministry of
104257	Brazil Hosp	Sistema de	01/2012 to	Country	Brazil	Administra	Discharge,	Ministry of
104258	Brazil Hosp	Sistema de	01/2013 to	Country	Brazil	Administra	Discharge,	Ministry of
221323	Brazil Hosp	Sistema de	01/2014 to	Country	Brazil	Administra	Discharge,	Ministry of
131303	Brunei Health	Informa	01/1994 to	Country	Brunei Dar	Report		Ministry of
131299	Brunei Health	Informa	01/1995 to	Country	Brunei Dar	Report		Ministry of
131264	Brunei Health	Informa	01/1996 to	Country	Brunei Dar	Report		Ministry of
131263	Brunei Health	Informa	01/1997 to	Country	Brunei Dar	Report		Ministry of
131250	Brunei Health	Informa	01/1998 to	Country	Brunei Dar	Report		Ministry of
131227	Brunei Health	Informa	01/1998 to	Country	Brunei Dar	Report		Ministry of
131203	Brunei Health	Informa	01/1999 to	Country	Brunei Dar	Report		Ministry of
131180	Brunei Health	Informa	01/2000 to	Country	Brunei Dar	Report		Ministry of
131175	Brunei Health	Informa	01/2008 to	Country	Brunei Dar	Report		Ministry of
317388	Brunei Health	Informa	01/2009 to	Country	Brunei Dar	Report		Ministry of
317390	Brunei Health	Informa	01/2010 to	Country	Brunei Dar	Report		Ministry of
317392	Brunei Health	Informa	01/2011 to	Country	Brunei Dar	Report		Ministry of
317394	Brunei Health	Informa	01/2012 to	Country	Brunei Dar	Report		Ministry of

403410	Brunei Health Informa	01/2011 to	Country	Brunei Dar	Report	Discharge,	Ministry of
154182	Burden of Rheumatic H	01/2013 to	Country	Solomon Is	Scientific literature		
50272	Burkina Fas	Annuaire S	01/2003 to	Country	Burkina Fas	Report	National St
46940	Burkina Fas	Annuaire S	01/2004 to	Country	Burkina Fas	Report	National St
261322	Burkina Fas	Annuaire S	01/2011 to	Country	Burkina Fas	Report	Epi surveill National St
261326	Burkina Fas	Annuaire S	01/2012 to	Country	Burkina Fas	Report	Epi surveill National St
261327	Burkina Fas	Annuaire S	01/2013 to	Country	Burkina Fas	Report	Epi surveill National St
263729	Burkina Fas	Annuaire S	01/2015 to	Country	Burkina Fas	Report	Epi surveill National St
336692	Burkina Fas	Annuaire S	01/2016 to	Country	Burkina Fas	Report	Epi surveill National St
401952	Burkina Fas	Annuaire S	01/2017 to	Country	Burkina Fas	Report	Epi surveill National St
86918	Canada Discharge Abst	04/1994 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86919	Canada Discharge Abst	04/1995 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86920	Canada Discharge Abst	04/1996 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86921	Canada Discharge Abst	04/1997 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86922	Canada Discharge Abst	04/1998 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86924	Canada Discharge Abst	04/1999 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86925	Canada Discharge Abst	04/2000 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86926	Canada Discharge Abst	04/2001 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86927	Canada Discharge Abst	04/2002 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86928	Canada Discharge Abst	04/2003 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86929	Canada Discharge Abst	04/2004 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86930	Canada Discharge Abst	04/2005 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86931	Canada Discharge Abst	04/2006 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86932	Canada Discharge Abst	04/2007 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86933	Canada Discharge Abst	04/2008 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
86934	Canada Discharge Abst	04/2009 to	Subnationa	Canada, All	Administra	Discharge,	Canadian In
31762	Chile - Sant	Salud, Bien	10/1999 to	Subnationa	Chile, Regi	Survey	Household Inter-unive
283815	Chinese Fa	ä¸-å›½å®¶	07/2012 to	Country	China	Survey	Household Institute of
283816	Chinese Fa	ä¸-å›½å®¶	07/2014 to	Country	China	Survey	Community Institute of
124026	Clinical epidemiology o	01/1994 to 12/1996		Fiji	Scientific literature		
234198	Croatia Hea	Hrvatski Zd	01/1990 to	Country	Croatia	Report	Epi surveill Croatian Na
234200	Croatia Hea	Hrvatski Zd	01/1990 to	Country	Croatia	Report	Epi surveill Croatian Na
234201	Croatia Hea	Hrvatski Zd	01/1990 to	Country	Croatia	Report	Epi surveill Croatian Na
234202	Croatia Hea	Hrvatski Zd	01/1990 to	Country	Croatia	Report	Epi surveill Croatian Na
234204	Croatia Hea	Hrvatski Zd	01/1990 to	Country	Croatia	Report	Epi surveill Croatian Na
234205	Croatia Hea	Hrvatski Zd	01/1990 to	Country	Croatia	Report	Epi surveill Croatian Na
234207	Croatia Hea	Hrvatski Zd	01/1990 to	Country	Croatia	Report	Epi surveill Croatian Na
234208	Croatia Hea	Hrvatski Zd	01/1990 to	Country	Croatia	Report	Epi surveill Croatian Na
260906	Croatia Hea	Hrvatski Zd	01/1990 to	Country	Croatia	Report	Epi surveill Croatian Na
31766	Cuba - Hav	Salud, Bien	10/1999 to	Subnationa	Cuba, La Ha	Survey	Household Inter-unive
339989	Cuba Healt	Anuario Est	01/2014 to	Country	Cuba	Report	Subnationa Ministry of
339991	Cuba Healt	Anuario Est	01/2015 to	Country	Cuba	Report	Subnationa Ministry of
339992	Cuba Healt	Anuario Est	01/2016 to	Country	Cuba	Report	Subnationa Ministry of
124033	Cumulative incidence o	01/1997 to 12/1997		Australia, F	Scientific literature		
438154	Current trends in the p	01/2002 to 12/2003		Nigeria, Og	Scientific literature		

124034	Declining prevalence c	01/2000 to 12/2001	India	Scientific literature			
65605	Dominican Anuario de	01/2010 to	Country	Dominican	Report	Health faci	National St
221336	Echocardiographic scr	01/2010 to 12/2010	Senegal, D	Scientific literature			
221334	Echocardiographic scr	01/2009 to 12/2010	Fiji	Scientific literature			
137306	Echocardiography scre	01/2010 to 12/2010	Uganda	Scientific literature			
86993	Ecuador Hc Egresos Ho	01/1993 to	Country	Ecuador	Administra	Discharge,	National In
86994	Ecuador Hc Egresos Ho	01/1994 to	Country	Ecuador	Administra	Discharge,	National In
86995	Ecuador Hc Egresos Ho	01/1995 to	Country	Ecuador	Administra	Discharge,	National In
86996	Ecuador Hc Egresos Ho	01/1996 to	Country	Ecuador	Administra	Discharge,	National In
86997	Ecuador Hc Egresos Ho	01/1997 to	Country	Ecuador	Administra	Discharge,	National In
86998	Ecuador Hc Egresos Ho	01/1998 to	Country	Ecuador	Administra	Discharge,	National In
86999	Ecuador Hc Egresos Ho	01/1999 to	Country	Ecuador	Administra	Discharge,	National In
87000	Ecuador Hc Egresos Ho	01/2000 to	Country	Ecuador	Administra	Discharge,	National In
87001	Ecuador Hc Egresos Ho	01/2001 to	Country	Ecuador	Administra	Discharge,	National In
87002	Ecuador Hc Egresos Ho	01/2002 to	Country	Ecuador	Administra	Discharge,	National In
87003	Ecuador Hc Egresos Ho	01/2003 to	Country	Ecuador	Administra	Discharge,	National In
87004	Ecuador Hc Egresos Ho	01/2004 to	Country	Ecuador	Administra	Discharge,	National In
87005	Ecuador Hc Egresos Ho	01/2005 to	Country	Ecuador	Administra	Discharge,	National In
87006	Ecuador Hc Egresos Ho	01/2006 to	Country	Ecuador	Administra	Discharge,	National In
87007	Ecuador Hc Egresos Ho	01/2007 to	Country	Ecuador	Administra	Discharge,	National In
87008	Ecuador Hc Egresos Ho	01/2008 to	Country	Ecuador	Administra	Discharge,	National In
87009	Ecuador Hc Egresos Ho	01/2009 to	Country	Ecuador	Administra	Discharge,	National In
87010	Ecuador Hc Egresos Ho	01/2010 to	Country	Ecuador	Administra	Discharge,	National In
87011	Ecuador Hc Egresos Ho	01/2011 to	Country	Ecuador	Administra	Discharge,	National In
114876	Ecuador Hospital Inpat	01/2012 to	Country	Ecuador	Administra	Discharge,	National In
140210	Egypt Evaluation of RF	01/1998 to	Country	Egypt	Survey		
124056	Epidemiological survey	01/1992 to 12/1993	India	Scientific literature			
221348	Epidemiological trends	01/2007 to 12/2008	India, Hima	Scientific literature			
124031	Epidemiology of rheun	01/1991 to 12/1991	India	Scientific literature			
3822	European Hospital Mo	01/1999 to	Country	Austria, Be	Administra	Discharge,	World Heal
295213	European Hospital Mo	01/1990 to	Country	Austria, Be	Administra	Discharge,	World Heal
124027	Evaluation of a screeni	01/2003 to 12/2004	Tonga	Scientific literature			
264845	Fiji Ministry of Health a	01/2014 to	Country	Fiji	Report		Ministry of
284974	Fiji Ministry of Health a	01/2015 to	Country	Fiji	Report		Ministry of
56428	Fiji Ministry of Health A	01/2001 to	Country	Fiji	Report	Subnationa	Ministry of
56430	Fiji Ministry of Health A	01/2006 to	Country	Fiji	Report	Subnationa	Ministry of
56432	Fiji Ministry of Health A	01/2007 to	Country	Fiji	Report	Subnationa	Ministry of
56528	Fiji Ministry of Health A	01/2008 to	Country	Fiji	Report		Ministry of
56534	Fiji Ministry of Health A	01/2009 to	Country	Fiji	Report		Ministry of
56540	Fiji Ministry of Health A	01/2010 to	Country	Fiji	Report		Ministry of
345792	Georgia Health Care St	01/1996 to	Country	Georgia	Report	Subnationa	National Ce
67132	Germany H Diagnosed	01/2009 to	Country	Germany	Administra	Discharge,	Federal Sta
344307	Global Burden of Disea	01/1990 to	Global	Global	Estimate		Institute fo
124055	High prevalence of rhe	01/2006 to 12/2006	Fiji	Scientific literature			
124024	High prevalence of rhe	01/2007 to 12/2008	India	Scientific literature			

137307	High prevalence of rhe	01/2008 to	12/2008	Fiji	Scientific literature		
221324	High prevalence of rhe	01/2008 to	12/2010	France, Ne	Scientific literature		
96443	IHME Cause of Death E	01/1990 to	Global	Andean Lat	Modeled data		
237616	IHME GBD 2015 DisMc	01/1990 to	Global	Global	Modeled data		
259601	IHME GBD Endemic Rh	Jan-90	Global	Global	Modeled data		
259602	IHME GBD Non-endem	Jan-90	Global	Global	Modeled data		
115480	Incidence and characte	01/2006 to	12/2007	South Afric	Scientific literature		
340908	India - Karnataka Medi	01/2016 to	Subnationa	India, Karn	Vital registration		Directorate
425540	India - Karnataka Medi	01/2017 to	Subnationa	India, Karn	Vital registration		Directorate
457843	India - Karnataka Medi	01/2018 to	Subnationa	India, Karn	Vital registration		Directorate
425558	India - Kerala Medical	01/2011 to	Subnationa	India, Kera	Vital registration		Departmer
425559	India - Kerala Medical	01/2012 to	Subnationa	India, Kera	Vital registration		Departmer
425560	India - Kerala Medical	01/2013 to	Subnationa	India, Kera	Vital registration		Departmer
425561	India - Kerala Medical	01/2014 to	Subnationa	India, Kera	Vital registration		Departmer
425562	India - Kerala Medical	01/2015 to	Subnationa	India, Kera	Vital registration		Departmer
425563	India - Kerala Medical	01/2016 to	Subnationa	India, Kera	Vital registration		Departmer
425564	India - Kerala Medical	01/2017 to	Subnationa	India, Kera	Vital registration		Departmer
467750	India - Kerala Medical	01/2018 to	Subnationa	India, Kera	Vital registration		Departmer
278978	India - Triva	THFR	01/2013 to	Subnationa	India, Kera	Disease registry	
93804	India Annual Health Su	10/2011 to	Subnationa	India, Assa	Survey	Household	Office of th
234353	India Annual Health Su	07/2010 to	Subnationa	India, Assa	Survey	Household, Individual,	
432098	India HealthRise Baseli	11/2014 to	Subnationa	India, Hima	Survey	Cross-secti	Institute fo
424883	India HealthRise Endlir	08/2018 to	Subnationa	India, Hima	Survey	Cross-secti	Institute fo
278544	India Jai Vigyan Missio	01/2001 to	Country	India, Assa	Disease registry		Indian Cou
206640	Indonesia I Sistem Info	01/2013 to	Country	Indonesia,	Administra	Emergency	Ministry of
301106	Iran - Goles	GCS	01/2004 to	Subnationa	Iran (Islami	Survey	Household, Individual,
305739	Iran - Pars Cohort Stud	13-Jan	Subnationa	Iran (Islami	Survey	Cross-secti	Shiraz Univ
285460	Italy - Friuli-Venezia Gi	01/2010 to	Subnationa	Italy, Friuli-	Administra	Discharge, Emergency,	
285464	Italy - Friuli-Venezia Gi	01/2011 to	Subnationa	Italy, Friuli-	Administra	Discharge, Emergency,	
285465	Italy - Friuli-Venezia Gi	01/2012 to	Subnationa	Italy, Friuli-	Administra	Discharge, Emergency,	
285467	Italy - Friuli-Venezia Gi	01/2013 to	Subnationa	Italy, Friuli-	Administra	Discharge, Emergency,	
285468	Italy - Friuli-Venezia Gi	01/2014 to	Subnationa	Italy, Friuli-	Administra	Discharge, Emergency,	
285471	Italy - Friuli-Venezia Gi	01/2015 to	Subnationa	Italy, Friuli-	Administra	Discharge, Emergency,	
331137	Italy Hospital Inpatient	01/2005 to	Country	Italy	Administra	Discharge, Emergency,	
331138	Italy Hospital Inpatient	01/2006 to	Country	Italy	Administra	Discharge, Emergency,	
331139	Italy Hospital Inpatient	01/2007 to	Country	Italy	Administra	Discharge, Emergency,	
331140	Italy Hospital Inpatient	01/2008 to	Country	Italy	Administra	Discharge, Emergency,	
331141	Italy Hospital Inpatient	01/2009 to	Country	Italy	Administra	Discharge, Emergency,	
331142	Italy Hospital Inpatient	01/2010 to	Country	Italy	Administra	Discharge, Emergency,	
331143	Italy Hospital Inpatient	01/2011 to	Country	Italy	Administra	Discharge, Emergency,	
331144	Italy Hospital Inpatient	01/2012 to	Country	Italy	Administra	Discharge, Emergency,	
331145	Italy Hospital Inpatient	01/2013 to	Country	Italy	Administra	Discharge, Emergency,	
331146	Italy Hospital Inpatient	01/2014 to	Country	Italy	Administra	Discharge, Emergency,	
331147	Italy Hospital Inpatient	01/2015 to	Country	Italy	Administra	Discharge, Emergency,	
331148	Italy Hospital Inpatient	01/2016 to	Country	Italy	Administra	Discharge, Emergency,	

421046	Italy Hospital Inpatient	01/2017 to	Country	Italy	Administra	Discharge,	Emergency,
421047	Italy Hospital Inpatient	01/2018 to	Country	Italy	Administra	Discharge,	Emergency,
140209	Laos Rheumatic Heart	01/2007 to	Country	Lao People	Survey		
222733	Lebanon St Ø§Ù„Ù†Ø´	01/2007 to	Country	Lebanon	Report	Epi surveill	Ministry of
117290	Malaysia H Petunjuk-P	01/1992 to	Country	Malaysia	Report	Discharge,	Ministry of
265328	Malaysia Health Indica	01/2007 to	Country	Malaysia	Report	Discharge,	Ministry of
240363	Malaysia H Petunjuk B	01/2008 to	Country	Malaysia	Report	Discharge,	Ministry of
283380	Malaysia Health Indica	01/2010 to	Country	Malaysia	Report	Discharge,	Ministry of
335815	Malaysia Health Indica	01/2011 to	Country	Malaysia	Report	Discharge,	Ministry of
423236	Malaysia Health Indica	01/2015 to	Country	Malaysia	Report	Discharge,	Ministry of
31770	Mexico - M Salud, Bien	10/1999 to	Subnationa	Mexico, Di	Survey	Household	Inter-unive
86949	Mexico Mi BASES DE D	01/2000 to	Country	Mexico	Administra	Discharge,	Secretariat
86950	Mexico Mi BASES DE D	01/2001 to	Country	Mexico	Administra	Discharge,	Secretariat
86951	Mexico Mi BASES DE D	01/2002 to	Country	Mexico	Administra	Discharge,	Secretariat
86952	Mexico Mi BASES DE D	01/2003 to	Country	Mexico	Administra	Discharge,	Secretariat
86953	Mexico Mi BASES DE D	01/2004 to	Country	Mexico	Administra	Discharge,	Secretariat
86954	Mexico Mi BASES DE D	01/2005 to	Country	Mexico	Administra	Discharge,	Secretariat
86955	Mexico Sec Bases De D	01/2006 to	Country	Mexico	Administra	Discharge,	Secretariat
86956	Mexico Sec Bases De D	01/2007 to	Country	Mexico	Administra	Discharge,	Secretariat
86957	Mexico Sec Bases De D	01/2008 to	Country	Mexico	Administra	Discharge,	Secretariat
86958	Mexico Sec Bases De D	01/2009 to	Country	Mexico	Administra	Discharge,	Secretariat
94170	Mexico Sec Bases De D	01/2010 to	Country	Mexico	Administra	Discharge,	Secretariat
94171	Mexico Sec Bases De D	01/2011 to	Country	Mexico	Administra	Discharge,	Secretariat
121282	Mexico Sec Bases De D	01/2012 to	Country	Mexico	Administra	Discharge,	Secretariat
220205	Mexico Sec Bases De D	01/2014 to	Country	Mexico	Administra	Discharge,	Secretariat
283829	Mexico SUI EpidemiolÃ	01/2001 to	Country	Mexico	Epi surveill	Subnationa	Directorate
283827	Mexico SUI EpidemiolÃ	01/2002 to	Country	Mexico	Epi surveill	Subnationa	Directorate
283823	Mexico SUI EpidemiolÃ	01/2004 to	Country	Mexico	Epi surveill	Subnationa	Directorate
283821	Mexico SUI EpidemiolÃ	01/2005 to	Country	Mexico	Epi surveill	Subnationa	Directorate
283818	Mexico SUI EpidemiolÃ	01/2006 to	Country	Mexico	Epi surveill	Subnationa	Directorate
282711	Mexico SUI BoletÃ-n E	01/2007 to	Country	Mexico	Epi surveill	Subnationa	Directorate
283825	Mexico SUI EpidemiolÃ	01/2003 to	Country	Mexico	Epi surveill	Subnationa	Directorate
282709	Mexico SUI BoletÃ-n E	01/2008 to	Country	Mexico	Epi surveill	Subnationa	Directorate
93575	Morocco H SantÃ© en	01/1994 to	Country	Morocco	Report		Ministry of
93854	Morocco H SantÃ© en	01/1995 to	Country	Morocco	Report		Ministry of
108548	Morocco H SantÃ© en	01/1995 to	Country	Morocco	Report	Subnationa	Ministry of
93768	Morocco H SantÃ© en	01/1996 to	Country	Morocco	Report	Subnationa	Ministry of
108549	Morocco H SantÃ© en	01/1996 to	Country	Morocco	Report	Subnationa	Ministry of
93767	Morocco H SantÃ© en	01/1997 to	Country	Morocco	Report	Subnationa	Ministry of
108550	Morocco H SantÃ© en	01/2000 to	Country	Morocco	Report	Subnationa	Ministry of
93576	Morocco H SantÃ© en	01/2001 to	Country	Morocco	Report	Subnationa	Ministry of
108551	Morocco H SantÃ© en	01/2002 to	Country	Morocco	Report	Subnationa	Ministry of
150481	Morocco H SantÃ© en	01/2004 to	Country	Morocco	Report	Subnationa	Ministry of
288558	Nepal Depa Annual Rep	07/2008 to	Country	Nepal	Report	Subnationa	Departmer
288559	Nepal Depa Annual Rep	07/2009 to	Country	Nepal	Report	Subnationa	Departmer

288560	Nepal Dep	Annual Rep	07/2010 to	Country	Nepal	Report	Subnationa	Departmer
288561	Nepal Dep	Annual Rep	07/2011 to	Country	Nepal	Report	Subnationa	Departmer
288562	Nepal Dep	Annual Rep	07/2012 to	Country	Nepal	Report	Subnationa	Departmer
288565	Nepal Dep	Annual Rep	07/2013 to	Country	Nepal	Report	Subnationa	Departmer
288566	Nepal Dep	Annual Rep	07/2014 to	Country	Nepal	Report	Subnationa	Departmer
126195	New Zealand	Health Su	07/2011 to	Country	New Zealar	Survey	Household	Ministry of
222052	New Zealand	Health Su	07/2012 to	Country	New Zealar	Survey	Cross-secti	Ministry of
222056	New Zealand	Health Su	07/2013 to	Country	New Zealar	Survey	Cross-secti	Ministry of
264325	New Zealand	Health Su	07/2014 to	Country	New Zealar	Survey	Cross-secti	Ministry of
294041	New Zealand	Health Su	07/2015 to	Country	New Zealar	Survey	Household	Ministry of
220786	New Zealand	National	01/2000 to	Country	New Zealar	Administra	Discharge,	Ministry of
220787	New Zealand	National	01/2001 to	Country	New Zealar	Administra	Discharge,	Ministry of
220788	New Zealand	National	01/2002 to	Country	New Zealar	Administra	Discharge,	Ministry of
220789	New Zealand	National	01/2003 to	Country	New Zealar	Administra	Discharge,	Ministry of
220790	New Zealand	National	01/2004 to	Country	New Zealar	Administra	Discharge,	Ministry of
220791	New Zealand	National	01/2005 to	Country	New Zealar	Administra	Discharge,	Ministry of
220792	New Zealand	National	01/2006 to	Country	New Zealar	Administra	Discharge,	Ministry of
220793	New Zealand	National	01/2007 to	Country	New Zealar	Administra	Discharge,	Ministry of
220794	New Zealand	National	01/2008 to	Country	New Zealar	Administra	Discharge,	Ministry of
220795	New Zealand	National	01/2009 to	Country	New Zealar	Administra	Discharge,	Ministry of
220796	New Zealand	National	01/2010 to	Country	New Zealar	Administra	Discharge,	Ministry of
220797	New Zealand	National	01/2011 to	Country	New Zealar	Administra	Discharge,	Ministry of
220798	New Zealand	National	01/2012 to	Country	New Zealar	Administra	Discharge,	Ministry of
220799	New Zealand	National	01/2013 to	Country	New Zealar	Administra	Discharge,	Ministry of
220800	New Zealand	National	01/2014 to	Country	New Zealar	Administra	Discharge,	Ministry of
293984	New Zealand	National	01/2015 to	Country	New Zealar	Administra	Discharge,	Ministry of
409529	New Zealand	National	01/2016 to	Country	New Zealar	Administra	Discharge,	Ministry of
409530	New Zealand	National	01/2017 to	Country	New Zealar	Administra	Discharge,	Ministry of
149500	Norway Pa	Norsk Pasie	01/2008 to	Country	Norway	Administra	Discharge,	Norwegian
149501	Norway Pa	Norsk Pasie	01/2009 to	Country	Norway	Administra	Discharge,	Norwegian
149502	Norway Pa	Norsk Pasie	01/2010 to	Country	Norway	Administra	Discharge,	Norwegian
149503	Norway Pa	Norsk Pasie	01/2011 to	Country	Norway	Administra	Discharge,	Norwegian
149504	Norway Pa	Norsk Pasie	01/2012 to	Country	Norway	Administra	Discharge,	Norwegian
137309	Optimising	echocardio	01/2008 to	12/2010	New Zealar	Scientific	literature	
156608	Palestine H	Health Ann	01/2002 to	Country	Palestine	Report	Epi surveill	Ministry of
209934	Palestine H	Health Ann	01/2008 to	Country	Palestine	Report	Epi surveill	Ministry of
299387	Palestine H	Health Ann	01/2009 to	Country	Palestine	Report	Epi surveill	Ministry of
317840	Palestine H	Health Ann	01/2009 to	Country	Palestine	Report	Epi surveill	Ministry of
265091	Philippines	Health Stat	01/2013 to	Country	Philippines	Report	Subnationa	Departmer
234396	Poland Der	Rocznik De	01/2006 to	Country	Poland	Vital regist	Subnationa	Central Sta
234395	Poland Der	Rocznik De	01/2007 to	Country	Poland	Vital regist	Subnationa	Central Sta
234393	Poland Der	Rocznik De	01/2008 to	Country	Poland	Vital regist	Subnationa	Central Sta
234394	Poland Der	Rocznik De	01/2009 to	Country	Poland	Vital regist	Subnationa	Central Sta
234392	Poland Der	Rocznik De	01/2010 to	Country	Poland	Vital regist	Subnationa	Central Sta
234385	Poland Der	Rocznik De	01/2012 to	Country	Poland	Vital regist	Subnationa	Central Sta

234272	Poland Der	Rocznik De	01/2013 to	Country	Poland	Vital regist	Subnationa Central Sta
234257	Poland Der	Rocznik De	01/2014 to	Country	Poland	Vital regist	Subnationa Central Sta
338502	Poland Der	Rocznik De	01/2016 to	Country	Poland	Vital regist	Subnationa Central Sta
221332	Population-based stud		01/2000 to	12/2009	Italy	Scientific literature	
285520	Portugal Hospital Inpa		01/2015 to	Country	Portugal	Administra	Discharge, Inpatient
137308	Prevalence and outcor		01/2008 to	12/2010	India	Scientific literature	
124060	Prevalence of chronic		01/2001 to	12/2002	China	Scientific literature	
124021	Prevalence of heart dis		01/1994 to	12/1994	Kenya	Scientific literature	
221338	Prevalence of rheumat		01/2011 to	12/2011	India, Andh	Scientific literature	
124023	Prevalence of rheumat		01/2002 to	12/2002	Nepal	Scientific literature	
124038	Prevalence of rheumat		01/1997 to	12/2000	India	Scientific literature	
124018	Prevalence of rheumat		01/1991 to	12/1991	Bangladesh	Scientific literature	
221330	Prevalence of rheumat		01/2010 to	12/2011	India, Hima	Scientific literature	
124054	Prevalence of rheumat		01/1993 to	12/1995	Nepal	Scientific literature	
124051	Prevalence of rheumat		01/1993 to	12/1995	Nepal	Scientific literature	
124020	Prevalence of rheumat		01/1992 to	12/1992	Brazil	Scientific literature	
124046	Prevalence of rheumat		01/1995 to	12/1995	Ethiopia	Scientific literature	
124017	Prevalence of rheumat		01/1993 to	12/1994	Egypt	Scientific literature	
221326	Prevalence of rheumat		01/2004 to	12/2005	Yemen	Scientific literature	
124040	Prevalence of rheumat		01/2001 to	12/2005	Cambodia,	Scientific literature	
221346	Prevalence of rheumat		01/2010 to	12/2011	Brazil, Min	Scientific literature	
124049	Prevalence of rheumat		01/2006 to	12/2009	Nicaragua	Scientific literature	
124050	Prevalence of rheumat		01/2002 to	12/2004	India	Scientific literature	
124053	Prevalence of rheumat		01/2001 to	12/2002	Pakistan	Scientific literature	
124041	Prevalence of rheumat		01/2003 to	12/2006	India	Scientific literature	
124044	Prevention and contro		01/1996 to	12/1996	Cuba	Scientific literature	
154703	RHD Prevention and C		01/2012 to	Country	Kiribati	Scientific literature	
124059	Rheumatic fever and r		01/2004 to	12/2005	Samoa	Scientific literature	
124030	Rheumatic fever and r		01/1996 to	12/2000	Fiji	Scientific literature	
124032	Rheumatic heart disea		01/1994 to	12/1996	Oman	Scientific literature	
124047	Rheumatic heart disea		01/1995 to	12/1995	Ethiopia	Scientific literature	
124022	Rheumatic heart disea		01/1991 to	12/1992	India	Scientific literature	
221352	Rheumatic heart disea		01/2007 to	12/2012	India, Andh	Scientific literature	
124035	Rheumatic heart disea		01/2005 to	12/2005	Congo	Scientific literature	
124045	Rheumatic heart disea		01/1995 to	12/1995	Turkey	Scientific literature	
124048	Rheumatic heart disea		01/1995 to	12/1995	Ethiopia	Scientific literature	
124015	Rheumatism in the Ru		01/1994 to	12/1994	Russian Fe	Scientific literature	
11117	Romania Li	Romanian	04/1994 to	Country	Romania	Survey	Household
408789	Russia Stat	Ð¡Ñ‚Ð°Ñ‚	01/2009 to	Country	Russian Fe	Report	Subnationa Ministry of
409153	Russia Stat	Ð¡Ñ‚Ð°Ñ‚	01/2010 to	Country	Russian Fe	Report	Subnationa Ministry of
409154	Russia Stat	Ð¡Ñ‚Ð°Ñ‚	01/2011 to	Country	Russian Fe	Report	Subnationa Ministry of
21313	Samoa Demographic a		08/2009 to	Country	Samoa	Survey	Cross-secti Demograpl
267785	Samoa Demographic a		07/2014 to	Country	Samoa	Survey	Cross-secti Samoa Bur
424449	San Marinc	Bollettino c	01/2015 to	Country	San Marinc	Report	Epi surveill Office of Ec
424451	San Marinc	Bollettino c	01/2016 to	Country	San Marinc	Report	Epi surveill Office of Ec

465655	San Marinc	Bollettino c	01/2017 to	Country	San Marinc	Report	Epi surveill	Office of Ec
59315	Saudi Arabia	Health St	01/1994 to	Country	Saudi Arab	Report		Ministry of
58940	Saudi Arabia	Health St	01/1991 to	Country	Saudi Arab	Report		Ministry of
59281	Saudi Arabia	Health St	01/1996 to	Country	Saudi Arab	Report		Ministry of
90699	Saudi Arab	Ø§Ù„ÙfØª(	01/2006 to	Country	Saudi Arab	Report	Discharge,	Ministry of
139727	Saudi Arab	Ø§Ù„ÙfØª(	01/2008 to	Country	Saudi Arab	Report	Discharge,	Ministry of
240594	Saudi Arab	Ø§Ù„ÙfØª(	01/2007 to	Country	Saudi Arab	Report		Ministry of
240597	Saudi Arab	Ø§Ù„ÙfØª(	01/2005 to	Country	Saudi Arab	Report		Ministry of
282133	Saudi Arab	Ø§Ù„ÙfØª(	01/2006 to	Country	Saudi Arab	Report	Epi surveill	Ministry of
318473	Saudi Arab	Ø§Ù„ÙfØª(	01/2007 to	Country	Saudi Arab	Report	Epi surveill	Ministry of
380042	Saudi Arab	Ø§Ù„ÙfØª(	01/2013 to	Country	Saudi Arab	Report	Epi surveill	Ministry of
425017	Saudi Arab	Ø§Ù„ÙfØª(	01/2014 to	Country	Saudi Arab	Report	Epi surveill	Ministry of
323996	School and	Communit	01/2014 to	12/2014	Malawi	Scientific literature		
221344	Screening for	rheumat	01/2013 to	12/2013	France, Ne	Scientific literature		
221340	Screening for	rheumat	01/2005 to	12/2005	Mozambiq	Scientific literature		
221342	Simplified	Rheumatic H	01/2013 to	12/2014	Uganda, G	Scientific literature		
425197	South Africa	HealthRis	18-Nov	Subnationa	South Afric	Survey	Cross-secti	Institute fo
155628	South Afric	SANHANES	04/2012 to	Country	South Afric	Survey	Cross-secti	Human Sci
228102	South Afric	SABSSM 2(	05/2008 to	Country	South Afric	Survey	Cross-secti	Human Sci
259997	Sri Lanka	Indoor Morb	01/2004 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
259996	Sri Lanka	Indoor Morb	01/2005 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
259995	Sri Lanka	Indoor Morb	01/2006 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
259994	Sri Lanka	Indoor Morb	01/2007 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
259993	Sri Lanka	Indoor Morb	01/2008 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
259992	Sri Lanka	Indoor Morb	01/2009 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
259991	Sri Lanka	Indoor Morb	01/2010 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
328685	Sri Lanka	Indoor Morb	01/2011 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
259990	Sri Lanka	Indoor Morb	01/2012 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
259989	Sri Lanka	Indoor Morb	01/2013 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
328682	Sri Lanka	Indoor Morb	01/2014 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
328684	Sri Lanka	Indoor Morb	01/2015 to	Country	Sri Lanka	Administra	Discharge,	Ministry of
124052	Status of	rheumatic he	01/1993 to	12/1994	Pakistan	Scientific literature		
221350	Subclinical	rheumatic H	01/2007 to	12/2008	Eritrea	Scientific literature		
25114	Sudan Health	Statistic	01/2000 to	Country	Sudan [Hist	Report	Discharge,	Inpatient, O
124039	Survey of	rheumatic h	01/1996 to	12/1996	Congo	Scientific literature		
305649	Sweden Na	Patientregi	01/1990 to	Country	Sweden	Administra	Discharge,	National Bo
305648	Sweden Na	Patientregi	01/1991 to	Country	Sweden	Administra	Discharge,	National Bo
305647	Sweden Na	Patientregi	01/1992 to	Country	Sweden	Administra	Discharge,	National Bo
305646	Sweden Na	Patientregi	01/1993 to	Country	Sweden	Administra	Discharge,	National Bo
305645	Sweden Na	Patientregi	01/1994 to	Country	Sweden	Administra	Discharge,	National Bo
305644	Sweden Na	Patientregi	01/1995 to	Country	Sweden	Administra	Discharge,	National Bo
305643	Sweden Na	Patientregi	01/1996 to	Country	Sweden	Administra	Discharge,	National Bo
305642	Sweden Na	Patientregi	01/1997 to	Country	Sweden	Administra	Discharge,	National Bo
121334	Sweden Na	Patientregi	01/1998 to	Country	Sweden	Administra	Discharge,	National Bo
121405	Sweden Na	Patientregi	01/1999 to	Country	Sweden	Administra	Discharge,	National Bo

121407	Sweden Na	Patientregi	01/2000 to	Country	Sweden	Administra	Discharge,	National Bo
121408	Sweden Na	Patientregi	01/2001 to	Country	Sweden	Administra	Discharge,	National Bo
121415	Sweden Na	Patientregi	01/2002 to	Country	Sweden	Administra	Discharge,	National Bo
121416	Sweden Na	Patientregi	01/2003 to	Country	Sweden	Administra	Discharge,	National Bo
121417	Sweden Na	Patientregi	01/2004 to	Country	Sweden	Administra	Discharge,	National Bo
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121421	Sweden Na	Patientregi	01/2008 to	Country	Sweden	Administra	Discharge,	National Bo
121422	Sweden Na	Patientregi	01/2009 to	Country	Sweden	Administra	Discharge,	National Bo
121423	Sweden Na	Patientregi	01/2010 to	Country	Sweden	Administra	Discharge,	National Bo
121424	Sweden Na	Patientregi	01/2011 to	Country	Sweden	Administra	Discharge,	National Bo
121425	Sweden Na	Patientregi	01/2012 to	Country	Sweden	Administra	Discharge,	National Bo
305653	Sweden Na	Patientregi	01/2013 to	Country	Sweden	Administra	Discharge,	National Bo
305654	Sweden Na	Patientregi	01/2014 to	Country	Sweden	Administra	Discharge,	National Bo
310042	Thailand	Public Health	01/1994 to	Country	Thailand	Report	Epi surveill	Ministry of
309938	Thailand	Public Health	01/1992 to	Country	Thailand	Report	Epi surveill	Bureau of H
93778	Thailand	Pı à¸ªà¸–à¸´à¸	01/1994 to	Country	Thailand	Report		Bureau of H
93780	Thailand	Public Health	01/2004 to	Country	Thailand	Report	National vi	Bureau of H
152023	Thailand	Public Health	01/1996 to	Country	Thailand	Report	National vi	Bureau of H
152022	Thailand	Public Health	01/2006 to	Country	Thailand	Report	National vi	Bureau of H
265095	Thailand	Public Health	01/1998 to	Country	Thailand	Report	National vi	Bureau of H
265096	Thailand	Public Health	01/1999 to	Country	Thailand	Report	National vi	Bureau of H
265097	Thailand	Public Health	01/2009 to	Country	Thailand	Report	National vi	Bureau of H
283358	Thailand	Pı à¸ªà¸–à¸´à¸	01/2001 to	Country	Thailand	Report	National vi	Bureau of H
140211	The prevalence of rhe		02/2007 to	Subnationa	Mali, Bama	Survey		
221328	The utility of handheld		01/2012 to	12/2012	Uganda, Gı	Scientific literature		
322460	Therapeutic Decision-I		01/2003 to	Subnationa	China	Scientific literature		
160563	Tonga Report of the M		01/1995 to	Country	Tonga	Report	Epi surveillance, Finan	
160555	Tonga Report of the M		07/1997 to	Country	Tonga	Report	Epi surveill	Ministry of
160458	Tonga Report of the M		07/1998 to	Country	Tonga	Report	Epi surveill	Ministry of
264605	Tonga Report of the M		07/2000 to	Country	Tonga	Report	Epi surveill	Ministry of
264606	Tonga Report of the M		07/2000 to	Country	Tonga	Report	Epi surveill	Ministry of
134187	United Kingdom - Engl		04/2001 to	Subnationa	United Kin	Administra	Inpatient	Informatio
121272	United Kingdom - Engl		04/2002 to	Subnationa	United Kin	Administra	Inpatient	Informatio
121273	United Kingdom - Engl		04/2003 to	Subnationa	United Kin	Administra	Inpatient, (	Informatio
121274	United Kingdom - Engl		04/2004 to	Subnationa	United Kin	Administra	Inpatient, (	Informatio
121275	United Kingdom - Engl		04/2005 to	Subnationa	United Kin	Administra	Inpatient, (	Informatio
121276	United Kingdom - Engl		04/2006 to	Subnationa	United Kin	Administra	Inpatient, (	Informatio
121277	United Kingdom - Engl		04/2007 to	Subnationa	United Kin	Administra	Emergency	Informatio
121278	United Kingdom - Engl		04/2008 to	Subnationa	United Kin	Administra	Emergency	Informatio
121279	United Kingdom - Engl		04/2009 to	Subnationa	United Kin	Administra	Emergency	Informatio
121280	United Kingdom - Engl		04/2010 to	Subnationa	United Kin	Administra	Emergency	Informatio
121281	United Kingdom - Engl		04/2011 to	Subnationa	United Kin	Administra	Emergency	Informatio
265423	United Kingdom - Engl		04/2012 to	Subnationa	United Kin	Administra	Emergency	NHS Digital

265424	United Kingdom - Engl	04/2013 to	Subnationa	United Kin	Administra	Emergency	NHS Digital
265425	United Kingdom - Engl	04/2014 to	Subnationa	United Kin	Administra	Emergency	NHS Digital
133729	United Kin	Health and	09/1991 to	Subnationa	United Kin	Survey	Household
310812	United States - King Cc	01/1990 to	Subnationa	United Stat	Estimate		Institute fo
223670	United States Market	01/2000 to	Country	United Stat	Administra	Discharge,	Truven Hea
224501	United States Market	01/2010 to	Country	United Stat	Administra	Discharge,	Truven Hea
307820	United States Market	01/2011 to	Country	United Stat	Administra	Discharge,	Truven Hea
224502	United States Market	01/2012 to	Country	United Stat	Administra	Discharge,	Truven Hea
307821	United States Market	01/2013 to	Country	United Stat	Administra	Discharge,	Truven Hea
307822	United States Market	01/2014 to	Country	United Stat	Administra	Discharge,	Truven Hea
307823	United States Market	01/2015 to	Country	United Stat	Administra	Discharge,	Truven Hea
377003	United States Market	01/2016 to	Country	United Stat	Administra	Discharge,	Truven Hea
418020	United States Market	01/2017 to	Country	United Stat	Administra	Discharge,	Truven Hea
223672	United States Market	01/2000 to	Country	United Stat	Administra	Discharge,	Truven Hea
224499	United States Market	01/2010 to	Country	United Stat	Administra	Discharge,	Truven Hea
307815	United States Market	01/2011 to	Country	United Stat	Administra	Discharge,	Truven Hea
224500	United States Market	01/2012 to	Country	United Stat	Administra	Discharge,	Truven Hea
307817	United States Market	01/2013 to	Country	United Stat	Administra	Discharge,	Truven Hea
307818	United States Market	01/2014 to	Country	United Stat	Administra	Discharge,	Truven Hea
307819	United States Market	01/2015 to	Country	United Stat	Administra	Discharge,	Truven Hea
377002	United States Market	01/2016 to	Country	United Stat	Administra	Discharge,	Truven Hea
418019	United States Market	01/2017 to	Country	United Stat	Administra	Discharge,	Truven Hea
40280	United States National	01/1990 to	Country	United Stat	Survey	Cross-secti	National Ce
40330	United States National	01/1991 to	Country	United Stat	Survey	Cross-secti	National Ce
40749	United States National	01/1992 to	Country	United Stat	Survey	Cross-secti	National Ce
40766	United States National	01/1993 to	Country	United Stat	Survey	Cross-secti	National Ce
40821	United States National	01/1994 to	Country	United Stat	Survey	Cross-secti	National Ce
41114	United States National	01/1995 to	Country	United Stat	Survey	Cross-secti	National Ce
41126	United States National	01/1996 to	Country	United Stat	Survey	Cross-secti	National Ce
86912	United States National	01/1990 to	Country	United Stat	Survey	Discharge,	National Ce
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86886	United States National	01/1996 to	Country	United Stat	Survey	Discharge,	National Ce
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86891	United States National	01/2001 to	Country	United Stat	Survey	Discharge,	National Ce
86892	United States National	01/2002 to	Country	United Stat	Survey	Discharge,	National Ce
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86894	United States National	01/2004 to	Country	United Stat	Survey	Discharge,	National Ce
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86898	United States National	01/2008 to	Country	United Stat	Survey	Discharge,	National Ce
86899	United States National	01/2009 to	Country	United Stat	Survey	Discharge,	National Ce
86900	United States National	01/2010 to	Country	United Stat	Survey	Discharge,	National Ce
90314	United States State In	01/2003 to	Country	United Stat	Administra	Discharge,	Healthcare
90315	United States State In	01/2004 to	Country	United Stat	Administra	Discharge,	Healthcare
90316	United States State In	01/2005 to	Country	United Stat	Administra	Discharge,	Healthcare
90317	United States State In	01/2006 to	Country	United Stat	Administra	Discharge,	Healthcare
90318	United States State In	01/2007 to	Country	United Stat	Administra	Discharge,	Healthcare
90319	United States State In	01/2008 to	Country	United Stat	Administra	Discharge,	Healthcare
90322	United States State In	01/2009 to	Country	United Stat	Administra	Discharge,	Healthcare
299086	United States State In	01/2010 to	Country	United Stat	Administra	Discharge,	Healthcare
299087	United States State In	01/2011 to	Country	United Stat	Administra	Discharge,	Healthcare
299088	United States State In	01/2012 to	Country	United Stat	Administra	Discharge,	Healthcare
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299090	United States State In	01/2014 to	Country	United Stat	Administra	Discharge,	Healthcare
31774	Uruguay - I	Salud, Bien	10/1999 to	Subnationa	Uruguay, N	Survey	Household	Inter-unive
299375	Vietnam Hospital Data	01/2013 to	Subnationa	Viet Nam	Administrative data		
292665	Yemen Anr	Ø§Ù„ØªÙ‚	01/2013 to	Country	Yemen	Report	Discharge,	Ministry of
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ı Annual Statistical Hea	########	katelw	########

Table S2. The proportion of population growth, aging and increase in age specific incidence rates on new cases of RHD

Location		Sex	New cases		Expected new cases in 2019		% 1990 - 2019 new cases change cause			% 1990 - 2019 new cases overall change
			1990	2019	Population growth	Population growth + Aging	Population growth	Age structure change	Incidence rate change	
Global		Both	1,863,318	2,789,443	2,694,910	2,455,090	44.6%	-12.9%	17.9%	49.7%
		Female	1,000,723	1,490,770	1,452,988	1,322,437	45.2%	-13%	16.8%	49%
		Male	862,595	1,298,673	1,242,769	1,131,080	44.1%	-12.9%	19.4%	50.6%
GBD Region	Andean Latin America	Both	22,192	31,560	36,968	31,536	66.6%	-24.5%	0.1%	42.2%
		Female	11,756	16,400	19,466	16,290	65.6%	-27%	0.9%	39.5%
		Male	10,436	15,160	17,490	15,199	67.6%	-22%	-0.4%	45.3%
	Australasia	Both	1,146	1,652	1,642	2,223	43.3%	50.7%	-49.8%	44.2%
		Female	705	969	1,019	1,329	44.5%	43.9%	-51.1%	37.3%
		Male	441	684	626	890	42.1%	59.8%	-46.7%	55.2%
	Caribbean	Both	18,112	22,113	24,218	20,562	33.7%	-20.2%	8.6%	22.1%
		Female	9,644	11,738	12,901	10,802	33.8%	-21.8%	9.7%	21.7%
		Male	8,468	10,375	11,318	9,746	33.6%	-18.6%	7.4%	22.5%
	Central Asia	Both	29,171	36,559	39,390	36,347	35%	-10.4%	0.7%	25.3%
		Female	15,087	18,405	20,127	18,500	33.4%	-10.8%	-0.6%	22%
		Male	14,085	18,154	19,257	17,827	36.7%	-10.2%	2.3%	28.9%
	Central Europe	Both	17,236	10,379	16,010	19,747	-7.1%	21.7%	-54.4%	-39.8%
		Female	9,785	5,944	9,133	11,159	-6.7%	20.7%	-53.3%	-39.3%
		Male	7,450	4,435	6,886	8,533	-7.6%	22.1%	-55%	-40.5%
	Central Latin America	Both	43,611	56,914	66,435	57,468	52.3%	-20.6%	-1.3%	30.5%
		Female	23,797	30,614	36,624	31,305	53.9%	-22.4%	-2.9%	28.6%
		Male	19,814	26,301	29,866	26,133	50.7%	-18.8%	0.8%	32.7%
	Central Sub-Saharan Africa	Both	55,678	137,074	131,920	134,416	136.9%	4.5%	4.8%	146.2%
		Female	27,716	69,012	65,460	67,044	136.2%	5.7%	7.1%	149%

	Male	27,962	68,063	66,466	67,386	137.7%	3.3%	2.4%	143.4%
East Asia	Both	377,447	277,451	453,565	341,478	20.2%	-29.7%	-17%	-26.5%
	Female	189,160	139,939	229,945	173,546	21.6%	-29.8%	-17.8%	-26%
	Male	188,287	137,512	223,784	167,898	18.9%	-29.7%	-16.1%	-27%
Eastern Europe	Both	37,137	23,020	34,426	39,780	-7.3%	14.4%	-45.1%	-38%
	Female	22,586	14,822	21,037	24,106	-6.9%	13.6%	-41.1%	-34.4%
	Male	14,550	8,198	13,415	15,603	-7.8%	15%	-50.9%	-43.7%
Eastern Sub-Saharan Africa	Both	179,848	426,528	389,433	394,974	116.5%	3.1%	17.5%	137.2%
	Female	95,248	225,322	206,002	208,267	116.3%	2.4%	17.9%	136.6%
	Male	84,599	201,205	183,408	186,556	116.8%	3.7%	17.3%	137.8%
High-income Asia Pacific	Both	7,834	9,731	8,456	14,757	7.9%	80.4%	-64.2%	24.2%
	Female	5,102	6,293	5,522	9,218	8.2%	72.4%	-57.3%	23.4%
	Male	2,732	3,438	2,941	5,410	7.6%	90.4%	-72.2%	25.8%
High-income North America	Both	33,720	57,228	43,759	57,715	29.8%	41.4%	-1.4%	69.7%
	Female	20,405	31,541	26,320	32,974	29%	32.6%	-7%	54.6%
	Male	13,316	25,686	17,388	24,522	30.6%	53.6%	8.7%	92.9%
North Africa and Middle East	Both	96,353	165,232	169,991	153,055	76.4%	-17.6%	12.6%	71.5%
	Female	48,427	82,198	84,173	75,798	73.8%	-17.3%	13.2%	69.7%
	Male	47,926	83,034	85,745	77,205	78.9%	-17.8%	12.2%	73.3%
Oceania	Both	2,983	6,305	6,122	5,814	105.2%	-10.3%	16.5%	111.3%
	Female	1,544	3,274	3,181	3,014	106%	-10.8%	16.8%	112%
	Male	1,439	3,031	2,943	2,800	104.4%	-9.9%	16.1%	110.6%
South Asia	Both	532,080	858,392	875,081	848,268	64.5%	-5%	1.9%	61.3%
	Female	297,480	479,056	498,844	479,896	67.7%	-6.4%	-0.3%	61%
	Male	234,600	379,336	378,845	369,287	61.5%	-4.1%	4.3%	61.7%
Southeast Asia	Both	94,836	123,836	136,889	123,616	44.3%	-14%	0.2%	30.6%
	Female	53,450	67,205	76,706	67,599	43.5%	-17%	-0.7%	25.7%
	Male	41,386	56,631	60,087	55,722	45.2%	-10.5%	2.2%	36.8%

Southern Latin America	Both	13,930	17,073	18,769	16,816	34.7%	-14%	1.8%	22.6%
	Female	7,090	8,580	9,587	8,535	35.2%	-14.8%	0.6%	21%
	Male	6,839	8,493	9,182	8,280	34.3%	-13.2%	3.1%	24.2%
Southern Sub-Saharan Africa	Both	46,379	62,165	69,424	61,295	49.7%	-17.5%	1.9%	34%
	Female	24,906	32,546	37,010	32,099	48.6%	-19.7%	1.8%	30.7%
	Male	21,474	29,619	32,391	29,109	50.8%	-15.3%	2.4%	37.9%
Tropical Latin America	Both	97,756	111,876	142,972	111,642	46.3%	-32%	0.2%	14.4%
	Female	51,728	58,965	76,500	58,080	47.9%	-35.6%	1.7%	14%
	Male	46,028	52,911	66,548	53,482	44.6%	-28.4%	-1.2%	15%
Western Europe	Both	30,608	33,622	34,724	45,277	13.4%	34.5%	-38.1%	9.8%
	Female	20,189	20,987	22,687	28,250	12.4%	27.6%	-36%	4%
	Male	10,419	12,634	11,938	16,448	14.6%	43.3%	-36.6%	21.3%
Western Sub-Saharan Africa	Both	125,262	320,733	296,804	305,405	136.9%	6.9%	12.2%	156%
	Female	64,920	166,960	156,257	157,729	140.7%	2.3%	14.2%	157.2%
	Male	60,342	153,773	140,687	147,642	133.2%	11.5%	10.2%	154.8%

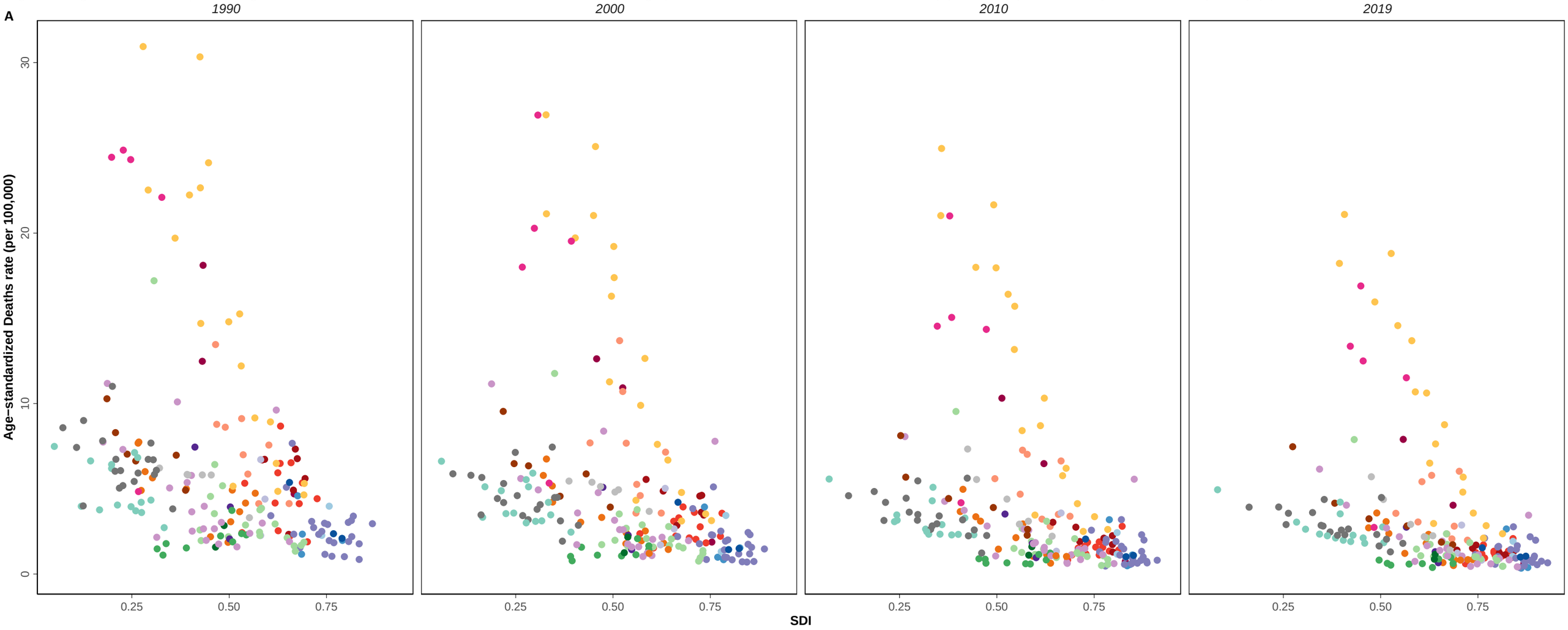
Table S3: Coefficient of age-period-cohort effect on rheumatic heart disease incidence and mortality

Effect	Factor	Incidence			Mortality		
		Coefficient	95% CI	P-Value	Coefficient	95% CI	P-Value
Age	Under 5	-0.58	(-0.62 to -0.53)	<0.001	-1.33	(-1.41 to -1.26)	<0.001
	5-9	0.47	(0.43 to 0.5)	<0.001	-1.83	(-1.92 to -1.75)	<0.001
	10-14	0.85	(0.83 to 0.88)	<0.001	-1.46	(-1.53 to -1.39)	<0.001
	15-19	0.98	(0.95 to 1)	<0.001	-0.84	(-0.9 to -0.79)	<0.001
	20-24	0.89	(0.86 to 0.91)	<0.001	-0.66	(-0.71 to -0.6)	<0.001
	25-29	0.72	(0.69 to 0.75)	<0.001	-0.56	(-0.61 to -0.51)	<0.001
	30-34	0.52	(0.48 to 0.56)	<0.001	-0.44	(-0.49 to -0.39)	<0.001
	35-39	0.25	(0.21 to 0.3)	<0.001	-0.22	(-0.26 to -0.17)	<0.001
	40-44	-0.12	(-0.18 to -0.07)	<0.001	0.03	(-0.01 to 0.07)	0.165
	45-49	-0.74	(-0.8 to -0.67)	<0.001	0.09	(0.05 to 0.13)	<0.001
	50-54	-1.06	(-1.14 to -0.97)	<0.001	0.35	(0.32 to 0.39)	<0.001
	55-59	-0.75	(-0.83 to -0.67)	<0.001	0.56	(0.53 to 0.59)	<0.001
	60-64	-0.6	(-0.67 to -0.52)	<0.001	0.72	(0.69 to 0.75)	<0.001
	65-69	-0.51	(-0.59 to -0.42)	<0.001	0.98	(0.95 to 1)	<0.001
	70-74	-0.39	(-0.48 to -0.3)	<0.001	1.2	(1.17 to 1.23)	<0.001
	75-79	-0.25	(-0.34 to -0.15)	<0.001	1.47	(1.44 to 1.5)	<0.001
	80+	0.3	(0.22 to 0.38)	<0.001	1.94	(1.91 to 1.97)	<0.001
Period	1990-1994	0.15	(0.12 to 0.17)	<0.001	0.18	(0.16 to 0.2)	<0.001
	1995-1999	0.09	(0.07 to 0.11)	<0.001	0.1	(0.08 to 0.12)	<0.001
	2000-2004	0.04	(0.02 to 0.05)	<0.001	0.03	(0.01 to 0.05)	0.001
	2005-2009	-0.02	(-0.04 to 0)	0.024	-0.05	(-0.07 to -0.03)	<0.001
	2010-2014	-0.09	(-0.11 to -0.07)	<0.001	-0.11	(-0.13 to -0.09)	<0.001
	2015-2019	-0.16	(-0.19 to -0.14)	<0.001	-0.14	(-0.16 to -0.12)	<0.001
Cohort	1910	-0.22	(-0.41 to -0.02)	0.029	0.81	(0.75 to 0.86)	<0.001
	1915	-0.19	(-0.35 to -0.04)	0.012	0.86	(0.81 to 0.9)	<0.001
	1920	-0.18	(-0.3 to -0.06)	0.004	0.83	(0.79 to 0.87)	<0.001
	1925	-0.17	(-0.28 to -0.07)	0.001	0.75	(0.72 to 0.78)	<0.001
	1930	-0.19	(-0.28 to -0.1)	<0.001	0.69	(0.66 to 0.72)	<0.001
	1935	-0.19	(-0.27 to -0.11)	<0.001	0.62	(0.59 to 0.65)	<0.001
	1940	-0.18	(-0.26 to -0.09)	<0.001	0.48	(0.45 to 0.51)	<0.001
	1945	-0.25	(-0.33 to -0.16)	<0.001	0.37	(0.33 to 0.4)	<0.001
	1950	-0.27	(-0.34 to -0.19)	<0.001	0.22	(0.18 to 0.26)	<0.001
	1955	-0.31	(-0.37 to -0.24)	<0.001	0.08	(0.04 to 0.12)	<0.001
	1960	-0.3	(-0.36 to -0.24)	<0.001	-0.03	(-0.08 to 0.01)	0.135
	1965	-0.24	(-0.3 to -0.19)	<0.001	-0.1	(-0.15 to -0.06)	<0.001
	1970	-0.16	(-0.21 to -0.12)	<0.001	-0.19	(-0.24 to -0.14)	<0.001
	1975	-0.08	(-0.11 to -0.04)	<0.001	-0.24	(-0.3 to -0.19)	<0.001
	1980	0	(-0.03 to 0.03)	0.89	-0.32	(-0.38 to -0.27)	<0.001
	1985	0.07	(0.04 to 0.09)	<0.001	-0.38	(-0.45 to -0.32)	<0.001
	1990	0.15	(0.12 to 0.17)	<0.001	-0.43	(-0.49 to -0.37)	<0.001
	1995	0.28	(0.26 to 0.31)	<0.001	-0.49	(-0.56 to -0.42)	<0.001
	2000	0.44	(0.41 to 0.46)	<0.001	-0.59	(-0.68 to -0.5)	<0.001
	2005	0.58	(0.54 to 0.61)	<0.001	-0.73	(-0.85 to -0.61)	<0.001
	2010	0.67	(0.62 to 0.72)	<0.001	-0.96	(-1.12 to -0.8)	<0.001
	2015	0.74	(0.66 to 0.83)	<0.001	-1.23	(-1.48 to -0.98)	<0.001
Constant		-8.41	(-8.43 to -8.39)	<0.001	-10.06	(-10.08 to -10.04)	<0.001
Deviance			57072.64			9601.68	
AIC			574.91			107.94	

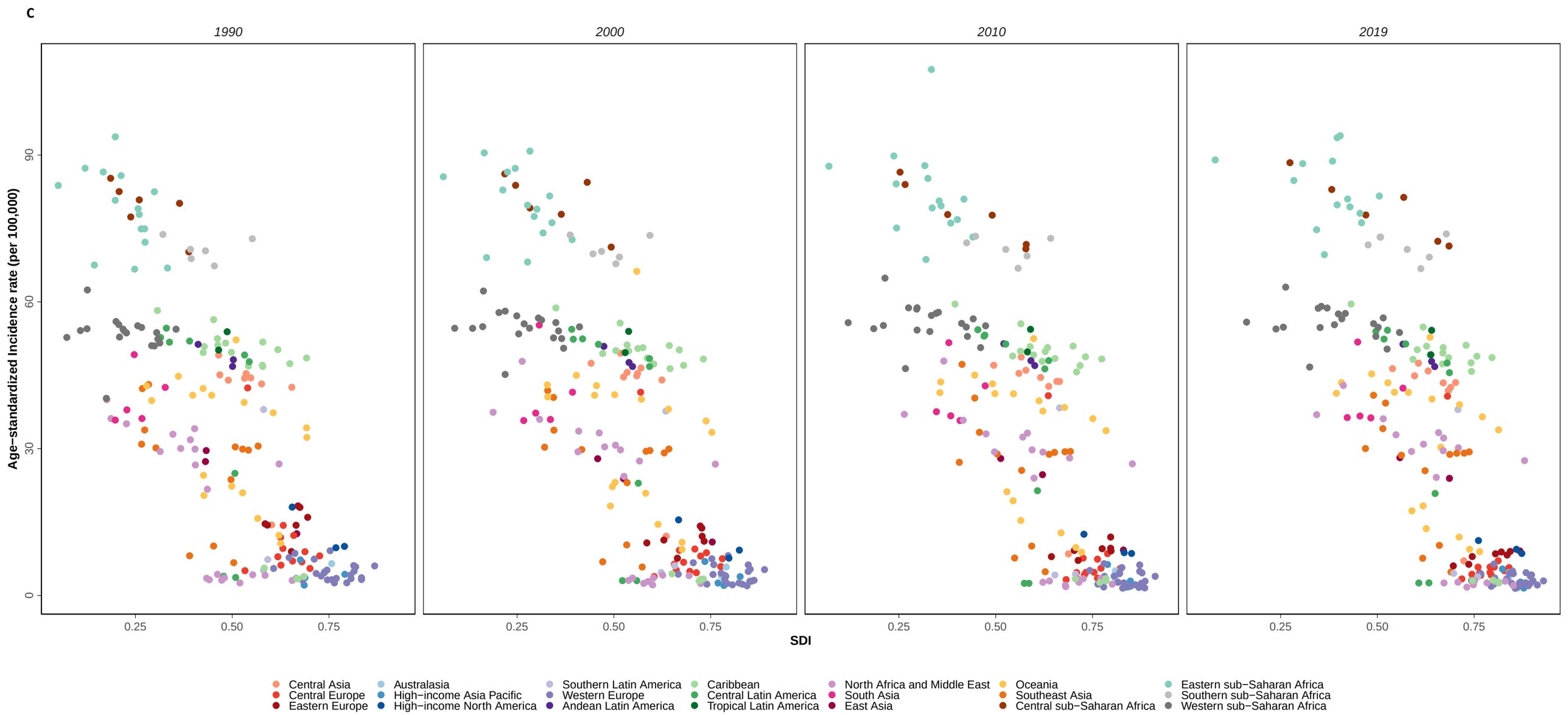
BIC	56795.14	9324.18

CI, Confidence Interval; AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion

Figure S1. Age-standardized epidemiological measures of Rheumatic Heart Disease based on socio-demographic index in 1990, 2000, 2010 and 2019 for (A) deaths, (B) Disability-Adjusted Life Years (DALYs), (C) incidence, and (D) prevalence.

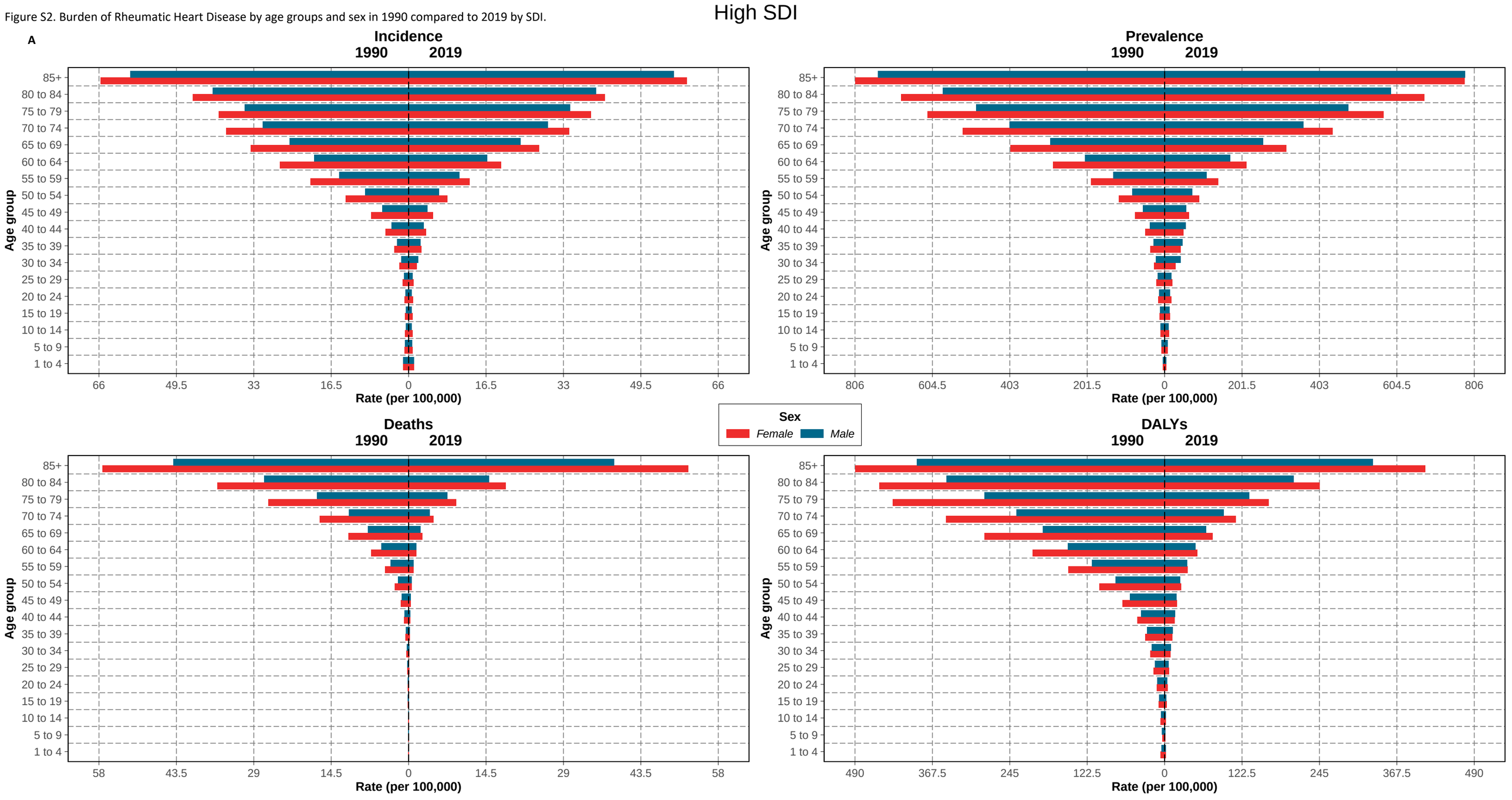



B
1990
2000
2010
2019
Age−standardized DALYs rate (per 100,000)
0
250
500
750
1000
1250
0.25
0.50
0.75
SDI
Central Asia
Central Europe
Eastern Europe
Australasia
High−income Asia Pacific
High−income North America
Southern Latin America
Western Europe
Andean Latin America
Caribbean
Central Latin America
Tropical Latin America
North Africa and Middle East
South Asia
East Asia
Oceania
Southeast Asia
Central sub−Saharan Africa
Eastern sub−Saharan Africa
Southern sub−Saharan Africa
Western sub−Saharan Africa


C
1990
2000
2010
2019
Age−standardized Incidence rate (per 100,000)
0
30
60
90
0.25
0.50
0.75
SDI
Central Asia
Central Europe
Eastern Europe
Australasia
High−income Asia Pacific
High−income North America
Southern Latin America
Western Europe
Andean Latin America
Caribbean
Central Latin America
Tropical Latin America
North Africa and Middle East
South Asia
East Asia
Oceania
Southeast Asia
Central sub−Saharan Africa
Eastern sub−Saharan Africa
Southern sub−Saharan Africa
Western sub−Saharan Africa

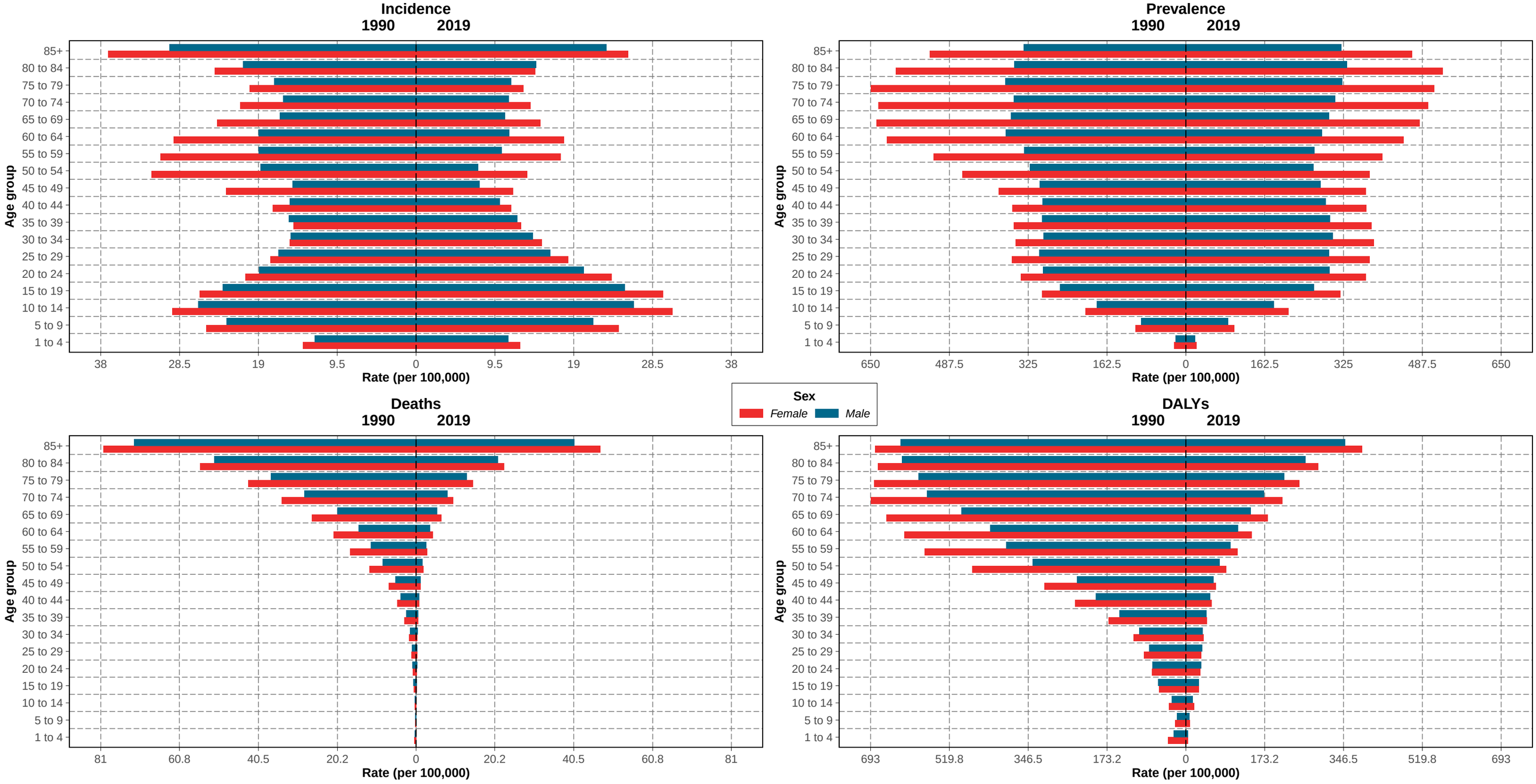

D
1990
2000
2010
2019
Age−standardized Prevalence rate (per 100,000)
0
500
1000
1500
0.25
0.50
0.75
SDI
Central Asia
Central Europe
Eastern Europe
Australasia
High−income Asia Pacific
High−income North America
Southern Latin America
Western Europe
Andean Latin America
Caribbean
Central Latin America
Tropical Latin America
North Africa and Middle East
South Asia
East Asia
Oceania
Southeast Asia
Central sub−Saharan Africa
Eastern sub−Saharan Africa
Southern sub−Saharan Africa
Western sub−Saharan Africa

Figure S2. Burden of Rheumatic Heart Disease by age groups and sex in 1990 compared to 2019 by SDI.



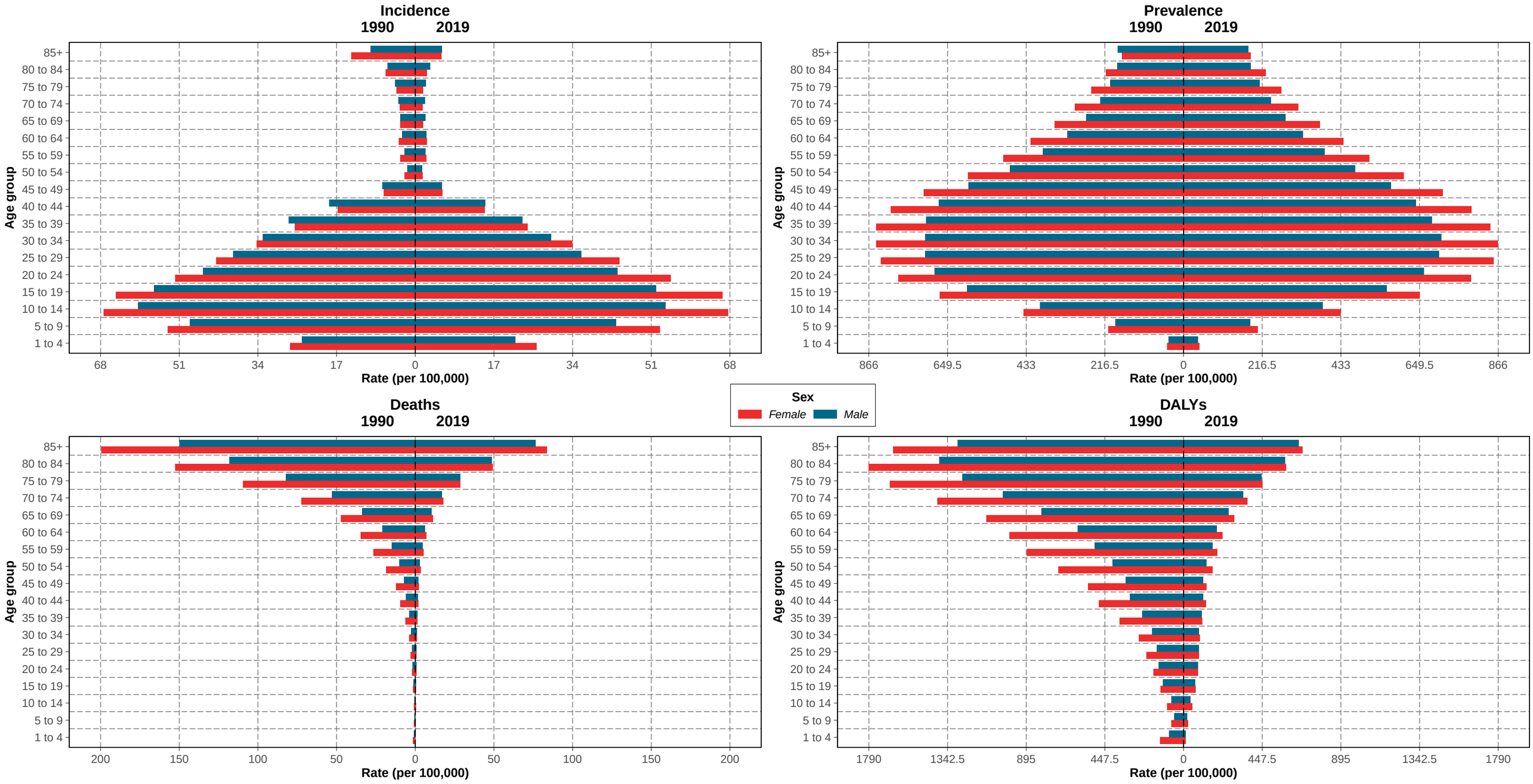
B

High−middle SDI



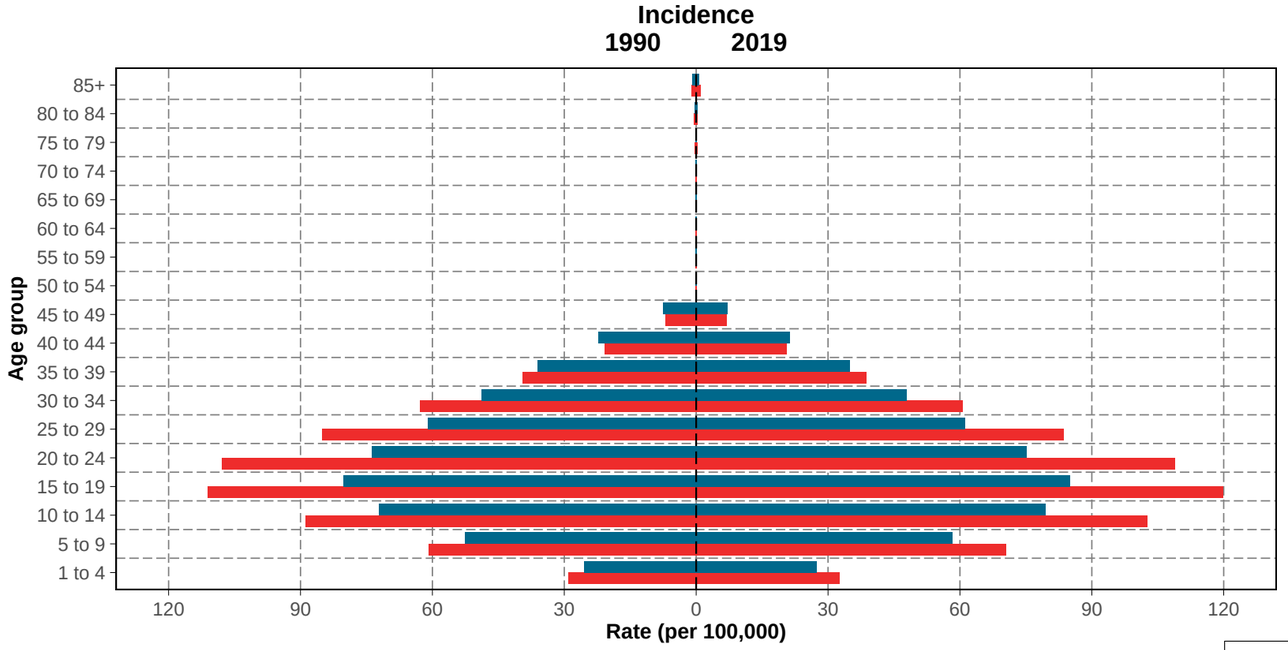
c

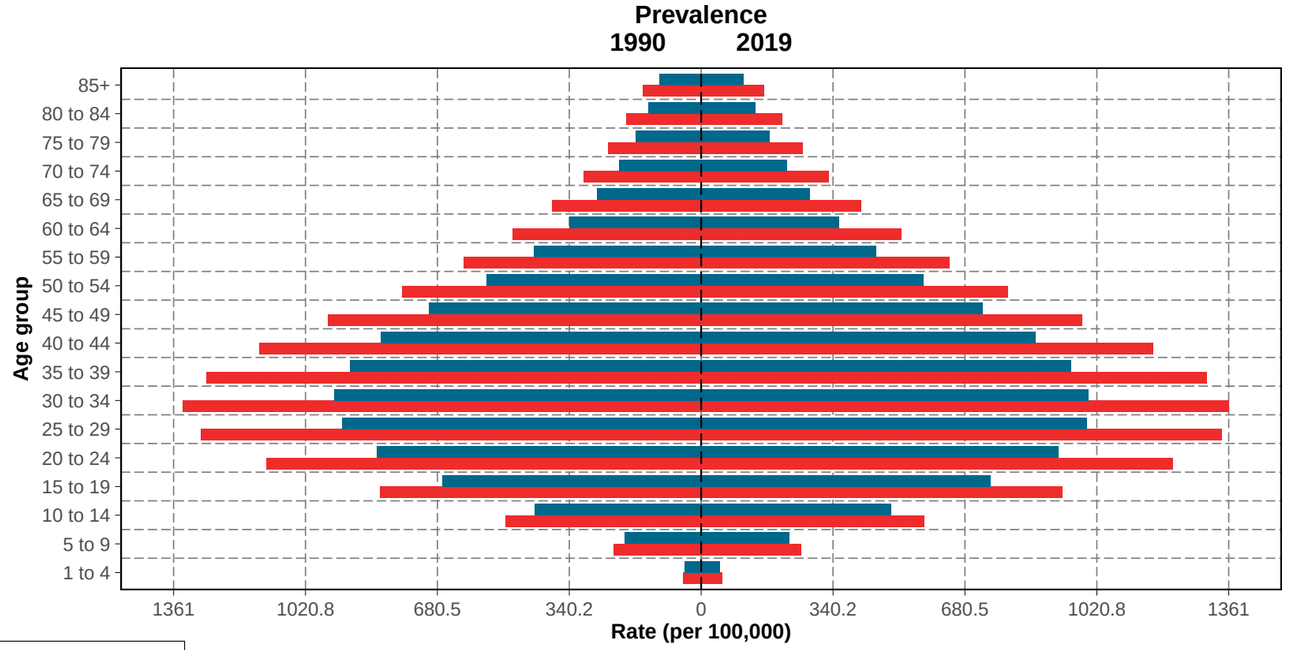
Middle SDI

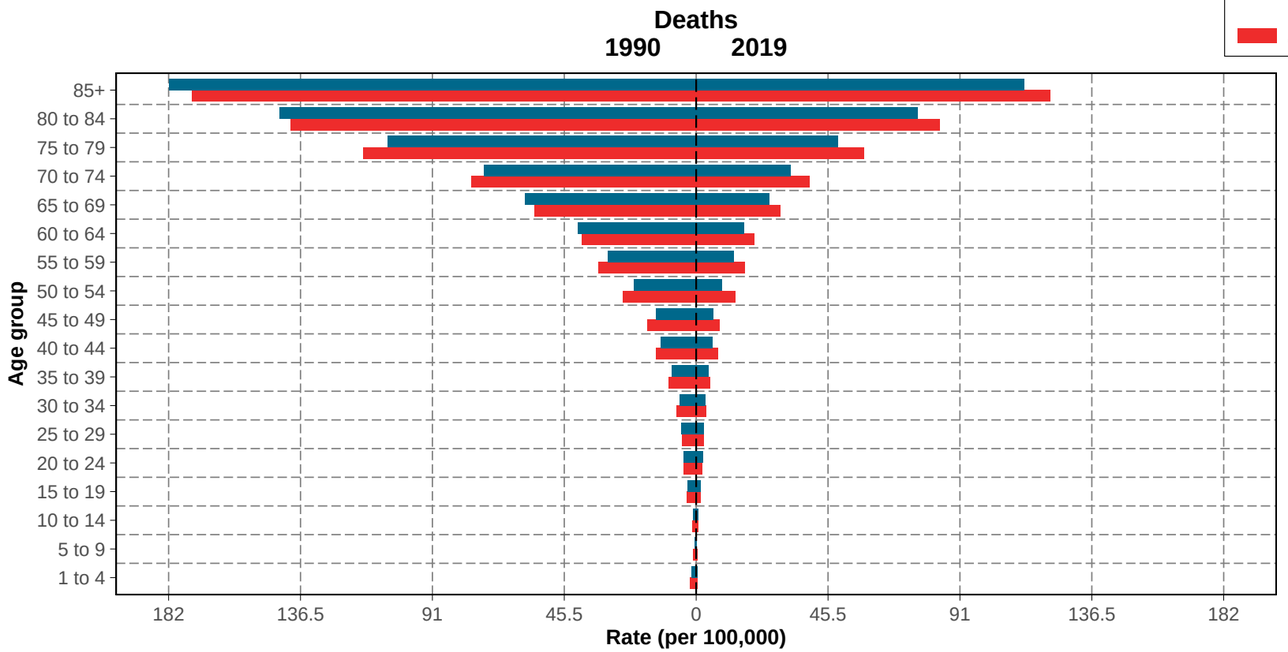

Incidence
1990 2019
Prevalence
1990 2019
Deaths
1990 2019
DALYs
1990 2019
Age group
85+
80 to 84
75 to 79
70 to 74
65 to 69
60 to 64
55 to 59
50 to 54
45 to 49
40 to 44
35 to 39
30 to 34
25 to 29
20 to 24
15 to 19
10 to 14
5 to 9
1 to 4
68 51 34 17 0 17 34 51 68
866 649.5 433 216.5 0 216.5 433 649.5 866
200 150 100 50 0 50 100 150 200
1790 1342.5 895 447.5 0 447.5 895 1342.5 1790
Rate (per 100,000)
Sex
Female
Male

D

Low−middle SDI

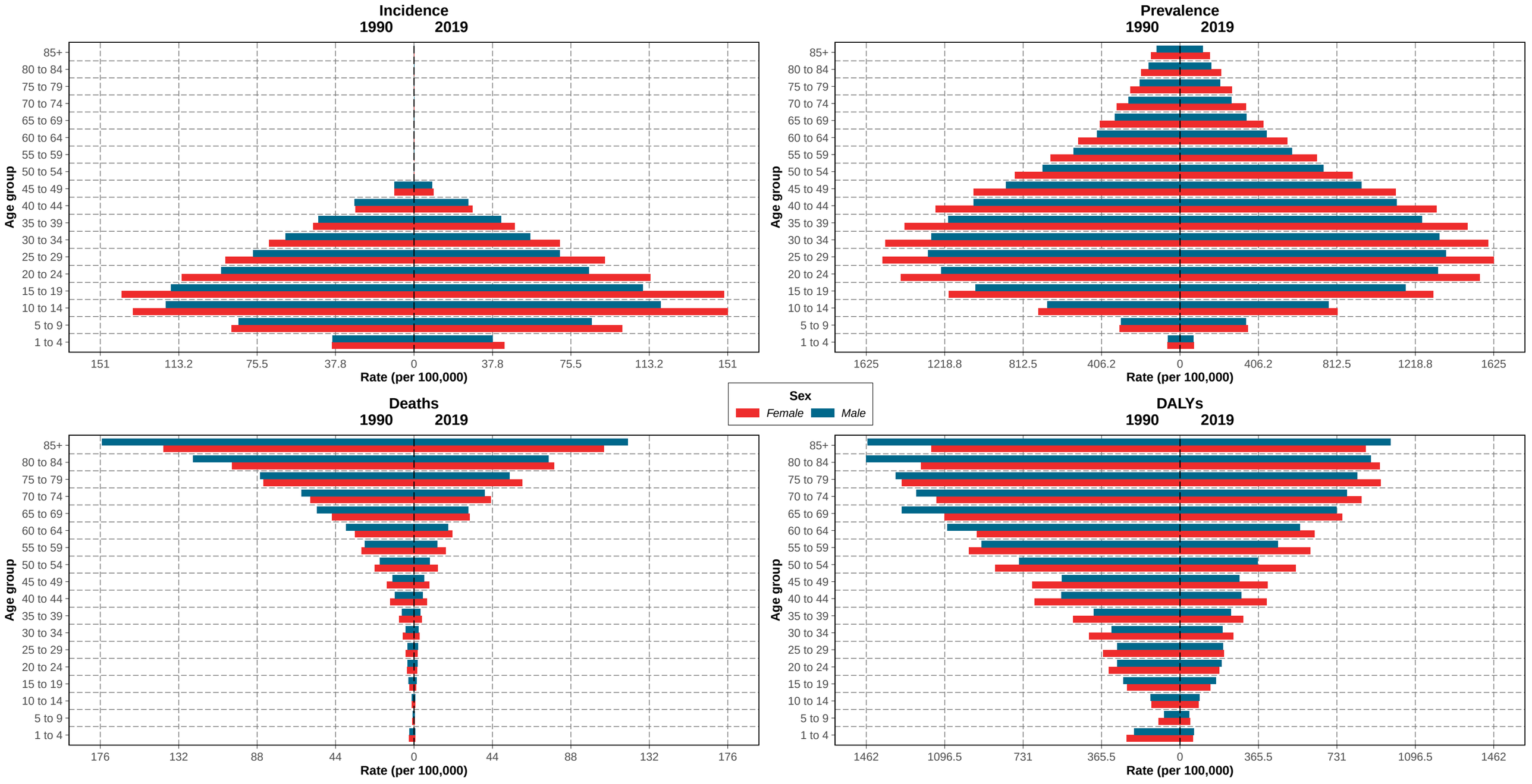






E

Low SDI


Incidence
1990 2019
Prevalence
1990 2019
Deaths
1990 2019
DALYs
1990 2019
Age group
85+
80 to 84
75 to 79
70 to 74
65 to 69
60 to 64
55 to 59
50 to 54
45 to 49
40 to 44
35 to 39
30 to 34
25 to 29
20 to 24
15 to 19
10 to 14
5 to 9
1 to 4
151 113.2 75.5 37.8 0 37.8 75.5 113.2 151
1625 1218.8 812.5 406.2 0 406.2 812.5 1218.8 1625
176 132 88 44 0 44 88 132 176
1462 1096.5 731 365.5 0 365.5 731 1096.5 1462
Rate (per 100,000)
Sex
Female
Male