Heliyon 10 (2024) e24052

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Global burden of atrial fibrillation/flutter: Trends from 1990 to 2019 and projections until 2044

Qunchao Ma [a], Jinyun Zhu [a], Pingping Zheng [c], Jiaru Zhang [d], Xiangyang Xia [a], Yun Zhao [e], Qingqiang Cheng [b], Ning Zhang [b,*]

[a] Department of Cardiology, Second Affiliated Hospital, Zhejiang University College of Medicine, 88 Jiefang Rd, Hangzhou, Zhejiang Province, 310009, PR China
[b] Department of Cardiology, the Affiliated Hangzhou First People's Hospital, College of Medicine, Westlake University, Hangzhou, Zhejiang Province, 310006, PR China
[c] Department of Emergency, The Affiliated Hangzhou First People's Hospital, College of Medicine, Westlake University, Hangzhou, Zhejiang Province, 310006, PR China
[d] Department of Cardiology, the First Affiliated Hospital of Fujian Medical University, Fuzhou, Fujian Province, 350000, PR China
[e] Department of Ultrasound, Second Affiliated Hospital of Shandong First Medical University, Taian, Shandong Province, 271000, PR China

ARTICLE INFO

Keywords:
Atrial fibrillation/atrial flutter
Disease burden
Estimated annual percentage change
Age-standardized rate
Risk factors
Prediction

ABSTRACT

Aims: Atrial fibrillation/atrial flutter (AF/AFL) is a critical public health issue worldwide, and its epidemiological patterns have changed over the decades. This work aimed to assess the global trends of AF/AFL and attributable risks from 1990 to 2019.

Methods and results: The present study utilized data from the Global Burden of Disease Study 2019 to examine the temporal trends, attributable risks, and projections of AF/AFL. The estimated annual percentage change (EAPC) and age-standardized rate (ASR) were employed for this purpose. The findings revealed that in 2019, AF/AFL accounted for 4.72 million incident cases, 59.70 million prevalent cases, 0.32 million deaths, and 8.39 million disability-adjusted life years (DALYs). Furthermore, the results indicated that males under 70 years of age had a higher incidence, prevalence, and DALYs than females, while the rates were similar for both genders between 70 and 74 years. However, this pattern was reversed in individuals over the age of 75, with females exhibiting a higher total incidence, prevalence, and DALYs than males. The age-standardized rates (ASRs) of prevalence, incidence, mortality, and DALYs increased with an increase in the socio-demographic index (SDI). The three primary contributors to AF/AFL were high systolic blood pressure, high body-mass index, and smoking. Majority of risk factors exhibited a unimodal distribution, with a peak between the ages of 50 and 70.

Conclusions: The disease burden of AF/AFL is still severe worldwide and getting worse. To encourage prevention and treatment, systematic regional surveillance of AF/AFL should be put in place.

1. Introduction

Atrial fibrillation/atrial flutter (AF/AFL) is the most prevalent type of cardiac arrhythmia [1–3]. Hospitalizations for AF/AFL have

* Corresponding author.
E-mail address: 11818157@zju.edu.cn (N. Zhang).

https://doi.org/10.1016/j.heliyon.2024.e24052
Received 3 June 2023; Accepted 3 January 2024
Available online 6 January 2024

increased yearly and are influenced by multiple factors, such as genetics, biological, and environmental variables [4]. Timely estimates of future trends, overall burden, and attributable risks are required to guide future health care resource allocation and planning for AF/AFL.

Despite improvements and innovations in AF treatment, including anticoagulation and ablation, the global prevalence and incidence of AF/AFL increased during the past three decades [4,5]. Even on optimal rhythm control and anticoagulation therapy, patients with AF are at a high risk of stroke, heart failure, and death, particularly progressive heart failure [6]. Moreover, the mortality and morbidity due to AF/AFL are increasing, expected to triple over the next three decades [7,8].

Additionally, there were significant differences in the prevalence and incidence of AF/AFL reported in various nations depending on several variables, including age, sex, body mass index (BMI), smoking, alcohol use, genetic condition, socioeconomic level, and education [5,9]. The reasons for the increase of AF/AFL burden remain incompletely understood [10,11], might include improved ability to detection, increased risk factors, and extended life expectancy due to enhanced medical treatment [12]. Comprehending the patterns and trends within the context of the evolving risk factors and forecasting future trends for AF/AFL incidence rates is imperative for the purposes of prevention, treatment, and resource allocation at the national level. However, there has been a lack of comprehensive analyses examining the long-term trend in AF/AFL rates globally. Therefore, we conducted a thorough investigation of historical temporal trends (1990–2019) and projected future trends (2019–2040) in AF/AFL incidence, prevalence, mortality, and disability-adjusted life years (DALYs) rates. Our objective was to shed light on temporal changes and geographical variations in both the past and future scenarios.

Hence, a systematic understanding of the current epidemiology is required for prevention measures, management, and treatment of AF/AFL. Herein, we estimated the global and regional burden of AF/AFL in terms of their incidence, prevalence, death, and DALYs, as well as attributable risks from 1990 to 2019, using the updated data derived from the GBD Study.

2. Methods

2.1. Data source

We retrieved data from the Global Burden of Disease (GBD) 2019 database using the Global Health Data Exchange (GHDx) query tool (http://ghdx.healthdata.org/gbd-results-tool). The incidence, prevalence, deaths, DALYs, and attributable risk factors of AF/AFL were extracted stratified by age, regions, sex, and countries. The GBD (2019) is hierarchically organized by geographic units or locations, including 204 countries grouped within 27 regions.

The socio-demographic index (SDI) is a composite indicator of overall development based on fertility, education, and income [13]. SDI scores range from 0 (lowest level) to 1 (highest level). Based on SDI values in 2019, countries and territories were categorized into Low, Low-middle, Middle, Middle-high, and High SDI regions. Data on the Human Development Index (HDI) were calculated the United Nations Development Programme (http://hdr.undp.org/en/countries), which incorporates key dimensions of human development: a long and healthy life, being knowledgeable, and having a decent standard of living. Using a cutoff value of 0.88, 21 high-income countries and 22 middle- and low-income countries were divided into two categories based on HDI.

2.2. Disease prediction model

The Nordpred age-period-cohort (APC) model and the Bayesian age-period-cohort (BAPC) model uses integrated nested Laplace approximations (INLA) were used to predict the trends of global AF/AFL burden from 2020 to 2044. These two approaches have been well-documented and validated in previous studies [14,15]. The R package Nordpred, BAPC, and INLA was used to project AF/AFL incidence, prevalence, death, and DALYs. The rates were computed for each 5-year age group and 5-year interval in the calibrated age-period-cohort model. The average trend based on all available data was extrapolated out to the year 2044. Age-standardized rates per 100,000 person-years were calculated by the World Standard Population (WHO 2000–2005). Moreover, we set the reference range to facilitate the comparison of prediction, including the conservative, optimistic, and pessimistic estimates as the previous study described [16]. The Age Period Cohort Tool (http://analysistools.nci.nih.gov/apc/) was utilized to conduct the Age-Period-Cohort analysis. The BAPC models were constructed using the R packages INLA (www.r-inla.org) and BAPC (http://r-forge.r-project.org/).

2.3. Statistical analyses

We used the age-standardized rates (ASRs) to describe the AF/AFL burden, including the age-standardized rate of incidence (ASIR), the age-standardized rate of prevalence (ASPR), the age-standardized rate of death (ASDR), and the age-standardized rate of DALY (ASDALYR). The formula of ASR (per 100,000 populations) is calculated as: $\mathrm{ASR} = \frac{\sum_{i=1}^{A} a_i w_i}{\sum_{i=1}^{A} a_i} \times 100,00$. We further calculated the estimated annual percentage change (EAPC) to quantify and evaluate the trends in ASR. The EAPC was defined as: $\mathrm{EAPC} = 100 \times (\exp(\beta)\ 1)$. Its 95 % confidence interval (CI) can also be computed from a similar linear regression model. An upward ASR trend was observed when the EAPC and lower CI limit were positive. On the contrary, ASR shows a downward trend when the EAPC and upper CI limit are negative. The ASR was deemed to be stable over time. Additionally, the correlation between EAPCs and ASRs as well as SDI in different countries was evaluated respectively by a Pearson correlation analysis. Additionally, the population attributable proportion fraction (PAF) is the estimated fraction of all cases attributable to exposure to a risk factor [17].

Table 1
Incidence, deaths, and DALYs ■for ischemic heart disease in 2019 and age-standardized prevalence rates (ASRS) per 100,000 people and EAPCs from 1990 to 2019.

	Incidence				Death				DALYs			
	2019		1990–2019		2019		1990–2019		2019		1990–2019	
	Number, × 10^3 (95 % UI)	ASR/100,000 (95 % UI)	Percentage (%)	EAPC (95% CI)	Number, × 10^3 (95 % UI)	ASR/100,000 (95 % UI)	Percentage (%)	EAPC (95% CI)	Number, × 10^3 (95 % UI)	ASR/100,000 (95 % UI)	Percentage (%)	EAPC (95% CI)
Global	4720.32 (3644.33–5961.6)	57.09 (44.07–71.9)	104.03 (100.27–108.76)	0.05 (−0.02 to 0.13)	8393.64 (6693.98–10541.46)	107.13 (86.18–133.73)	121.59 (111.51–131.96)	−0.03 (−0.06 to 0)	8393.64 (6693.98–10541.46)	107.13 (86.18–133.73)	121.59 (111.51–131.96)	−0.03 (−0.06 to 0)
Sex												
Male	2376.46 (1837.67–3010.75)	60.82 (47.14–76.29)	102.18 (96.59–108.53)	0.01 (−0.07 to 0.09)	3956.02 (3087.37–5050.02)	114.15 (90.08–144.12)	124.3 (110.27–137.46)	−0.02 (−0.06 to 0.02)	3956.02 (3087.37–5050.02)	114.15 (90.08–144.12)	124.3 (110.27–137.46)	−0.02 (−0.06 to 0.02)
Female	2343.86 (1796.33–2973.62)	53.5 (41.09–67.72)	105.94 (102.2–110.34)	0.1 (0.03–0.08)	4437.62 (3574.32–5539.38)	100.96 (81.3–125.99)	119.23 (105.83–132.27)	−0.04 (−0.06 to −0.01)	4437.62 (3574.32–5539.38)	100.96 (81.3–125.99)	119.23 (105.83–132.27)	−0.04 (−0.06 to −0.01)
Socio-demographic index												
High SDI	1235.2 (976.18–1518.13)	69.22 (55.37–85.18)	67.11 (59.85–76.21)	0.26 (0.09–0.44)	2517.23 (2012.61–3144.01)	122.64 (97.3–153.57)	84.92 (74.37–94.56)	0.03 (−0.05 to 0.11)	2517.23 (2012.61–3144.01)	122.64 (97.3–153.57)	84.92 (74.37–94.56)	0.03 (−0.05 to 0.11)
High-middle SDI	1194.91 (912.92–1531.24)	57.97 (44.57–74.2)	82.23 (77.1–87.67)	−0.12 (−0.15 to −0.09)	2214.11 (1734.63–2823.35)	110.21 (86.73–140.14)	99.7 (90.71–108.04)	−0.25 (−0.28 to −0.23)	2214.11 (1734.63–2823.35)	110.21 (86.73–140.14)	99.7 (90.71–108.04)	−0.25 (−0.28 to −0.23)
Middle SDI	1347.02 (1024.38–1717.86)	54.27 (41.16–69.05)	149.1 (144.12–154.43)	0.14 (0.08–0.2)	2113.47 (1653.61–2694.93)	97.9 (78.07–122.72)	183.43 (164.52–202.78)	0.17 (0.14–0.2)	2113.47 (1653.61–2694.93)	97.9 (78.07–122.72)	183.43 (164.52–202.78)	0.17 (0.14–0.2)
Low-middle SDI	733.95 (558–935.19)	54.72 (41.51–69.76)	135.13 (128.44–143.14)	0.08 (0.06–0.09)	1173.89 (929.51–1468.08)	101.01 (81.22–123.92)	178.66 (154.12–208.38)	0.34 (0.32–0.37)	1173.89 (929.51–1468.08)	101.01 (81.22–123.92)	178.66 (154.12–208.38)	0.34 (0.32–0.37)
Low SDI	207.39 (158.05–265.31)	41.97 (31.77–53.69)	116.08 (111.72–121.25)	0.12 (0.11–0.12)	370.88 (291.5–456.05)	91.91 (71.89–111.57)	148.71 (125.67–178.17)	0.3 (0.27–0.33)	370.88 (291.5–456.05)	91.91 (71.89–111.57)	148.71 (125.67–178.17)	0.3 (0.27–0.33)
Regions												
Andean Latin America	8.08 (6.05–10.36)	14.84 (11.11–19.17)	217.7 (204.89–232.74)	0.43 (0.35–0.52)	33.84 (28.08–40.06)	63.61 (52.67–75.22)	200.65 (151.71–262)	0.11 (0.04–0.18)	33.84 (28.08–40.06)	63.61 (52.67–75.22)	200.65 (151.71–262)	0.11 (0.04–0.18)
Australasia	42.63 (32.4–54.82)	90.39 (69.71–114.51)	82.74 (73.95–91.76)	−0.24 (−0.3 to −0.19)	89.7 (71.28–113.67)	168.28 (132.54–214.32)	112.46 (101.43–126.39)	−0.36 (−0.39 to −0.34)	89.7 (71.28–113.67)	168.28 (132.54–214.32)	112.46 (101.43–126.39)	−0.36 (−0.39 to −0.34)
Caribbean	15.39 (11.49–19.9)	29.72 (22.18–38.44)	106.09 (100.58–112.45)	0.07 (0.06–0.08)	43.2 (36.15–51.75)	83.27 (69.65–99.83)	130.31 (108.67–154.53)	0.19 (0.13–0.25)	43.2 (36.15–51.75)	83.27 (69.65–99.83)	130.31 (108.67–154.53)	0.19 (0.13–0.25)
Central Asia	51 (38.43–65.52)	64.77 (49.64–82.66)	69.26 (62.84–75.91)	0.1 (0.09–0.12)	81.52 (63.51–104.68)	138.35 (109.64–176.31)	76.95 (59.5–92.05)	0.82 (0.76–0.88)	81.52 (63.51–104.68)	138.35 (109.64–176.31)	76.95 (59.5–92.05)	0.82 (0.76–0.88)
Central Europe	142.51 (108.56–183.04)	70.59 (54.18–89.82)	29.5 (23.1–35.84)	0.02 (−0.06 to 0.11)	302.86 (237.3–385.69)	136.04 (106.47–173.32)	60.79 (50.19–71.63)	0.07 (0.01–0.12)	302.86 (237.3–385.69)	136.04 (106.47–173.32)	60.79 (50.19–71.63)	0.07 (0.01–0.12)
Central Latin America	73.69 (55.67–95.27)	31.77 (23.84–41.21)	194.49 (187.24–203.42)	0.01 (0–0.02)	185.65 (152.66–228.15)	82.84 (68.32–101.95)	230.92 (201.51–260.23)	−0.01 (−0.05 to 0.04)	185.65 (152.66–228.15)	82.84 (68.32–101.95)	230.92 (201.51–260.23)	−0.01 (−0.05 to 0.04)
Central Sub-Saharan Africa	16.18 (12.34–20.97)	32.22 (24.45–41.46)	130.74 (118.99–144.75)	−0.1 (−0.12 to −0.09)	40.76 (28.8–53.88)	104.25 (72.95–138.1)	150.09 (100.07–203.36)	0.14 (0.07–0.2)	40.76 (28.8–53.88)	104.25 (72.95–138.1)	150.09 (100.07–203.36)	0.14 (0.07–0.2)
East Asia	1202.91 (907.84–1545.47)	57.4 (43.67–72.99)	159.55 (152.97–167.51)	0.16 (0.04–0.28)	1793.19 (1356.4–2304.89)	96.78 (75.08–122.56)	173.95 (148.95–198.48)	−0.05 (−0.13 to 0.03)	1793.19 (1356.4–2304.89)	96.78 (75.08–122.56)	173.95 (148.95–198.48)	−0.05 (−0.13 to 0.03)
Eastern Europe	253.92 (193.15–325.65)	74.4 (57.18–95.28)	31.02 (27.33–35.04)	0.35 (0.32–0.38)	481.41 (368.86–621.28)	136.59 (104.82–177.07)	52.07 (43.7–60.86)	0.36 (0.28–0.43)	481.41 (368.86–621.28)	136.59 (104.82–177.07)	52.07 (43.7–60.86)	0.36 (0.28–0.43)

(*continued on next page*)

Table 1 (*continued*)

	Incidence				Death				DALYs			
	2019		1990–2019		2019		1990–2019		2019		1990–2019	
	Number, × 10^3 (95 % UI)	ASR/100,000 (95 % UI)	Percentage (%)	EAPC (95% CI)	Number, × 10^3 (95 % UI)	ASR/100,000 (95 % UI)	Percentage (%)	EAPC (95% CI)	Number, × 10^3 (95 % UI)	ASR/100,000 (95 % UI)	Percentage (%)	EAPC (95% CI)
Eastern Sub-Saharan Africa	30.35 (23.23–38.67)	19.89 (15.18–25.61)	126.4 (120.92–133.08)	0.16 (0.1–0.23)	94.3 (66.63–115.07)	77.09 (53.33–94.33)	131.25 (94.07–179.12)	0.18 (0.1–0.27)	94.3 (66.63–115.07)	77.09 (53.33–94.33)	131.25 (94.07–179.12)	0.18 (0.1–0.27)
High-income Asia Pacific	77.9 (59.59–99.92)	21.12 (16.28–27.19)	41.58 (33.08–53.61)	−1.58 (−1.91 to −1.24)	265.23 (212.78–329.1)	53.53 (43.1–66.58)	112.54 (93.78–131.87)	−1.06 (−1.22 to −0.91)	265.23 (212.78–329.1)	53.53 (43.1–66.58)	112.54 (93.78–131.87)	−1.06 (−1.22 to −0.91)
High-income North America	675.44 (539.47–822.53)	108.53 (87.59–131.44)	100.72 (84.39–120.48)	1.33 (0.95–1.72)	1059.27 (837.81–1336.17)	160.18 (125.7–202.67)	105.83 (92.46–117.79)	0.89 (0.71–1.07)	1059.27 (837.81–1336.17)	160.18 (125.7–202.67)	105.83 (92.46–117.79)	0.89 (0.71–1.07)
North Africa and Middle East	173.92 (133–221.69)	41.93 (31.66–53.56)	158.63 (152.79–166.11)	−0.08 (−0.11 to −0.05)	290 (229.1–361.79)	81.61 (65.1–100.78)	171.11 (148.36–207.34)	0.01 (−0.01 to 0.04)	290 (229.1–361.79)	81.61 (65.1–100.78)	171.11 (148.36–207.34)	0.01 (−0.01 to 0.04)
Oceania	3.97 (3–5.1)	59.26 (44.94–75.2)	144.18 (134.03–155.14)	0.07 (0.05–0.09)	6.58 (5.07–8.43)	116.58 (91.06–148.01)	159.14 (131.64–190.33)	0.23 (0.22–0.25)	6.58 (5.07–8.43)	116.58 (91.06–148.01)	159.14 (131.64–190.33)	0.23 (0.22–0.25)
South Asia	851.08 (645.14–1089.23)	61.37 (46.53–78)	160.6 (150.97–170.86)	0.06 (0.06–0.07)	1257.58 (971.3–1609.1)	106.05 (82.89–132.86)	208.62 (173.69–248.48)	0.26 (0.22–0.31)	1257.58 (971.3–1609.1)	106.05 (82.89–132.86)	208.62 (173.69–248.48)	0.26 (0.22–0.31)
Southeast Asia	378.09 (288.27–482.01)	62.77 (47.54–79.6)	150.92 (147.4–155.2)	0.09 (0.08–0.1)	544.42 (417.74–695.21)	105.7 (82.22–133.52)	178.9 (159.19–201.73)	0.37 (0.34–0.4)	544.42 (417.74–695.21)	105.7 (82.22–133.52)	178.9 (159.19–201.73)	0.37 (0.34–0.4)
Southern Latin America	34.68 (26.26–44.62)	41.8 (31.8–53.39)	83.47 (76.44–91.15)	0.07 (0–0.14)	86.62 (71.63–107.6)	100.95 (83.35–125.77)	113.53 (100.39–129.23)	0.18 (0.13–0.22)	86.62 (71.63–107.6)	100.95 (83.35–125.77)	113.53 (100.39–129.23)	0.18 (0.13–0.22)
Southern Sub-Saharan Africa	20.37 (15.61–26.06)	37.09 (28.17–47.62)	104.61 (100.79–108.38)	−0.02 (−0.03 to −0.01)	36.88 (30.13–45.19)	79.24 (65.78–95.69)	120.02 (106.49–134.44)	0.36 (0.24–0.48)	36.88 (30.13–45.19)	79.24 (65.78–95.69)	120.02 (106.49–134.44)	0.36 (0.24–0.48)
Tropical Latin America	107.86 (81.58–138.99)	44.8 (33.81–57.84)	184.22 (175.54–196.28)	0.55 (0.39–0.7)	235.08 (193.67–285.76)	102.34 (84.28–124.34)	221.32 (191.27–238.41)	0.52 (0.4–0.64)	235.08 (193.67–285.76)	102.34 (84.28–124.34)	221.32 (191.27–238.41)	0.52 (0.4–0.64)
Western Europe	495.12 (378.48–631.5)	63.01 (48.37–79.79)	22.91 (20.34–25.85)	−0.36 (−0.39 to −0.32)	1347.22 (1087.69–1676.38)	132.81 (105.93–168.11)	56.51 (43.58–67.42)	−0.19 (−0.22 to −0.16)	1347.22 (1087.69–1676.38)	132.81 (105.93–168.11)	56.51 (43.58–67.42)	−0.19 (−0.22 to −0.16)
Western Sub-Saharan Africa	65.22 (49.91–83.72)	36.01 (27.33–46.19)	117.32 (111.71–123.8)	0.05 (0.01–0.08)	118.34 (94.72–145.56)	86.19 (70–103.25)	119.3 (80.73–147.37)	0.08 (0.05–0.1)	118.34 (94.72–145.56)	86.19 (70–103.25)	119.3 (80.73–147.37)	0.08 (0.05–0.1)

The R-statistical software was used for data analysis and visualization (R version 4.2.0). A two-sided P value of less than 0.05 was considered statistically significant.

3. Results

3.1. Trends in incidence of AF/AFL

Globally, the incident number of AF/AFL in 2019 had a progressive increase of 104.03 % since 1990 with an estimated 4.72 million (95 % UI, 3.64 to 5.96). There were 2.38 million males (95 % UI, 1.84 to 3.01) and 2.34 million females (95 % UI, 1.80 to 2.97) **(Table 1)**. In 2019, the incident cases increased with age, peaked at 65–69 years. Notably, compared with females, males had more incident cases under 65 years, similar at 65–69 years and less above 70 years (Fig. 1A). After standardized for age, the age-standardized incident rate (ASIR) increased globally and showed an upward trend from 1990 to 2019, with an EAPC of 0.05 (95 % UI, −0.02 to 0.13) **(Table 1)**. Compared with females, males had higher ASIR (males:60.82; 95 % UI, 47.14 to 76.29; females:53.5; 95 % UI, 41.09 to 67.72) but significantly lower EAPC (males:0.01; 95 % UI, −0.07 to 0.09; females:0.1; 95 % UI, 0.03 to 0.08) **(Table 1)**.

Regarding SDI level analysis, in 2019, the Middle SDI region displayed the highest number of cases (1.35 million; 95 % UI, 1.02 to 1.72). The High SDI region displayed the highest ASIR in 2019 (69.22; 95 % UI, 55.37 to 85.18), and presented the largest upward trend of ASIR (EAPC, 0.26; 95 % UI, 0.09 to 0.44). However, the Low SDI region had the lowest ASIR of 41.97 (95 % UI, 31.77 to 53.69) and High-middle SDI region presented a declining trend (EAPC, −0.12; 95 % UI, −0.15 to −0.09) **(Table 1; Supplementary Fig. 1A)**.

In regions, the incident number was most in East Asia (1.2 million; 95 % UI, 0.91 to 1.55) and least in Oceania (0.004 million; 95 % UI, 0.003 to 0.005 million). High-income North America displayed the highest ASIR of 108.53 (95 % UI, 87.59 to 131.44), with the largest increase trend by an EAPC of 1.33 (95 % UI, 0.95 to 1.72). From 1990 to 2019, only six regions (Australasia, Central Sub-Saharan Africa, North Africa and the Middle East, High-income Asia Pacific, Southern Sub-Saharan Africa, and Western Europe) showed declining trends of ASIR (Table 1).

At the national level, China had the highest number of incident cases of AF/AFL (1.17 million), followed by India (0.70 million) and the USA (0.61 million) (Supplementary Table 2). However, the United Arab Emirates had the highest increased percentage of cases (840.96 %), while Georgia had the highest percentage of cases with a decrease (−6.33 %) (Fig. 2A). United States of America had the

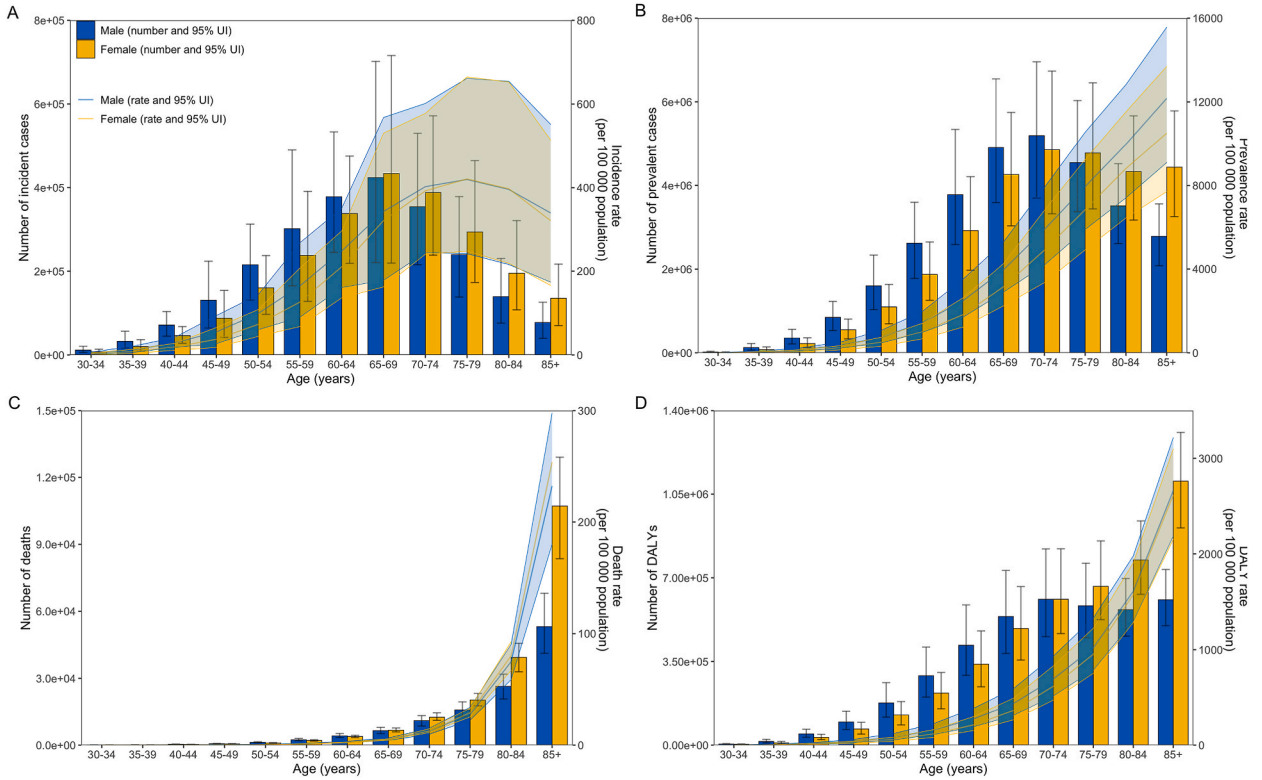


Fig. 1. The numbers and ASRs of incidence (A), prevalence(B) death (C), and DALYs (D) of AF/AFL by age and sex in 2019. Shading indicates the upper and lower limits of the 95 % uncertainty intervals (95 % UI). Male (blue), female (yellow), AF/AFL, atrial fibrillation/atrial flutter; DALYs, disability-adjusted life-year; ASRs, age-standardized rates (per100,000 population). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

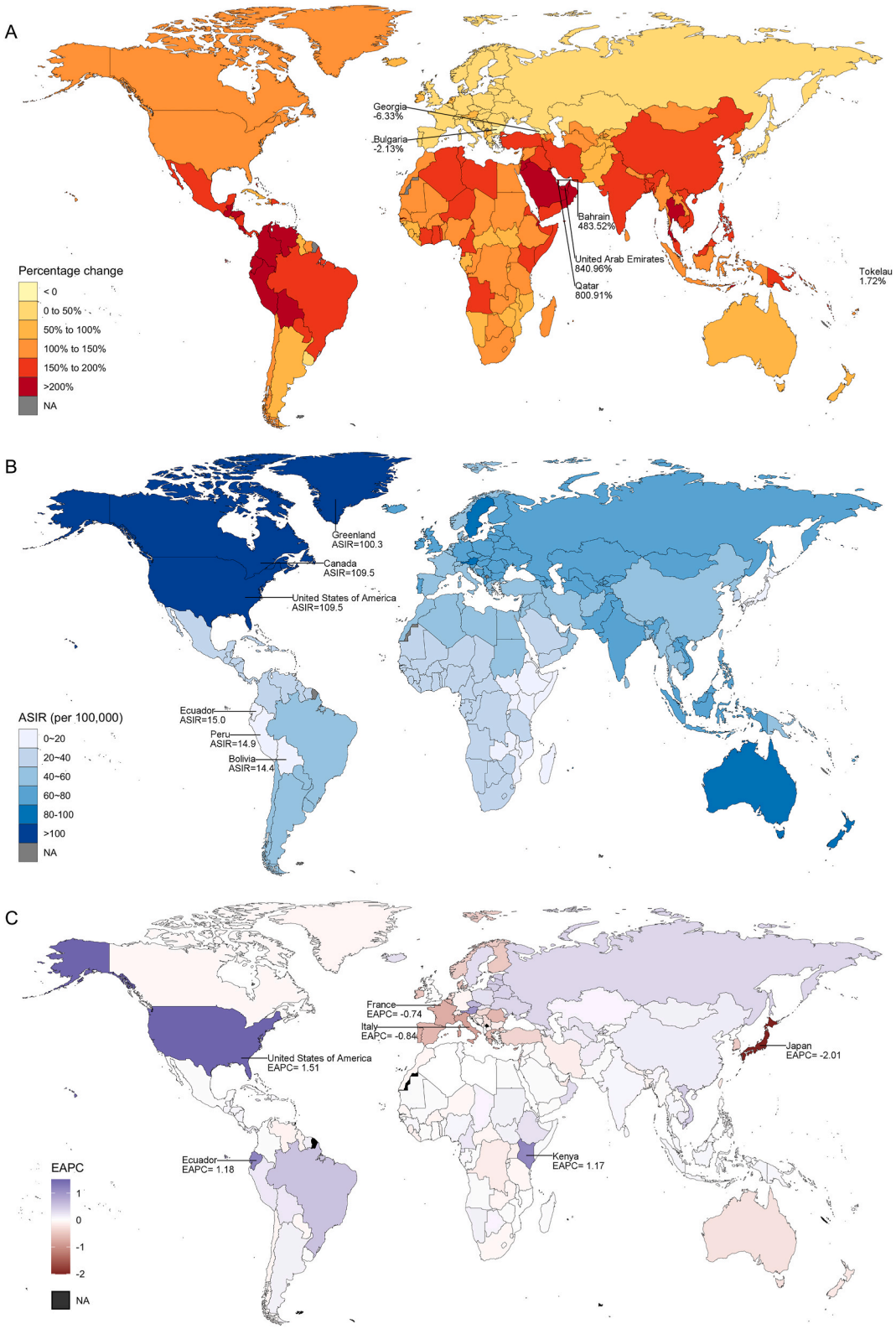


Fig. 2. The percentage changes (A), ASRs (B), and EAPCs (C) of AF/AFL incidence at the national level between 1990 and 2019. AF/AFL, atrial fibrillation/atrial flutter; ASR, age-standardized rate. EAPC, estimated annual percentage change.

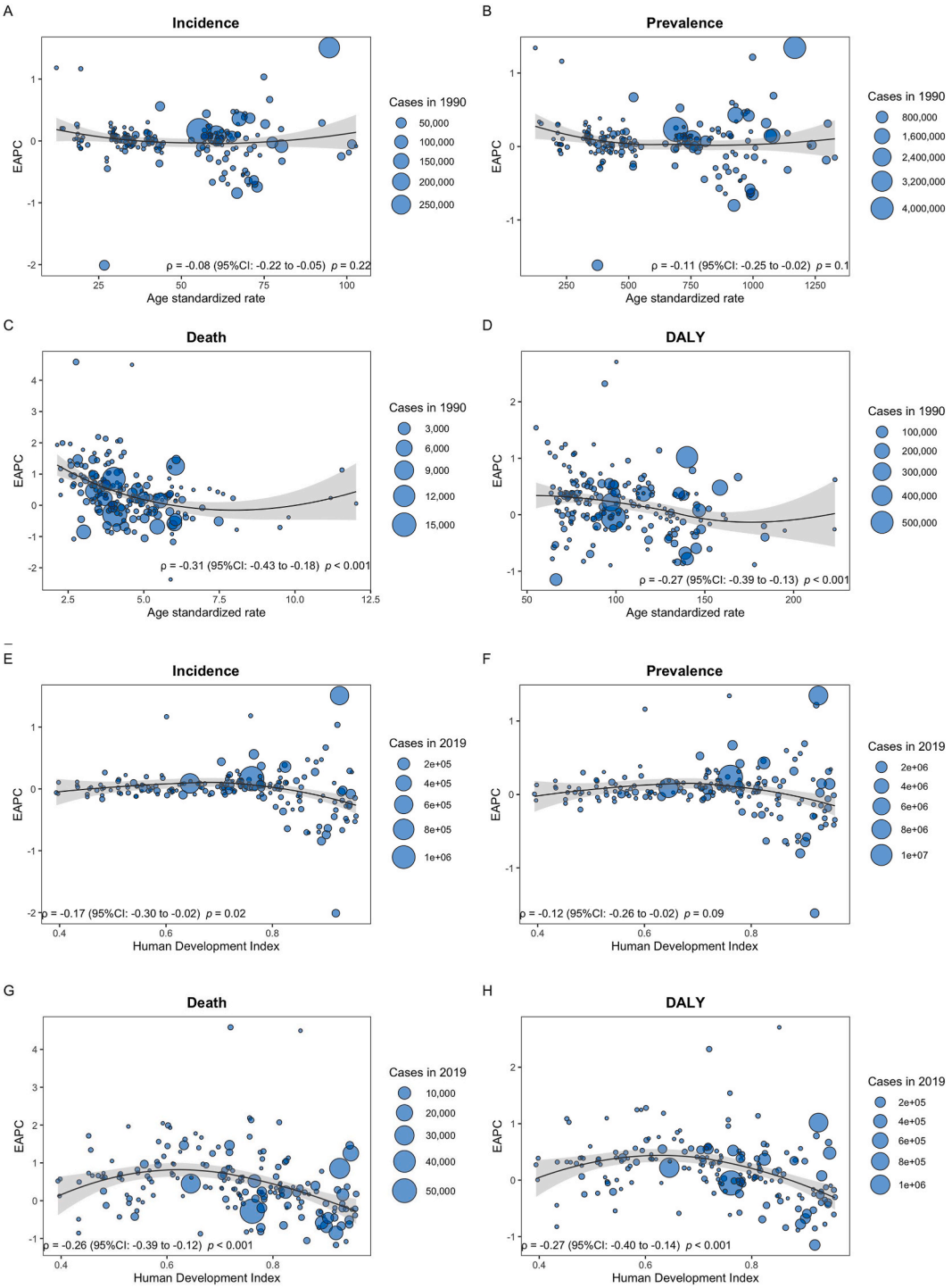


Fig. 3. The association between EAPCs and ASRs of incidence (A), prevalence (B), death (C), and DALYs (D) of AF/AFL in 1990 at the national level. The association between EAPCs and HDI of incidence (E), prevalence (F), death (G) and DALYs (H) of AF/AFL in 2019 at the national level. The circles represent countries that were available on SDI and HDI data. The size of the circle represents the number of AF/AFL patients. AF/AFL, atrial fibrillation/atrial flutter; DALYs, disability-adjusted life-year; ASRs, age-standardized rates (per100,000 population); SDI, socio-demographic index; HDI, human development index; EAPC, estimated annual percentage change.

highest ASIR (109.5; 95 % UI, 89 to 131.9), while Bolivia had the lowest ASIR (14.4, 95 % UI: 10.70 to 18.7) (Fig. 2B). Additionally, ASIR rose more quickly in the United States than in any other nation (EAPC, 1.51, 95 % CI: 1.07 to 1.95) and fell most quickly in Japan (EAPC, −2.01; 95 % CI, −1.6 to-2.42) (Fig. 2C; Supplementary Table 2).

EAPCs had a non-significant correlation with the ASIRs in 1990 ($\rho = -0.08$, $p = 0.22$; Fig. 3A), and had a negative association with HDI ($\rho = -0.17$, $p = 0.02$; Fig. 3E).

3.2. Trends in prevalence of AF/AFL

From 1990 to 2019, the global AF/AFL prevalence increased by 111.04 % and reached 59.70 million (95 % UI, 45.73 to 75.29). Globally, the ASR of prevalence (ASPR) on AF/AFL was 743.47 (95 % UI, 571.16 to 938.34) and displayed an increasing trend from 1990 to 2019, with the EAPC of 0.01 (95 % UI, −0.06 to 0.08). In 2019, the prevalent cases increased with age, peaked at 70–74 years. Notably, compared with females, males had more prevalent cases under 70 years, similar cases at 70–74 years and less cases above 74 years (Fig. 1B). From 1990 to 2019, despite the total prevalent number was similar between males (30.28 million; 95 % UI, 23.42 to 38.33) and females (29.41 million; 95 % UI, 22.42 to 37.34), the trend of ASPR increased in females (EAPC, 0.05; 95 % CI, −0.02 to 0.12), but decreased in males (EAPC, −0.05; 95 % CI, −0.12 to 0.03) (Supplementary Table 1).

In 2019, the highest ASPR was observed in High SDI regions (895.72; 95 % CI, 707.83 to 1104.92). In contrast, the lowest prevalence was observed in the Low SDI region (514.2; 95%CI, 390.12 to 658.39) (Supplementary Table 1; Supplementary Fig. 1B). The EAPC of ASPR was largest in the Middle SDI region (0.19, 95 % UI, 0.13 to 0.25), but lowest in High-middle SDI region (−0.14, 95 % UI, −0.16 to −0.12 %) (Supplementary Table 1).

In terms of regions, High-income North America showed the highest ASPR (1322.15; 95 % CI, 1074.86 to 1600.72) and the increasing trend of ASPR (EAPC, 1.21; 95 % UI, 0.86 to 1.55). Conversely, Andean Latin America displayed the lowest ASPR (158.15, 95 % UI, 119.61 to 202.13), and High-income Asia Pacific displayed the most significant decline with an EAPC of −1.31 (95 % UI, −1.62 to −1) (Supplementary Table 1).

Nationally, China had the highest number of prevalent cases of AF/AFL (13.88 million), followed by India (8 million) and the USA (7.73 million). However, Georgia experienced the largest declining prevalence (−1.52 %), and the United Arab Emirates had the largest increasing prevalence cases (796.17 %). The United States of America had the highest ASPR (1331.4; 95%UI, 1088.7 to 1608), whereas Bolivia had the lowest ASPR (151.8, 95 % UI, 115 to 197.6). In addition, ASPR rose more quickly in the United States than in other countries (EAPC,1.35, 95 % CI, 0.96 to 1.74) and fell most rapidly in Japan (EAPC, −1.62; 95 % CI, −1.25 to −1.98) (Supplementary Table 3).

EAPCs had a non-significant correlation with the ASPR s in 1990 ($\rho = -0.11$, $p = 0.1$; Fig. 3B), and had a negative association with HDI ($\rho = -0.12$, $p = 0.09$; Fig. 3F).

3.3. Trends in death due to AF/AFL

With an increase of 169.43 % from 1990, there were 0.32 million deaths (95 % UI 0.37 to 0.36) attributable to AF/AFL in 2019 (Table 1). The overall age-standardized death rate (ASDR) was 4.38 (95 % UI, 3.7 to 5.05) in 2019, and presented an upward tendency from 1990 to 2019 (EAPC, 0.04; 95%CI, 0.02 to 0.06) (Table 1). In 2019, the deaths steadily rose with age, peaked at above 85 years old, and females had more deaths than males (Fig. 1C). From 1990 to 2019, females (4.4; 95 % UI, 3.65 to 5.11) had similar ASDR with males (4.13; 95 % UI, 3.23 to 5.37), but the trend of ASDR decreased in females (EAPC, −0.01; 95 % UI, −0.03 to 0.02) and increased in males (EAPC, 0.15; 95 % UI, −0.13 to 0.17) (Table 1).

All five SDI regions had a rise in the number of AF/AFL-related deaths, but the Low-Middle SDI region saw the highest increase, by 264.46 %. The ASDR was highest in High SDI region (4.61, 95 % UI, 3.67 to 5.52) and lowest in Middle SDI region (4.11,95 % UI, 3.5 to 4.75) (Table 1; Supplementary Fig. 1C). Increasing trends of ASDR were seen in most SDI regions, particularly in the Low-middle SDI region (EAPC, 0.61; 95 % UI, 0.55 to 0.67). Only the High-middle SDI region displayed a declining ASDR trend (EAPC, −0.25; 95 % UI, −0.32 to −0.18) (Table 1).

Regionally, South Asia experienced the most significant increase in AF/AFL (318.37 %) and an increasing trend of ASDR (EAPC, 0.59; 95 % UI, 0.47 to 0.71). In addition, most GBD regions had increasing trends of ASDR, only four regions—Australasia, Central Latin America, East Asia, and High-Income Asia Pacific—displayed a decreasing trend (Table 1).

Nationally, China had the largest number of death cases (0.05 million) and the largest increase (218.43 %), followed by the USA (0.03 million). When standardized for age, Montenegro had the highest ASDR (14.4; 95%UI, 11.3 to 19.4), whereas Singapore had the lowest ASDR (2, 95 % UI, 1.4 to 2.4). Besides, ASDR rose more quickly in Uzbekistan than other countries (EAPC, 4.58, 95 % CI: 4.23 to 4.94) and fell most rapidly in Guam (EAPC, −2.37; 95 % CI, −1.87 to −2.87) (Supplementary Table 4).

EAPCs had a negative relationship with the ASDR s in 1990 ($\rho = -0.31$, $p < 0.001$; Fig. 3C) and had a negative association with HDI ($\rho = -0.26$, $p < 0.001$; Fig. 3G).

3.4. Trends in DALYs due to AF/AFL

In 2019, there were 8.39 million (95 % UI 6.69 to 10.54) DALYs due to AF/AFL, with an increase of 121.59 % since 1990 (Table 1). The overall age-standardized ASR of DALYs (ASDALYR) was 107.13 (95 % UI, 86.18 to 133.73) in 2019, and presented a downward tendency during 1990–2019 (EAPC, −0.03; 95%CI, −0.06 to 0) (Table 1). The DALYs numbers increased both in males (3.96 million; 95 % UI, 3.09 to 5.05) and females (4.44 million; 95 % UI, 3.57 to 5.54), but with the decreased trend of ASDALYR (male: EAPC, −0.02;

95%CI, −0.06 to 0.02; female: EAPC, −0.04; 95%CI, −0.06 to −0.01) (Table 1). In 2019, the DALYs increased with age for both genders, Notably, males had more DALYs than females under 70 years, similar DALYs at 70–74 years and less DALYs above 74 years compared to females (Fig. 1D).

The percentage of DALYs increased in all five SDI regions, while the Middle SDI region showed the biggest increase by 183.43 % (Table 1; Supplementary Fig. 1D). The ASDALYR was highest in High-Middle SDI region (122.64, 95 % UI, 97.3 to 153.57), and lowest in Low SDI (91.91, 95 % UI, 71.89 to 111.57) (Table 1). Most SDI regions, especially the Low-Middle SDI region, showed rising ASDALYR trends (EAPC, 0.34; 95 % UI, 0.32 to 0.37). Only the High-Middle SDI region showed a declining trend (EAPC, −0.25; 95 % UI, −0.28 to −0.23) (Table 1).

Regionally, Central Latin America showed the biggest increasing change in DALYs of AF/AFL (230.92 %; 95 % UI, 201.51 to 260.23), but a declining trend of ASDALYR (EAPC, −0.01; 95 % UI, −0.05 to 0.04). Moreover, most GBD regions showed rising ASDALYR trends, whereas only five regions (Australasia, Central Latin America, East Asia, High-Income Asia Pacific, and Western Europe) displayed declining ASDALYR trends (Table 1).

At the national level, China had the highest number of DALY cases (1.73 million), followed by India (1.02 million) and the USA (0.96 million). However, the United Arab Emirates had the greatest increase (793.33 %), while Niue showed biggest reduction (−6.73 %). The ASDALYR was lowest in Singapore (51.9, 95 % UI, 40.1 to 67) and highest in Montenegro (250.6; 95 % UI, 205.8 to 313.7). Additionally, ASDALYR grew more quickly in Bahrain than in other nations (EAPC, 2.71; 95 % CI, 2.27 to 3.14) and reduced more quickly in Japan than in any other nation (EAPC, −1.15; 95 % CI, −1.32 to −0.97) (Supplementary Table 5).

EAPCs had a negative relationship with the ASDALYR in 1990 ($\rho = -0.27$, $p < 0.001$; Fig. 3D), and had a negative relationship with HDI ($\rho = -0.27$, $p < 0.001$; Fig. 3H).

3.5. The burden of AF/AFL by SDI

Generally, during 1990–2019, positive relationships existed between the ASIR and SDI values ($\rho = 0.44$, $p < 0.001$; Fig. 4A). ASIR showed a steady upward trend in most regions but a downward trend in Australasia, Western Europe, and the high-income Asia Pacific. Moreover, similar positive relationships were also seen between SDI and ASPR ($\rho = 0.49$, $p < 0.001$; Supplementary Fig. 2A). There was a significant positive correlation between SDI and ASDR ($\rho = 0.27$, $p < 0.001$; Supplementary Fig. 2B). ASDR showed a steady upward trend in most regions but a downward trend in Australasia and the high-income Asia Pacific. Additionally, ASDALYR was also positively associated with the SDI across the world ($\rho = 0.45$, $p < 0.001$; Supplementary Fig. 2C). Most regions displayed increases in ASDALYR as SDI increased. High-income Asia Pacific is the exception, with high SDI but the lowest DALYs rate and a continuous downward trend.

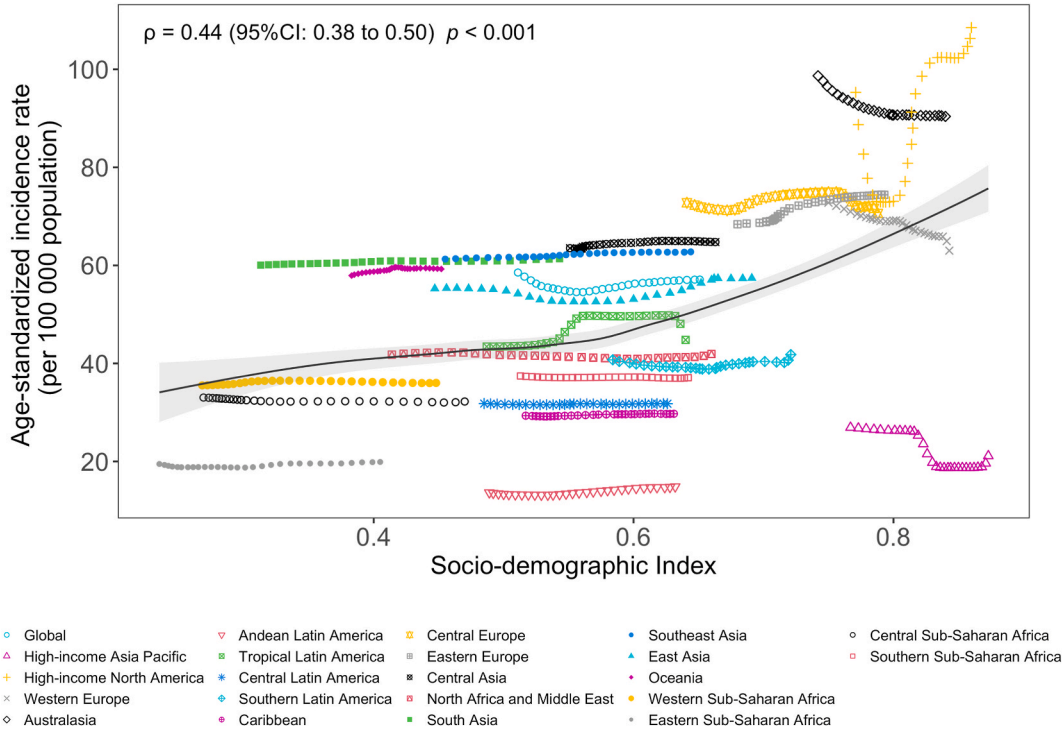


Fig. 4. The association between SDI and ASRs of incidence for AF/AFL by region between 1990 and 2019. The blue line represents the expected value based on SDI. AF/AFL, atrial fibrillation/atrial flutter; DALYs, disability-adjusted life-year; ASRs, age-standardized rates (per100,000 population), SDI, Socio-Demographic Index; EAPC, estimated annual percentage change. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

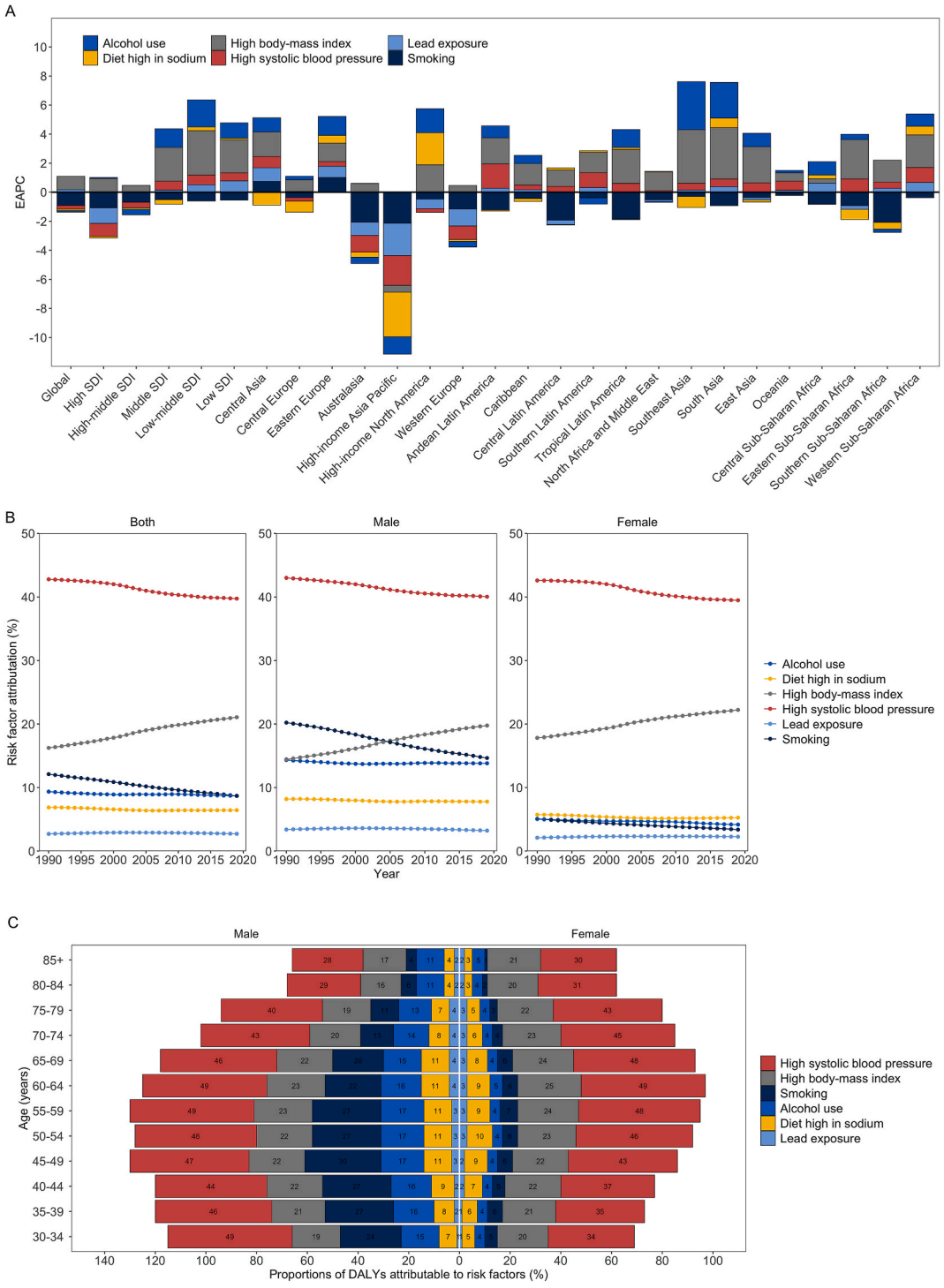
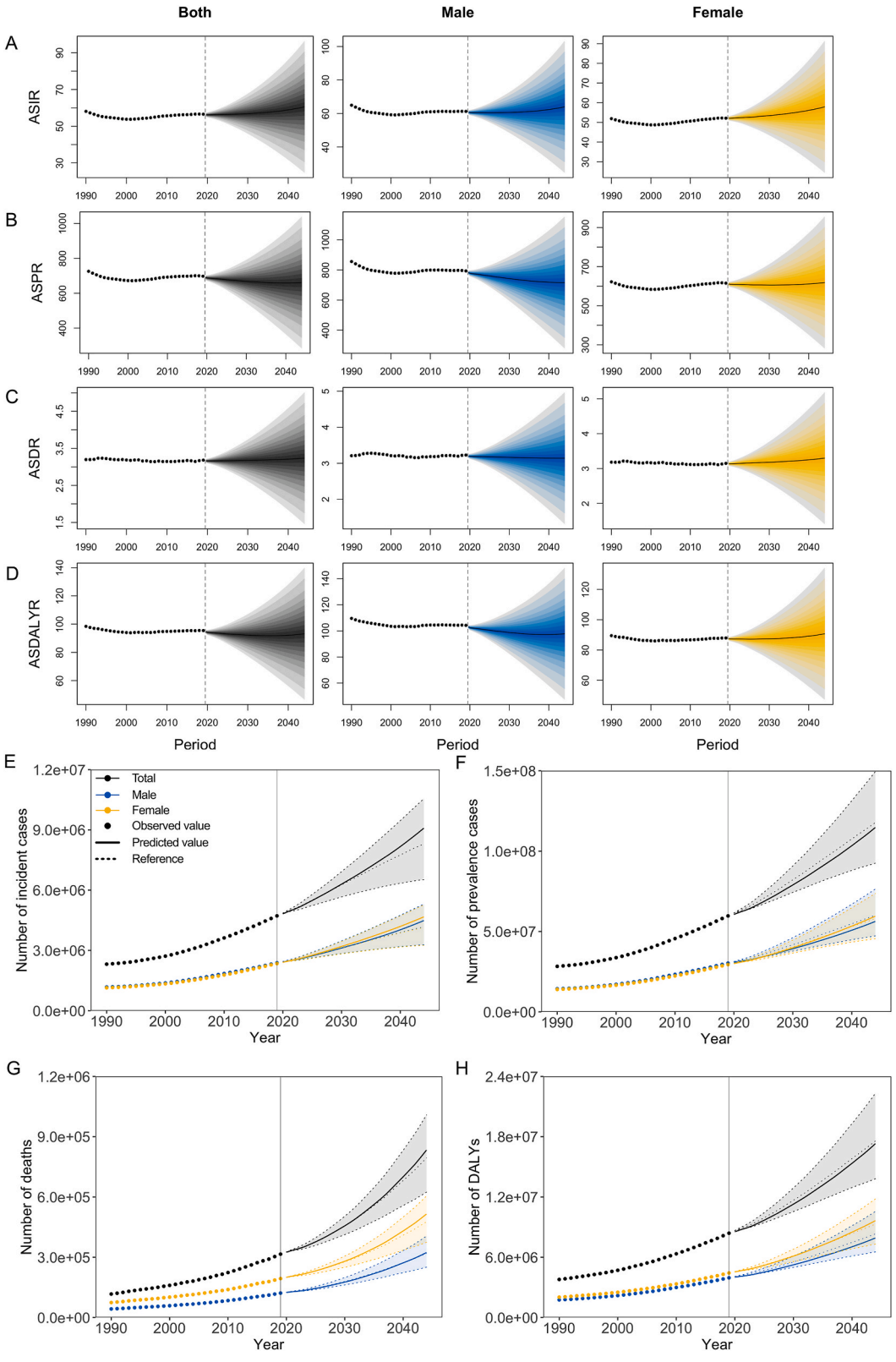


Fig. 5. Trends in attributable risk-related DALYs due to AF/AFL (A) The EAPC of DALYs due to attributable risks at the global and region level. (B) Proportions attributable fractions for risk factors attributed for DALYs by sex from 1990 to 2019. (C) Proportions of DALYs attributable to risk factors by age and sex. AF/AFL, atrial fibrillation/atrial flutter; DALYs, disability-adjusted life-year; ASRs, age-standardized rates (per100,000 population), EAPC, estimated annual percentage change.

The national-level analysis found a positive association between SDI and ASIR ($\rho = 0.50$, $p < 0.001$; Supplementary Fig. 3A), ASPR ($\rho = 0.54$, $p < 0.001$; Supplementary Fig. 3B), ASDR ($\rho = 0.20$, $p < 0.001$; Supplementary Fig. 4A) as well as ASDALYR ($\rho = 0.47$, $p < 0.001$; Supplementary Fig. 4B).



(caption on next page)

Fig. 6. Predictions of AF/AFL trends was projected by BAPC-INLA model
The projected ASRs of incidence (A), prevalence (B), death (C), and DALYs (D) for AF/AFL by sex from 1990 to 2044, The dots represent the observed values, and the fan shape represent the predictive distribution between the 2.5 and 97.5 % quantiles. The solid line represents the predicted ASRs during 2020–2044. The projected number of incidence (A), prevalence (B), death (C), and DALYs (D) for AF/AFL by sex from 1990 to 2044. The solid line represents the predicted numbers during 2020–2044. The dashed line and related area represent the reference if the rate remained stable (baseline reference, middle dash line), decreased by 1 % per year (optimistic reference, lower dash line), and increased by 1 % per year (pessimistic reference, upper dash line) based on the observed rate in 2019. AF/AFL, atrial fibrillation/atrial flutter; DALYs, disability-adjusted life-year; ASRs, age-standardized rates (per100,000 population).

3.6. Trends in attributable risk-related death and DALYs due to AF/AFL

Globally, high systolic blood pressure was considered as the major contributor to ASDR of AF/AFL in both males and females (male: 34 %; female: 34 %), with decreasing trends (EAPC, −0.30; 95 % CI, −0.34 to −0.26). In SDI regions, the High SDI region displayed the highest declining trend (EAPC, −0.85; 95 % CI, −0.94 to −0.75), followed by the High-middle SDI region (EAPC, −0.55; 95 % CI, −0.64 to −0.46). Regionally, we noticed that High systolic blood pressure-related ASDR showed an increasing trend in most regions, especially in Andean Latin America (EAPC, 2.00; 95 % CI, 1.73 to 2.27). Conversely, only four regions (High-income Asia Pacific, Australasia, Western Europe, and Central Europe) showed declining trend. Similar declining trends were observed in alcohol use, smoking, and a diet high in sodium. In most countries, smoking and alcohol consumption were more strongly linked to AF/AFL in males than in females (Supplementary Fig. 10A; Supplementary Fig. 11A).

The second contributor was the high body-mass index, which was moderately higher in females than in males in all regions (male: 18 %; female: 22 %). ASDR of AF/AFL from high body-mass index had a growing tendency in all SDI regions, especially in the Low-middle SDI (EAPC, 2.95; 95 % CI, 2.87 to 3.03). Regionally, the high body-mass index had the highest increasing trend in Southeast Asia with an EAPC of 4.02 (95 % CI, 3.97 to 4.08), and only the High-income Asia Pacific displayed a decreasing trend (EAPC, −0.38; 95 % CI, −0.45 to −0.30). Similar increasing trend were observed in lead exposure. (Supplementary Fig. 5A; Supplementary Fig. 6A).

Similarly, the leading cause of the ASDALYR in both genders was high systolic blood pressure (male: 40 %; female: 39 %), with decreasing trends (EAPC, −0.26; 95 % CI, −0.29 to −0.23). In SDI regions, the High SDI region displayed the highest downward trend (EAPC, −0.90; 95 % CI, −1.00 to −0.79), followed by the High-middle SDI region (EAPC, −0.39; 95 % CI, −0.43 to −0.35). Regionally, we noticed that High systolic blood pressure-related ASDALYR showed an increasing trend in most regions, except of Central Europe, Australasia, High-income Asia Pacific, High-income North America, Western Europe, and Central Sub-Saharan Africa. Besides, except for Central Sub-Saharan Africa, the high body mass index for females appeared to have higher correlations with ASDALYR of AF/AFL than it did for males. Similar declining trends were observed in alcohol use, smoking, and a diet high in sodium (Fig. 5A; Supplementary Fig. 5B).

Conversely, ASDALYR of AF/AFL from high body-mass index had a growing tendency globally (EAPC, 0.92; 95 % CI, 0.88 to 0.97) and in all SDI regions, especially in the Low-middle SDI (EAPC, 3.06; 95 % CI, 2.99 to 3.13). Regionally, the high body-mass index had the highest increasing trend in Southeast Asia with an EAPC of 3.69 (95 % CI, 3.64 to 3.74), and only High-income Asia Pacific displayed a decreasing trend (EAPC, −0.48; 95 % CI, −0.65 to −0.31). Similar increasing trend was also found in lead exposure (EAPC, 0.17; 95 % CI, 0.09 to 0.25) (Fig. 5A; Supplementary Fig. 5B).

In general, we found that high systolic blood pressure was the most prominent risk factor contributing to ASDR and ASDALYR in all age groups, without difference between genders, and gradually decreased from 1990 to 2019. Additionally, the proportions of ASDR and ASDALYR attributed to smoking also displayed a slight reduction since 1990 for both genders. (Fig. 5B; Supplementary Fig. 6B). High body-mass index was found to be a risk factor for AF/AFL burden that cannot be ignored—even counteracting or exceeding the reduction of other factors induced-disease burden in all age groups. Moreover, most risk factors induced deaths and DALYs displayed a unimodal distribution, peaking at age 50–70 (Fig. 5C; Supplementary Fig. 6C).

3.7. Predictions of AF/AFL trends

Based on GBD of AF/AFL data from 1990 to 2019, the Nordpred age-period-cohort (APC) model and the Bayesian APC-INLA model were used to predict the trends of global AF/AFL burden from 2020 to 2044. Both prediction methods yielded very consistent results.

From 2020 to 2044, the ASR of incidence were projected to slight growth in male and in female, respectively. The number of incidences would continue to rise from 2020 to 2044, particularly for females (Male incidence number in 2044: 4.01 million predicted by NORDPRED or 4.49 million predicted by BAPC-INLA; Female incidence number in 2044: 4.30 million predicted by NORDPRED or 4.67 million predicted by BAPC-INLA; Fig. 6A and E; Supplementary Figs. 7A and 7E). Similar results were observed in the projection analysis for prevalence of AF/AFL (Male prevalence number in 2044: 5.72 million predicted by NORDPRED or 5.63 million predicted by BAPC-INLA; Female prevalence number in 2044: 6.04 million predicted by NORDPRED or 5.95 million predicted by BAPC-INLA; Fig. 6B and F; Supplementary Figs. 7B and 7F).

The trends for the ASDALYR and ASDR were stable over the projection period. The numbers of AF/AFL deaths and DALYs would be expected to continue to increase during the next 25 years (Deaths in 2044: 0.83 million predicted by NORDPRED or 0.78 million predicted by BAPC-INLA; DALYs in 2044: 17.58 million predicted by NORDPRED or 17.31 million predicted by BAPC-INLA) with stationary ASRs of deaths and DALYs. This increase might be driven by both population aging and population growth. Additionally, we predicted the death number in female would be significantly higher than that in male from 2020 to 2044, whereas ASDR would not differ between males and females (Male death number in 2044: 0.31 million predicted by NORDPRED or 0.32 million predicted by

BAPC-INLA; Female deaths number in 2044: 0.47 million predicted by NORDPRED or 0.52 million predicted by BAPC-INLA; Fig. 6C and G; Supplementary Figs. 7C and 7G). It might be due to a longer life expectancy in females than in males. Moreover, we predicted higher DALYs number in females than in males in the next 25 years, albeit the estimated ASDALYR in females was persistently lower than in males (Male DALYs number in 2044: 8.08 million predicted by NORDPRED or 7.92 million predicted by BAPC-INLA; Female DALYs number in 2044: 9.63 million predicted by NORDPRED or 9.64 million predicted by BAPC-INLA; Fig. 6D and H; Supplementary Figs. 7D and 7H).

4. Discussion

In this paper, we used the GBD database to present the prevalence, incidence, death, DALYs, and ASRs in 204 countries from 1990 to 2019.

Globally, the burden of AF/AFL was increasing with an estimated 4.72 million incident cases, 59.70 million prevalent cases, 0.32 million death cases, and 8.39 million DALYs. From 1990 to 2019, the ASIR, ASPR, and ASDALYR rate increased varied by region, while the ASDR fluctuated within a small range. Most regions carried the increasing burden of AF/AFL, with a steady upward trend. The distribution of the disease burden of AF/AFL varies significantly across regions and countries. Generally, ASIR, ASPR, ASDR, and ASDALYR in most regions rose when SDI increased. However, the High or High-Middle SDI regions experienced the biggest growth and the most significant fall in the ASR from 1990 to 2019. Nationally, China carried the largest burden of AF/AFL, followed by the United States and India. When adjusted for age, the United States had the highest ASIR and increased more quickly than other countries.

The current study has demonstrated a reduction in the age-standardized estimated annual percentage change (EAPC) for AF/AFL incidence, prevalence, and disability-adjusted life years (DALY) in High-income Asia Pacific, Australasia, and Western European countries from 1990 to 2019. This trend can be attributed to the probability that regions or countries with greater economic resources are more likely to have access to superior medical care, increased health awareness among their population, and effective public health services, including health education and intervention. Besides, we found High SDI regions compared to other regions with pronouncedly higher ASIR. The regional variation of this disease could be attributed to bigger aging populations and lower overall fertility rates [18]. The types demographic profiles of populations included (e.g., hospital, primary-care, community-based), and methods used to ascertain AF/AFL [e.g., screening ECG, health claims data] may vary considerably in different countries, making substantially impact the incidence and prevalence of AF/AFL [19]. The paroxysmal and unpredictable nature of atrial fibrillation episodes implies that longer recording durations increase the likelihood of detecting asymptomatic episodes of AF/AFL. Additionally, it should be noted that the detection rates of atrial fibrillation may vary across different devices [20]. For instance, wearable devices such as smartwatches utilizing photoplethysmography have expanded the screening capacity for atrial fibrillation. However, they may be susceptible to noise interference, necessitating the need for ECG verification [20,21]. This may have an impact on the incidence rate of atrial fibrillation. A thorough collection of potential differentiating features worldwide and a direct comparison of AF/AFL burden between regions with a similar demographic profile using similar methods of AF/AFL ascertainment could strengthen the available evidence and yield valuable additional information [4,8,22–24]. The present evidence could be strengthened by an entire global inventory of potential differentiating characteristics and a direct comparison of AF/AFL burden between regions with comparable demographics using comparable techniques for AF ascertainment.

We also identified sex and age-specific differences in the global prevalence of AF/AFL. Female sex is an age-dependent risk modifier for AF/AFL -related ischemic strokes [25–27]. The Framingham Heart study showed that in AF/AFL patients, women have lower prevalence and incidence but higher stroke and mortality than men between 1958–67 and 1998–2007 [28]. Moreover, women with other CHA2DS2-CASc factors had a higher risk of ischemic stroke than men [29]. As expected, we observed an increased prevalence, incidence, death, and DALY cases in both genders across all time points. Besides, males had a higher incidence and prevalence rate of AF/AFL than females, whereas females had higher ASDR and ASDALYR. The PINNACLE Registry study showed that females with atrial fibrillation had a lower rate of anticoagulant use than males, despite a higher risk of thromboembolism [30]. More effective and targeted interventions will be needed to address the sex difference in AF/AFL burden. Globally, the disease burden was low under the age of 30 and increased with age, reaching a peak among 60–69 for incidence, 70–74 for prevalence, 85 for death, and 80-for DALYs, respectively. Under 70 years of age, males had more incidence, prevalence, and DALYs than females, and they were similar for both genders between 70 and 74 years. However, this trend was reversed over 75 years, that females had higher total incidence, prevalence, and DALYs than males. These findings point toward sex-specific, age-related targets for preventing and managing AF/AFL.

In the future decades, the disease burden of AF/AFL will continue to rise due to the rise in high-risk factors and the aged population globally. According to our projection analysis, the incidence, prevalence, and DALY cases will continue to rise in both genders over the next 25 years. Even though the estimated death rates showed a decline trend globally, the disease burden of AF/AFL is still severe, with substantially new cases. Hence, the disease burden will remain severe if no effective interventions are implemented.

Although aging is a critical AF risk factor [31], recent studies showed metabolic risk plays a vital role in AF burden, particularly hypertension, diabetes mellitus, and obesity [32]. Behavior risk factors like smoking and alcohol use are also potent contributors to AF pathogenesis [33]. Additionally, approximately 22 % of AF in the UK biobank has genetic heritability [34]. This study found that high systolic blood pressure was the most prominent risk factor for ASDR and ASDALYR in all age groups and did not differ between males and females. The behavior risk factors, including smoking and alcohol use, rank second and third in males, which could be the primary cause of variations between males and females.

It is well known that high systolic blood pressure is a major modifiable risk factor for cardiovascular morbidity and mortality across different age categories [35–37]. The data demonstrated that the proportion of DALYs attributable to high systolic blood pressure gradually decreased from 1990 to 2019. In most nations, high systolic blood pressure showed an upward tendency but a downward

trend in high-income nations. Rich countries experienced an increased rate of hypertension detection and timely treatment in the early stage [38].

Additionally, the proportion of DALYs attributable to smoking was observed to display a slight downward trend. The reduction in the number of smoking probably due to the support and promotion of smoking cessation. The sixth WHO report suggested that over 3.5 billion people benefited from the considerable reduction in global cigarette sales [39]. For instance, there was a reduction of 2.5 % in smoking rates across 126 countries, and smoking cessation reduced cardiovascular disease incidence and mortality.

The high body-mass index has become a risk factor for AF/AFL burden that cannot be ignored and even counteracted or exceed the reduction of other factors induced-disease burden. Globally, there was an increasing adult population's BMI over the past 30 years [40], with 1.5 billion overweight and 500 million obese adults according to the WHO report [41]. The risk is more significant in High and High-Middle regions in 2019 but has accelerated in Low and Low-middle regions. The data was consistent with the previous study [42]. Moreover, the proportion of DALYs attributable to the high body-mass index was increasing in most regions, except for High-income Asia Pacific. This trend is particularly strong in Low and Low-middle SDI regions, which might be due to the disadvantages experienced in Low and Low-middle SDI regions: lower income and education, a lack of availability and higher price of healthy foods, and fewer leisure and sports facilities.

We did not analyze the data for those aged 0–30 years because this group's mortality attributed to AF was negligible. At age onset, most risk factors induced DALYs displayed a unimodal distribution, peaking at age 50–70 years, which could possibly explain why the highest incident number of AF/AFL was observed in the age group of 65–69 years. Hence, as the most common arrhythmia, AF/AFL remains a substantial global impact on public health with an increasing incidence and prevalence rate. Moving forward, more effort is needed to improve preventive care and treatment for AF/AFL. Aggressive management and modification of risk factors are warranted. People with these AF modifiable risk factors may benefit from positive lifestyle changes (e.g., moderate alcohol consumption, weight control, and smoking cessation) that may aid in reducing the burden of AF [43]. Additionally, a STROKESTOP trial [44] has shown that large-scale screening of AF in 75- and 76-year-olds living for anticoagulant therapy was associated with a significant reduction in stroke and risk of ischemic stroke or systemic thromboembolism.

4.1. Limitation

First, the data provided by GBD 2019 Study originated from various sources; the quality of individual studies providing data could influence the accuracy and robustness of estimates. Second, levels of AF/AFL surveillance vary among countries and are inadequate in less developed countries, which may represent an underestimate of the AF/AFL burden. Third, considerable evidence is that coronary artery disease, heart failure, and obstructive sleep apnea are important risk factors for AF/AFL. The GBD 2019 database currently does not have the corresponding data. At last, AF has two main subtypes valvular AF and non-valvular AF, the current GBD databases do not classify the subtype of AF in detail.

5. Conclusion

In summary, we found that the ASRs of incidence and prevalence decreased, but the absolute number of individuals with AF/AFL increased yearly. The decreases are less pronounced in the High and High-middle SDI region, contributed to the decreases, and even counteracted the reduction of Middle, Low and Low-middle SDI regions. There is pronounced variation in AF/AFL burden between males and females. In addition to controlling hypertension and reducing smoking, we should pay close attention to the education and prevention of obesity, particularly in deprived economic groups. The findings offer insightful information that can be used to create increasingly integrated solutions to tackle the AF/AFL concerns.

Funding

This work was supported by the National Natural Science Foundation of China Grant (No.82300427).

Author contributions

QCM designed and conceived the study; QCM and NZ acquired and analyzed the data from GBD database; NZ, JYZ and PPZ conducted stratified analyses on data; JRZ, YZ, QQC and XYX helped statistical advisory and provided supervision for data analysis. NZ, JYZ and QCM wrote the manuscript and prepared the Figures; QCM revised the manuscript. All authors read and approved the final manuscript.

Declaration of competing interest

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

Acknowledgements

We would like to thank the countless individuals who prepared the Global Burden of Disease Study 2019 publicly database.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24052.

References

[1] J. Carlsson, S. Miketic, J. Windeler, A. Cuneo, S. Haun, S. Micus, S. Walter, U. Tebbe, S. Investigators, Randomized trial of rate-control versus rhythm-control in persistent atrial fibrillation: the Strategies of Treatment of Atrial Fibrillation (STAF) study, J. Am. Coll. Cardiol. 41 (2003) 1690–1696, https://doi.org/10.1016/s0735-1097(03)00332-2.

[2] S.H. Hohnloser, K.H. Kuck, J. Lilienthal, Rhythm or rate control in atrial fibrillation–Pharmacological Intervention in Atrial Fibrillation (PIAF): a randomised trial, Lancet 356 (2000) 1789–1794, https://doi.org/10.1016/s0140-6736(00)03230-x.

[3] E. Anter, M. Jessup, D.J. Callans, Atrial fibrillation and heart failure: treatment considerations for a dual epidemic, Circulation 119 (2009) 2516–2525, https://doi.org/10.1161/CIRCULATIONAHA.108.821306.

[4] S.S. Chugh, R. Havmoeller, K. Narayanan, D. Singh, M. Rienstra, E.J. Benjamin, R.F. Gillum, Y.H. Kim, J.H. McAnulty Jr., Z.J. Zheng, et al., Worldwide epidemiology of atrial fibrillation: a global burden of disease 2010 study, Circulation 129 (2014) 837–847, https://doi.org/10.1161/CIRCULATIONAHA.113.005119.

[5] L. Wang, F. Ze, J. Li, L. Mi, B. Han, H. Niu, N. Zhao, Trends of global burden of atrial fibrillation/flutter from Global Burden of Disease Study 2017, Heart 107 (2021) 881–887, https://doi.org/10.1136/heartjnl-2020-317656.

[6] G.B.D. Mortality, C. Causes of Death, Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980-2015: a systematic analysis for the Global Burden of Disease Study 2015, Lancet 388 (2016) 1459–1544, https://doi.org/10.1016/S0140-6736(16)31012-1.

[7] J. Heeringa, D.A. van der Kuip, A. Hofman, J.A. Kors, G. van Herpen, B.H. Stricker, T. Stijnen, G.Y. Lip, J.C. Witteman, Prevalence, incidence and lifetime risk of atrial fibrillation: the Rotterdam study, Eur. Heart J. 27 (2006) 949–953, https://doi.org/10.1093/eurheartj/ehi825.

[8] R.B. Schnabel, X. Yin, P. Gona, M.G. Larson, A.S. Beiser, D.D. McManus, C. Newton-Cheh, S.A. Lubitz, J.W. Magnani, P.T. Ellinor, et al., 50 year trends in atrial fibrillation prevalence, incidence, risk factors, and mortality in the Framingham Heart Study: a cohort study, Lancet 386 (2015) 154–162, https://doi.org/10.1016/S0140-6736(14)61774-8.

[9] M.K. Chung, L.L. Eckhardt, L.Y. Chen, H.M. Ahmed, R. Gopinathannair, J.A. Joglar, P.A. Noseworthy, Q.R. Pack, P. Sanders, K.M. Trulock, et al., Lifestyle and risk factor modification for reduction of atrial fibrillation: a scientific statement from the American heart association, Circulation 141 (2020) e750–e772, https://doi.org/10.1161/CIR.0000000000000748.

[10] A.S. Go, E.M. Hylek, K.A. Phillips, Y. Chang, L.E. Henault, J.V. Selby, D.E. Singer, Prevalence of diagnosed atrial fibrillation in adults: national implications for rhythm management and stroke prevention: the AnTicoagulation and Risk Factors in Atrial Fibrillation (ATRIA) Study, JAMA 285 (2001) 2370–2375, https://doi.org/10.1001/jama.285.18.2370.

[11] H. Stefansdottir, T. Aspelund, V. Gudnason, D.O. Arnar, Trends in the incidence and prevalence of atrial fibrillation in Iceland and future projections, Europace 13 (2011) 1110–1117, https://doi.org/10.1093/europace/eur132.

[12] L. Frost, P. Vestergaard, L. Mosekilde, L.S. Mortensen, Trends in incidence and mortality in the hospital diagnosis of atrial fibrillation or flutter in Denmark, 1980-1999, Int. J. Cardiol. 103 (2005) 78–84, https://doi.org/10.1016/j.ijcard.2004.08.024.

[13] G.B.D.C.o.D. Collaborators, Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980-2017: a systematic analysis for the Global Burden of Disease Study 2017, Lancet 392 (2018) 1736–1788, https://doi.org/10.1016/S0140-6736(18)32203-7.

[14] A. Riebler, L. Held, Projecting the future burden of cancer: Bayesian age-period-cohort analysis with integrated nested Laplace approximations, Biom. J. 59 (2017) 531–549, https://doi.org/10.1002/bimj.201500263.

[15] B. Møller, H. Fekjaer, T. Hakulinen, H. Sigvaldason, H.H. Storm, M. Talbäck, T. Haldorsen, Prediction of cancer incidence in the Nordic countries: empirical comparison of different approaches, Stat. Med. 22 (2003) 2751–2766, https://doi.org/10.1002/sim.1481.

[16] S. Li, H. Chen, J. Man, T. Zhang, X. Yin, Q. He, X. Yang, M. Lu, Changing trends in the disease burden of esophageal cancer in China from 1990 to 2017 and its predicted level in 25 years, Cancer Med. 10 (2021) 1889–1899, https://doi.org/10.1002/cam4.3775.

[17] A.J. Cohen, M. Brauer, R. Burnett, H.R. Anderson, J. Frostad, K. Estep, K. Balakrishnan, B. Brunekreef, L. Dandona, R. Dandona, et al., Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015, Lancet 389 (2017) 1907–1918, https://doi.org/10.1016/S0140-6736(17)30505-6.

[18] G.B.D. Population, C. Fertility, Population and fertility by age and sex for 195 countries and territories, 1950-2017: a systematic analysis for the Global Burden of Disease Study 2017, Lancet 392 (2018) 1995–2051, https://doi.org/10.1016/S0140-6736(18)32278-5.

[19] G.A. Roth, C. Johnson, A. Abajobir, F. Abd-Allah, S.F. Abera, G. Abyu, M. Ahmed, B. Aksut, T. Alam, K. Alam, et al., Global, regional, and national burden of cardiovascular diseases for 10 causes, 1990 to 2015, J. Am. Coll. Cardiol. 70 (2017) 1–25, https://doi.org/10.1016/j.jacc.2017.04.052.

[20] A. Brandes, S. Stavrakis, B. Freedman, S. Antoniou, G. Boriani, A.J. Camm, C.K. Chow, E. Ding, J. Engdahl, M.M. Gibson, et al., Consumer-led screening for atrial fibrillation: frontier review of the AF-SCREEN international collaboration, Circulation 146 (2022) 1461–1474, https://doi.org/10.1161/CIRCULATIONAHA.121.058911.

[21] J. Wasserlauf, C. You, R. Patel, A. Valys, D. Albert, R. Passman, Smartwatch performance for the detection and quantification of atrial fibrillation, Circulation. Arrhythmia and electrophysiology 12 (2019) e006834, https://doi.org/10.1161/circep.118.006834.

[22] P.A. Wolf, R.D. Abbott, W.B. Kannel, Atrial fibrillation as an independent risk factor for stroke: the Framingham Study, Stroke 22 (1991) 983–988, https://doi.org/10.1161/01.str.22.8.983.

[23] E.J. Benjamin, P.A. Wolf, R.B. D'Agostino, H. Silbershatz, W.B. Kannel, D. Levy, Impact of atrial fibrillation on the risk of death: the Framingham Heart Study, Circulation 98 (1998) 946–952, https://doi.org/10.1161/01.cir.98.10.946.

[24] D. Conen, C.U. Chae, R.J. Glynn, U.B. Tedrow, B.M. Everett, J.E. Buring, C.M. Albert, Risk of death and cardiovascular events in initially healthy women with new-onset atrial fibrillation, JAMA 305 (2011) 2080–2087, https://doi.org/10.1001/jama.2011.659.

[25] J.S. Kim, S.Y. Shin, J.H. Kang, H.S. Yong, J.O. Na, C.U. Choi, S.H. Kim, E.J. Kim, S.W. Rha, C.G. Park, et al., Influence of sex on the association between epicardial adipose tissue and left atrial transport function in patients with atrial fibrillation: a multislice computed tomography study, J. Am. Heart Assoc. 6 (2017), https://doi.org/10.1161/JAHA.117.006077.

[26] D. Poli, E. Antonucci, E. Grifoni, R. Abbate, G.F. Gensini, D. Prisco, Gender differences in stroke risk of atrial fibrillation patients on oral anticoagulant treatment, Thromb. Haemostasis 101 (2009) 938–942.

[27] J.B. Olesen, G.Y. Lip, M.L. Hansen, P.R. Hansen, J.S. Tolstrup, J. Lindhardsen, C. Selmer, O. Ahlehoff, A.M. Olsen, G.H. Gislason, C. Torp-Pedersen, Validation of risk stratification schemes for predicting stroke and thromboembolism in patients with atrial fibrillation: nationwide cohort study, BMJ 342 (2011) d124, https://doi.org/10.1136/bmj.d124.

[28] B. Freedman, J. Camm, H. Calkins, J.S. Healey, M. Rosenqvist, J. Wang, C.M. Albert, C.S. Anderson, S. Antoniou, E.J. Benjamin, et al., Screening for atrial fibrillation: a report of the AF-SCREEN international collaboration, Circulation 135 (2017) 1851–1867, https://doi.org/10.1161/CIRCULATIONAHA.116.026693.

[29] B.F. Gage, C. van Walraven, L. Pearce, R.G. Hart, P.J. Koudstaal, B.S. Boode, P. Petersen, Selecting patients with atrial fibrillation for anticoagulation: stroke risk stratification in patients taking aspirin, Circulation 110 (2004) 2287–2292, https://doi.org/10.1161/01.CIR.0000145172.55640.93.

[30] L.E. Thompson, T.M. Maddox, L. Lei, G.K. Grunwald, S.M. Bradley, P.N. Peterson, F.A. Masoudi, A. Turchin, Y. Song, G. Doros, et al., Sex differences in the use of oral anticoagulants for atrial fibrillation: a report from the national cardiovascular data Registry (NCDR((R))) PINNACLE Registry, J. Am. Heart Assoc. 6 (2017), https://doi.org/10.1161/JAHA.117.005801.
[31] R. Sankaranarayanan, G. Kirkwood, K. Dibb, C.J. Garratt, Comparison of atrial fibrillation in the young versus that in the elderly: a review, Cardiol. Res. Pract. 2013 (2013) 976976, https://doi.org/10.1155/2013/976976.
[32] G.Y. Lip, R. Nieuwlaat, R. Pisters, D.A. Lane, H.J. Crijns, Refining clinical risk stratification for predicting stroke and thromboembolism in atrial fibrillation using a novel risk factor-based approach: the euro heart survey on atrial fibrillation, Chest 137 (2010) 263–272, https://doi.org/10.1378/chest.09-1584.
[33] M. Jacobsen, T.A. Dembek, A.P. Ziakos, R. Gholamipoor, G. Kobbe, M. Kollmann, C. Blum, D. Muller-Wieland, A. Napp, L. Heinemann, et al., Reliable detection of atrial fibrillation with a medical wearable during inpatient conditions, Sensors 20 (2020), https://doi.org/10.3390/s20195517.
[34] L.-C. Weng, S.H. Choi, D. Klarin, J.G. Smith, P.-R. Loh, M. Chaffin, C. Roselli, O.L. Hulme, K.L. Lunetta, J. Dupuis, Heritability of atrial fibrillation, Circulation: Cardiovascular Genetics 10 (2017) e001838.
[35] C. Blood Pressure Lowering Treatment Trialists, Pharmacological blood pressure lowering for primary and secondary prevention of cardiovascular disease across different levels of blood pressure: an individual participant-level data meta-analysis, Lancet 397 (2021) 1625–1636, https://doi.org/10.1016/S0140-6736(21)00590-0.
[36] K. Rahimi, C.A. Emdin, S. MacMahon, The epidemiology of blood pressure and its worldwide management, Circ. Res. 116 (2015) 925–936, https://doi.org/10.1161/CIRCRESAHA.116.304723.
[37] E. Rapsomaniki, A. Timmis, J. George, M. Pujades-Rodriguez, A.D. Shah, S. Denaxas, I.R. White, M.J. Caulfield, J.E. Deanfield, L. Smeeth, et al., Blood pressure and incidence of twelve cardiovascular diseases: lifetime risks, healthy life-years lost, and age-specific associations in 1.25 million people, Lancet 383 (2014) 1899–1911, https://doi.org/10.1016/S0140-6736(14)60685-1.
[38] D. Ettehad, C.A. Emdin, A. Kiran, S.G. Anderson, T. Callender, J. Emberson, J. Chalmers, A. Rodgers, K. Rahimi, Blood pressure lowering for prevention of cardiovascular disease and death: a systematic review and meta-analysis, Lancet 387 (2016) 957–967, https://doi.org/10.1016/S0140-6736(15)01225-8.
[39] W.H. Organization, WHO Report on the Global Tobacco Epidemic, 2017: Monitoring Tobacco Use and Prevention Policies, World Health Organization, 2017.
[40] M.M. Finucane, G.A. Stevens, M.J. Cowan, G. Danaei, J.K. Lin, C.J. Paciorek, G.M. Singh, H.R. Gutierrez, Y. Lu, A.N. Bahalim, et al., National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants, Lancet 377 (2011) 557–567, https://doi.org/10.1016/S0140-6736(10)62037-5.
[41] K. Whitlock, R.S. Gill, D.W. Birch, S. Karmali, The association between obesity and colorectal cancer, Gastroenterol Res Pract 2012 (2012) 768247, https://doi.org/10.1155/2012/768247.
[42] N.C.D.R.F. Collaboration, Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults, Lancet 390 (2017) 2627–2642, https://doi.org/10.1016/S0140-6736(17)32129-3.
[43] M.E. Middeldorp, J. Ariyaratnam, D. Lau, P. Sanders, Lifestyle modifications for treatment of atrial fibrillation, Heart 106 (2020) 325–332, https://doi.org/10.1136/heartjnl-2019-315327.
[44] E. Svennberg, L. Friberg, V. Frykman, F. Al-Khalili, J. Engdahl, M. Rosenqvist, Clinical outcomes in systematic screening for atrial fibrillation (STROKESTOP): a multicentre, parallel group, unmasked, randomised controlled trial, Lancet 398 (2021) 1498–1506, https://doi.org/10.1016/s0140-6736(21)01637-8.