Estimation of Global and Regional Incidence and Prevalence of Abdominal Aortic Aneurysms 1990 to 2010

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ABSTRACT

The global burden of abdominal aortic aneurysm (AAA) has not been studied previously. Such information is important given the emergence of cardiovascular diseases in developing countries. We conducted a systematic literature review and estimated the global and regional incidence and prevalence of AAA in 21 world regions by age and sex. The search for prevalence and incidence of AAA using standard clinical and epidemiological terms was conducted using MEDLINE (1950 to 2010), EMBASE (1980 to 2010), AMED (1985 to 2010), CINAHL (1982 to 2010), and LILACS (2008 to 2010). Data abstracted from the systematic review served as priors for Bayesian meta-regression analyses. The analysis drew from 26 high-quality studies to estimate AAA prevalence and incidence. In 1990, the global age-specific prevalence rate per 100,000 ranged from 8.43 (95% CI: 7.03 to 10.14) in the 40 to 44 years age group to 2,422.53 (95% CI: 2,298.63 to 2,562.25) in the 75 to 79 years age group; the corresponding range in 2010 was 7.88 (95% CI: 6.54 to 9.59) to 2,274.82 (95% CI: 2,149.77 to 2,410.17). Prevalence was higher in developed versus developing nations, and the rates within each development stratum decreased between 1990 and 2010. Globally, the age-specific annual incidence rate per 100,000 in 1990 ranged from 0.89 (95% CI: 0.66 to 1.17) in 40 to 44 years age group to 176.08 (95% CI: 162.72 to 190.28) in the 75 to 79 years age group. In 2010, this range was 0.83 (95% CI: 0.61 to 1.11) to 164.57 (95% CI: 152.20 to 178.78). The highest prevalence in 1990 was in Australasia and North America high income regions: 382.65 (95% CI: 356.27 to 410.88) and 300.59 (95% CI: 280.93 to 321.54), respectively. Australasia had the highest prevalence in 2010, although the prevalence decreased to 310.27 (95% CI: 289.01 to 332.94). Regional prevalence increased in Oceania, tropical Latin America, Asia Pacific high income, Southern Sub-Saharan Africa (SSA), Central SSA, South Asia, Western SSA, and Central Asia. AAA global prevalence and incidence rates have decreased over the last 20 years. However, rising rates in some regions highlight the need for policies to enhance global disease surveillance and prevention.

Abdominal aortic aneurysm (AAA) is a focal dilation of the abdominal aorta of at least 1.5 times the normal diameter or an absolute value of 3.0 cm or greater [1]. Known risk factors for AAA include male sex, atherosclerosis, smoking, hypertension, and history of AAA in a first-degree relative [2–4]. During the 20th century, many developed nations reported a consistent increase in the incidence and mortality associated with AAA [5–9]. The reported overall prevalence in developed countries was approximately 5%, and it was shown to be 4 times higher in men than in women [10,11], although women diagnosed with AAA appear to have a worse prognosis than men [12,13]. AAA mortality is greatest among those previously undiagnosed who may present with rupture; such individuals have up to 90% mortality rate if rupture occurs outside of the hospital [2,3,14–16].

The observed adverse epidemiological trends [5–9] led to targeted screening efforts as an important component of the management of AAA, and the benefit of screening was supported by systematic evidence review and synthesis of data from randomized controlled trials [17]. In this context, recent reports on the basis of data over the past 2 decades suggest that the mortality associated with AAA has declined in the United States, England, Wales, Australia, New Zealand, and Sweden [18–22]. However, these country-level reports from developed nations are not enough to provide reliable global estimates of incidence and prevalence of AAA. To aid in the planning of policies and programs for the global

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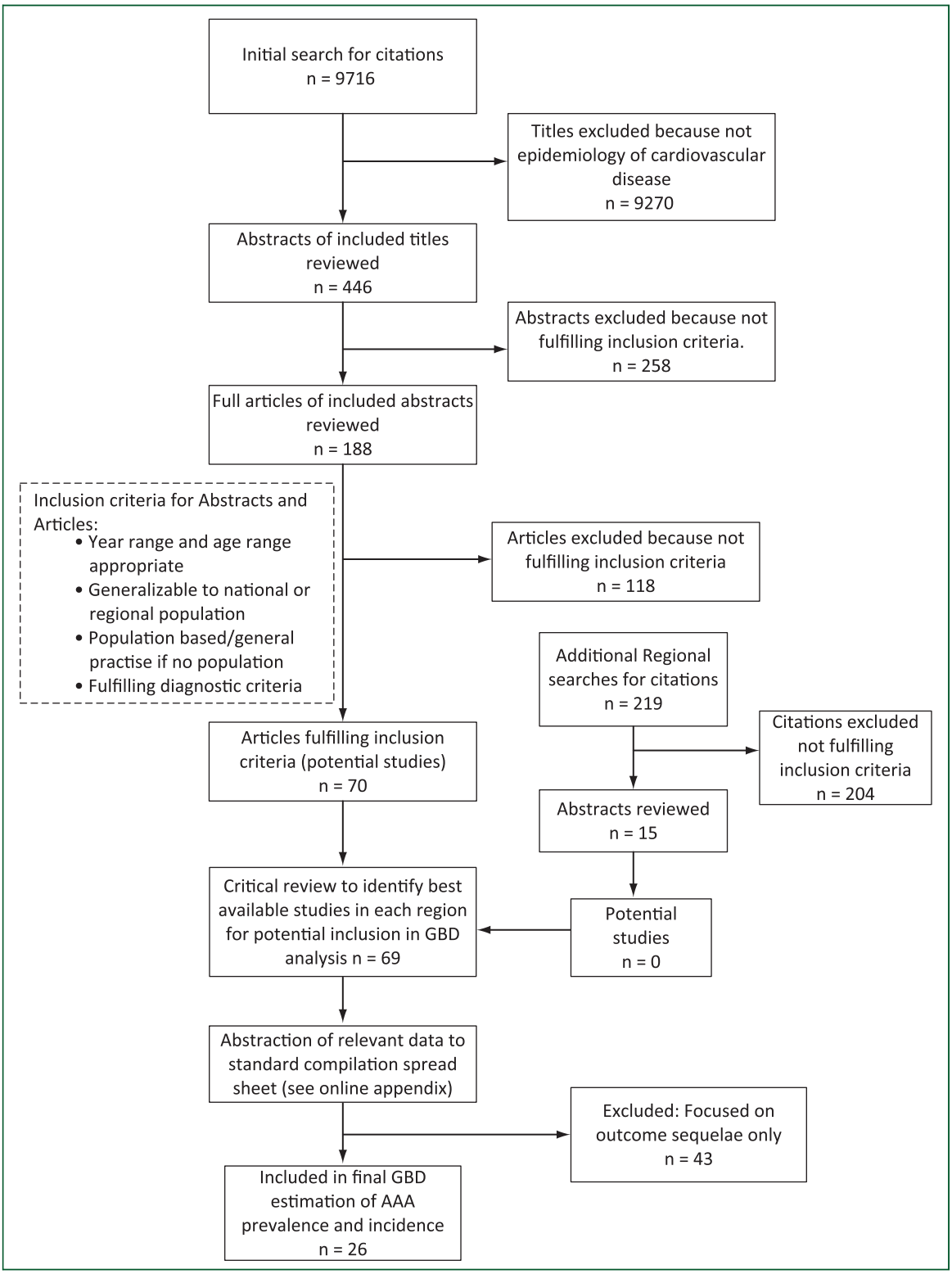

FIGURE 1. Literature review and data abstraction flow chart for AAA systematic analysis. Abdominal aortic aneurysm (AAA) studies included the definition of important clinical sequelae for AAA, which were intact AAA (infrarenal aortic diameter $\geq$30 mm), fatal ruptured AAA, emergency surgical repair for ruptured AAA, and elective surgical repair of AAA (open or endovascular). GBD, global burden of disease.

TABLE 1. Age-specific AAA prevalence rates per 100,000 population by country development status, 1990 and 2010

	Age group, yrs											
Region	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	≥80
1990												
Developed												
Estimate	2.71	3.60	5.90	10.16	28.69	156.51	440.16	894.50	1,501.89	2,171.32	2,666.91	3,404.25
CI lower	2.03	2.72	4.74	8.09	25.04	145.54	411.89	849.48	1,429.27	2,068.36	2,536.17	3,243.10
CI upper	3.66	4.85	7.39	12.73	33.42	169.34	472.52	943.63	1,579.25	2,281.32	2,799.43	3,579.85
Developing												
Estimate	2.04	2.78	4.62	7.70	21.07	117.95	332.82	685.27	1,165.47	1,709.27	2,190.06	2,882.98
CI lower	1.55	2.10	3.62	6.01	17.79	105.43	298.04	621.62	1,060.83	1,547.18	1,995.39	2,621.50
CI upper	2.73	3.78	6.03	10.04	25.06	131.86	373.11	754.73	1,286.28	1,893.16	2,413.17	3,158.70
Global												
Estimate	2.19	2.98	4.95	8.43	23.33	130.46	368.44	764.26	1,301.44	1,890.59	2,422.53	3,174.85
CI lower	1.75	2.39	4.10	7.03	20.80	121.21	343.78	720.75	1,227.29	1,779.46	2,298.63	3,021.94
CI upper	2.81	3.84	6.10	10.14	26.35	140.66	396.87	812.47	1,379.98	2,013.09	2,562.25	3,339.34
2010												
Developed												
Estimate	2.43	3.24	5.31	9.06	25.71	142.12	397.73	827.97	1,402.69	1,943.94	2,478.62	3,158.28
CI lower	1.83	2.42	4.26	7.10	22.34	131.78	370.37	783.24	1,336.95	1,852.43	2,361.96	3,006.07
CI upper	3.14	4.23	6.64	11.56	30.11	153.14	424.92	871.27	1,474.43	2,038.61	2,603.68	3,314.10
Developing												
Estimate	1.94	2.63	4.43	7.59	20.66	116.63	333.64	678.22	1,146.26	1,654.68	2,139.31	2,836.16
CI lower	1.50	2.01	3.53	5.96	17.64	104.44	296.61	613.62	1,042.59	1,497.68	1,943.86	2,599.24
CI upper	2.60	3.49	5.62	9.66	24.39	130.72	376.47	749.21	1,261.74	1,820.22	2,350.28	3,103.74
Global												
Estimate	2.02	2.74	4.60	7.88	21.85	123.25	350.94	725.66	1,229.12	1,761.18	2,274.82	3,002.78
CI lower	1.62	2.17	3.79	6.54	19.42	113.63	322.47	677.33	1,154.16	1,658.85	2,149.77	2,861.13
CI upper	2.57	3.47	5.66	9.59	24.77	133.98	383.45	776.35	1,312.17	1,871.27	2,410.17	3,150.92

AAA, abdominal aortic aneurysm.

prevention and management of AAA, comprehensive epidemiological surveillance is warranted, especially in light of the current worldwide epidemiological transition and emergence of cardiovascular diseases in developing countries. We conducted a systematic analysis of all the evidence available in the public domain to identify high-quality studies of AAA epidemiology. Using the information from those studies and Bayesian meta-regression methods, we provide the first comprehensive estimates of global and regional incidence and prevalence of AAA in 21 regions worldwide from 1990 to 2010.

METHODS

The methods consisted of 2 main stages: 1) literature search and extraction of data from studies on AAA incidence and prevalence and 2) statistical modeling of regional and global incidence and prevalence of AAA on the basis of the extracted data.

Literature search and data extraction

Important clinical sequelae (conditions) were defined for AAA a priori. Sequelae for AAA were intact AAA (infrarenal aortic diameter ≥30 mm), fatal ruptured AAA, emergency surgical repair for ruptured AAA, and elective surgical repair of AAA (open or endovascular). We conducted a systematic review of published literature on AAA. The initial search for prevalence and incidence of sequelae using standard clinical and epidemiological terms was conducted using the following databases: MEDLINE (1950 to 2010), EMBASE (1980 to 2010), AMED (1985 to 2010), CINAHL (1982 to 2010), and LILACS (2008 to 2010). Due to a paucity of papers covering some regions and countries, a broader search using simply AAA was conducted for these areas. Experts on AAA were approached, and reference lists of included papers were scanned for additional papers. Papers considered for inclusion were evaluated for their quality and relevance prior to a final decision on which to include in the review. For each of the 21 global regions, a "best available data" approach was employed.

Initial screening retrieved 9,716 titles of articles (Fig. 1), of which 446 abstracts were reviewed, resulting in full assessment of 188 full-text papers and final abstraction of data from 69 studies (Online Appendix). The extracted data included study characteristics (e.g., setting, duration, design), diagnostic criteria, mean age of study participants,

TABLE 2. Age-specific AAA annual incidence rates per 100,000 population by country development status, 1990 and 2010

	Age group, yrs											
Region	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	≥80
1990												
Developed												
Estimate	0.15	0.31	0.70	1.10	13.94	44.70	81.74	125.12	157.93	177.30	189.26	223.17
CI lower	0.09	0.24	0.51	0.75	12.77	41.04	75.95	115.22	145.14	162.24	172.97	203.75
CI upper	0.22	0.41	0.96	1.55	15.34	49.22	87.92	135.66	171.95	194.57	208.39	244.62
Developing												
Estimate	0.12	0.24	0.53	0.81	10.01	33.56	61.26	94.90	123.28	144.78	163.55	197.89
CI lower	0.08	0.18	0.37	0.54	8.94	29.54	54.70	84.01	109.63	127.86	144.50	174.76
CI upper	0.18	0.31	0.76	1.20	11.34	38.24	69.16	107.46	139.65	164.50	187.90	225.52
Global												
Estimate	0.12	0.26	0.57	0.89	11.17	37.17	68.06	106.31	137.28	157.54	176.08	212.04
CI lower	0.09	0.20	0.44	0.66	10.34	34.23	63.45	98.43	127.18	144.97	162.72	197.04
CI upper	0.17	0.32	0.75	1.17	12.14	40.65	73.02	114.59	147.57	170.08	190.28	227.47
2010												
Developed												
Estimate	0.13	0.28	0.62	0.96	12.57	40.60	74.05	116.52	147.64	158.37	175.12	203.38
CI lower	0.09	0.21	0.45	0.65	11.40	36.61	68.67	106.67	134.92	145.02	159.43	185.00
CI upper	0.20	0.36	0.87	1.41	13.88	44.75	80.16	127.04	160.84	171.67	191.64	223.97
Developing												
Estimate	0.11	0.22	0.51	0.79	9.94	33.39	61.70	94.29	121.12	139.26	157.56	188.59
CI lower	0.07	0.17	0.36	0.53	8.80	29.21	54.68	82.65	106.79	124.01	139.33	169.09
CI upper	0.16	0.29	0.70	1.15	11.24	37.93	69.55	107.16	137.17	157.23	178.77	211.89
Global												
Estimate	0.12	0.23	0.53	0.83	10.56	35.27	65.03	101.33	129.69	146.30	164.57	196.24
CI lower	0.08	0.19	0.40	0.61	9.65	32.07	59.81	92.95	119.83	135.47	152.20	182.94
CI upper	0.16	0.29	0.68	1.11	11.60	38.92	71.10	110.98	141.65	158.83	178.78	211.53

Abbreviation as in Table 1.

and sex ratio of patients. The final global burden of disease (GBD) estimation of prevalence and incidence was executed with data from 26 studies [23–48], which spanned 6 GBD regions: Europe (Western), Australasia, North Africa/Middle East, Asia Pacific (high income), Latin America (tropical), and North America (high income).

Epidemiological modeling

Estimates were made from data gathered in systematic reviews of epidemiological data using the previously described Bayesian meta-regression method (DisMod-MR) developed for the GBD 2010 [49]. In addition to assumptions of the generic model of DisMod-MR, we assumed that 1) remission of AAA (regardless of any treatments such as repair) was zero for all ages modeled; 2) incidence and prevalence before age 25 was zero; 3) relative difference of prevalence between men and women was used to adjust incidence in women; and 4) level of prevalence in different regions was proportional to number of deaths due to ruptured aneurysm in the regions in ages 50 to 65 years.

The DisMoD-MR uses 2 types of covariates: those that explain true variation in prevalence and those that explain variation due to case definitions or diagnostic technology. This tool estimates a generalized negative binomial model for all of the epidemiological data with various types of fixed and random effects. DisMod-MR can be used to estimate age-sex-population specific prevalence from heterogeneous and often sparse data sets. The GBD dealt with the problem of absent or low-quality epidemiological data from some regions or countries by incorporating covariates (e.g., cardiovascular risk factors, national income, differences in measurement method) and "borrowing strength" from nearby regions and years of observation in DisMod-MR models and by using prior standard assumptions about the relationship among disease-specific incidence, prevalence, case fatality, and mortality in DisMod-MR models [49–51].

RESULTS

The AAA prevalence rates per 100,000 population by country development status are detailed in Table 1. In 1990, the global prevalence rate ranged from 8.43 (95% CI: 7.03 to 10.14) in the 40 to 44 years age group to 2,422.53 (95% CI: 2,298.63 to 2,562.25) in the 75 to 79 years age group, whereas the corresponding rates in 2010 were 7.88 (95% CI: 6.54 to 9.59) to 2,274.82 (95% CI: 2,149.77 to 2,410.17). In

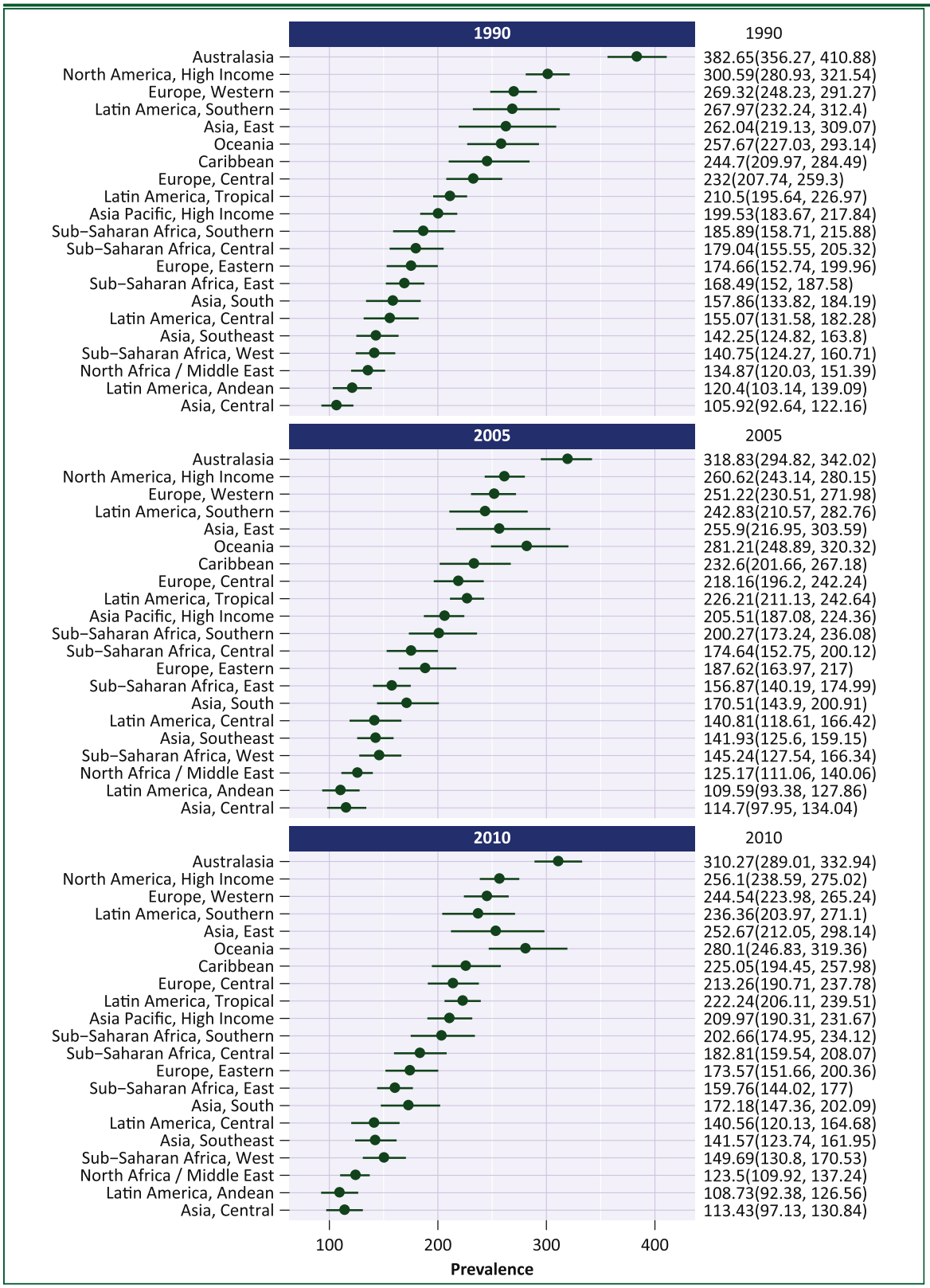

FIGURE 2. AAA prevalence by GBD region in 1990, 2005, and 2010. The dots denote estimates of AAA prevalence rates per 100,000 population in all GBD regions. The bars around the estimates are the corresponding 95% uncertainty intervals. Abbreviations as in Figure 1.

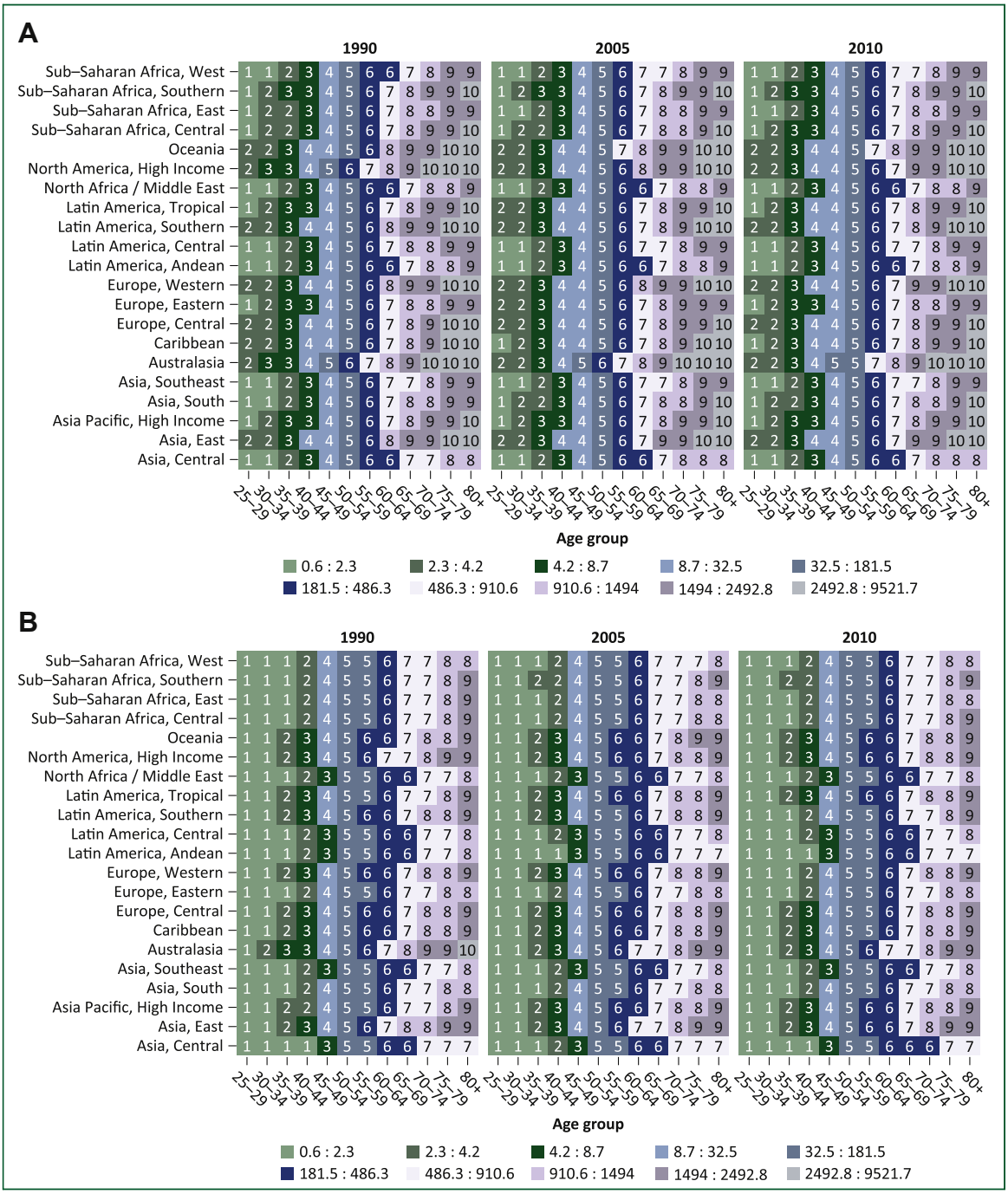

FIGURE 3. AAA prevalence by GBD region and age group in 1990, 2005, and 2010. (A) Total population. (B) Women. (C) Men. Each color-coded box represents a range of age-specific prevalence rates per 100,000 population for a GBD region in 1990, 2005, and 2010. Color gradations (also delineated by numbers within the color-coded boxes) represent different tiers of prevalence rates. The color gradient from green to blue to purple to gray (or increasing numbers) observed with increasing age indicates an increase in AAA prevalence by age within each region in 1990, 2005, and 2010. Age groups are in years. Abbreviations as in Figure 1.

both years, the global prevalence rate increased with age, and there was a consistent decrease in AAA prevalence from 1990 to 2010 across all age groups. In developed nations, the 1990 rates were 10.16 (95% CI: 8.09 to 12.73) in the 40 to 44 years age group and 2,666.91 (95% CI: 2,536.17 to 2,799.43) in the 75 to 79 years age group; in 2010, they

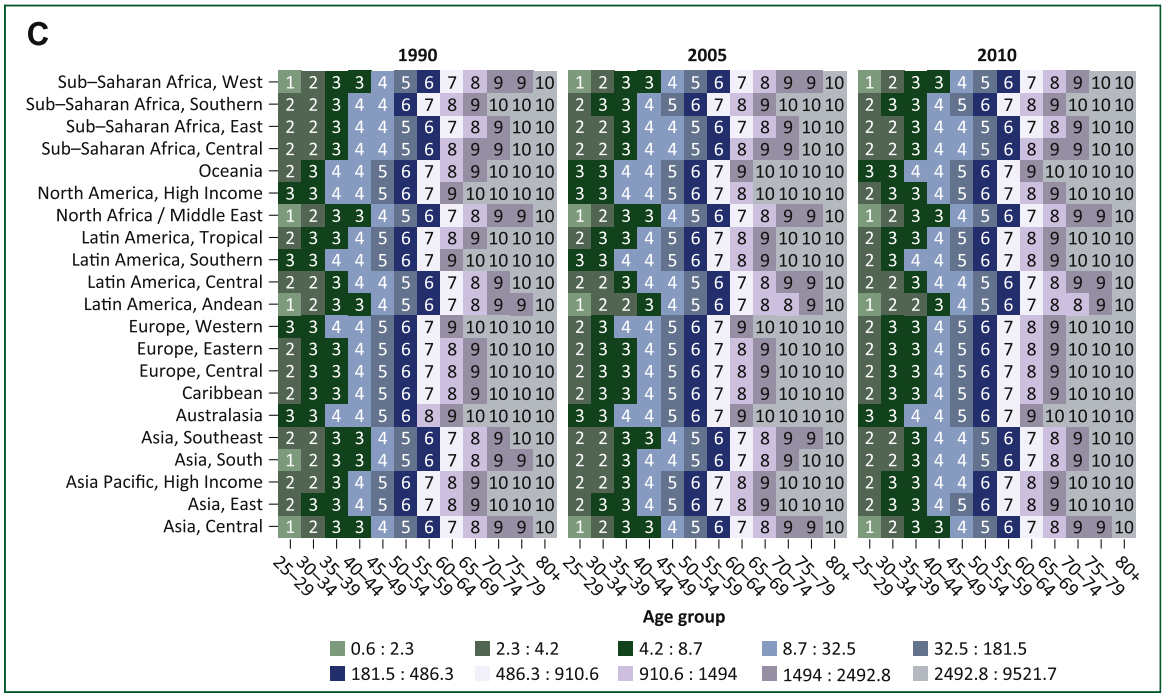

FIGURE 3. (*continued*).

were 9.06 (95% CI: 7.10 to 11.56) and 2,478.62 (95% CI: 2,361.96 to 2,603.68), respectively. In developing nations, these rates were 7.70 (95% CI: 6.01 to 10.04) to 2,190.06 (95% CI: 1,995.39 to 2,413.17) in 1990 and 7.59 (95% CI: 5.96 to 9.66) to 2,139.31 (95% CI: 1,943.86 to 2,350.28), respectively. Across all age groups, the rates in developed nations were higher than in developing countries in 1990 and 2010.

Globally, the age-specific annual incidence rate per 100,000 in 1990 ranged from 0.89 (95% CI: 0.66 to 1.17) in the 40 to 44 years age group to 176.08 (95% CI: 162.72 to 190.28) in the 75 to 79 years age group, whereas this range in 2010 was 0.83 (95% CI: 0.61 to 1.11) to 164.57 (95% CI: 152.20 to 178.78). Both globally and by country development status, the incidence rates detailed in Table 2 mirror the observed prevalence rate pattern; that is, the rates increased with age and were higher in 1990 than 2010 across all age groups. Furthermore, the incidence rates in developed nations were consistently higher than in developing nations.

Differences in regional prevalence rates of AAA are illustrated in Figure 2. The highest prevalence rates in 1990 were in Australasia and North America high income: 382.65 (95% CI: 356.27 to 410.88) and 300.59 (95% CI: 280.93 to 321.54), respectively (Fig. 2). Australasia remained at the top of the list in 2010, although the rate dropped to 310.27 (95% CI: 289.01 to 332.94); however, rates in the Oceania region rose from 257.67 (95% CI: 227.03 to 293.14) in 1990, a fourth place position, to 280.10 (95% CI: 246.83 to 319.36) in 2010, a second place position. Rates also declined in Western Europe from 269.32 (95% CI: 248.23 to 291.27) in 1990 to 244.54 (95% CI: 223.98 to 265.24) in 2010.

Other instances of decline in regional rates were in Southern Latin America, East Asia, Caribbean, Central Europe, Eastern Europe, East Sub-Saharan Africa (SSA), Central Latin America, Southeast Asia, North Africa/Middle East, and Andean Latin America. In addition to Oceania, other increases in regional rates were observed in tropical Latin America, Asia Pacific high income, Southern SSA, Central SSA, South Asia, West SSA, and Central Asia. The pattern of increasing prevalence with age was preserved regionally (Fig. 3A) and within sex, as depicted by the color chart in Figures 3B and 3C. However, across all ages, the rates were distinctly higher among men across all age groups. Regional differences in incidence rates (Fig. 4) were similar to differences in prevalence. Figures 5A, 5B, and 5C depict the increasing incidence rates with age across all regions, which were consistent within sex, albeit with higher rates among men compared with women of similar age groups.

DISCUSSION

This systematic evaluation of the global epidemiology of AAA provides evidence that the prevalence and incidence of AAA have declined over the past 2 decades, which is consistent with reports from individual countries [18–22]. This study provides further evidence that the burden of AAA increases with age and that men are affected more frequently than women. At the global level, the incidence and prevalence rates are higher in developed versus

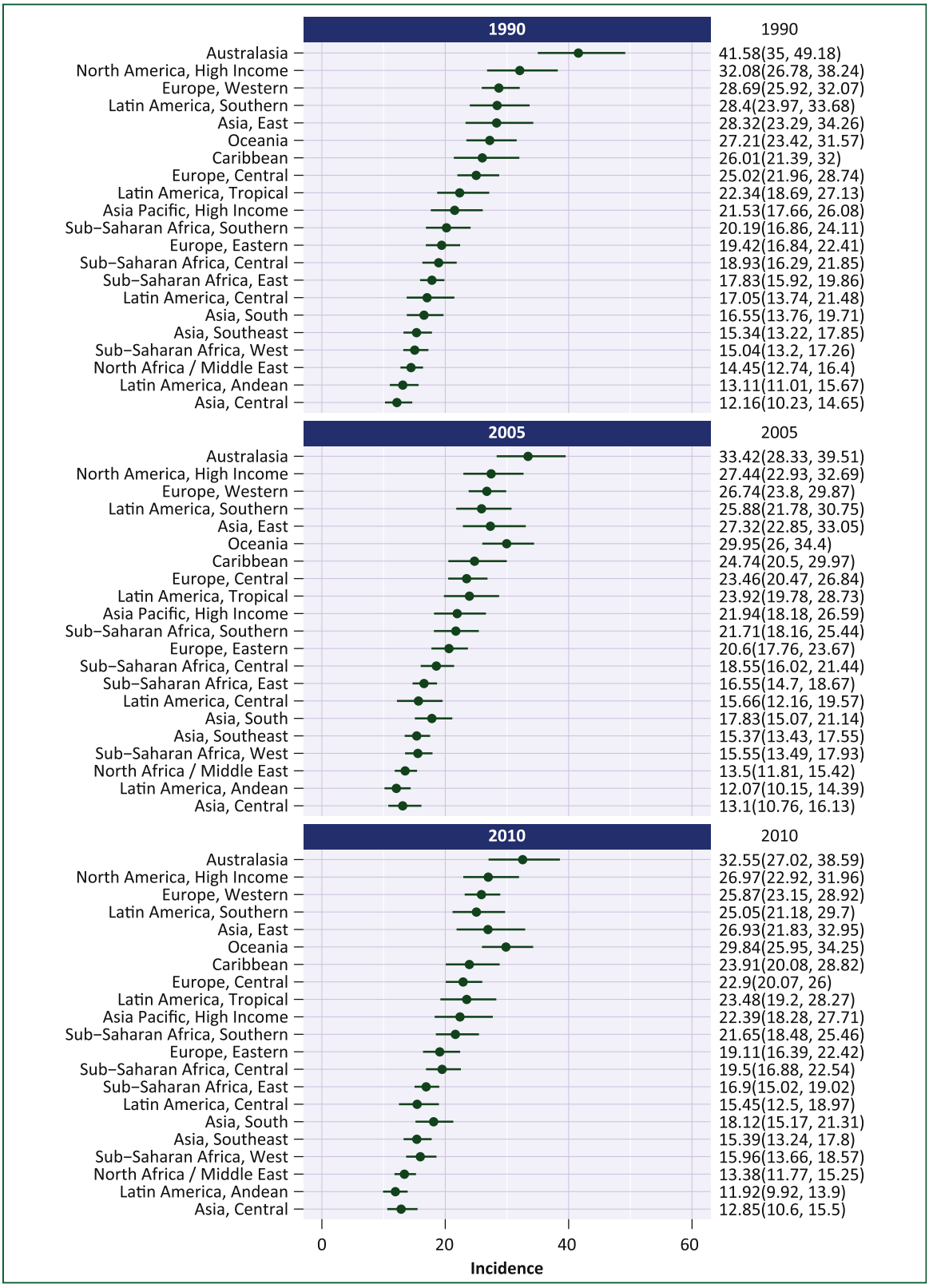

FIGURE 4. AAA annual incidence rates by GBD region in 1990, 2005, and 2010. The dots denote estimates of the annual incidence rates of AAA per 100,000 population in all GBD regions. The bars around the estimates are the corresponding 95% uncertainty intervals. Abbreviations as in Figure 1.

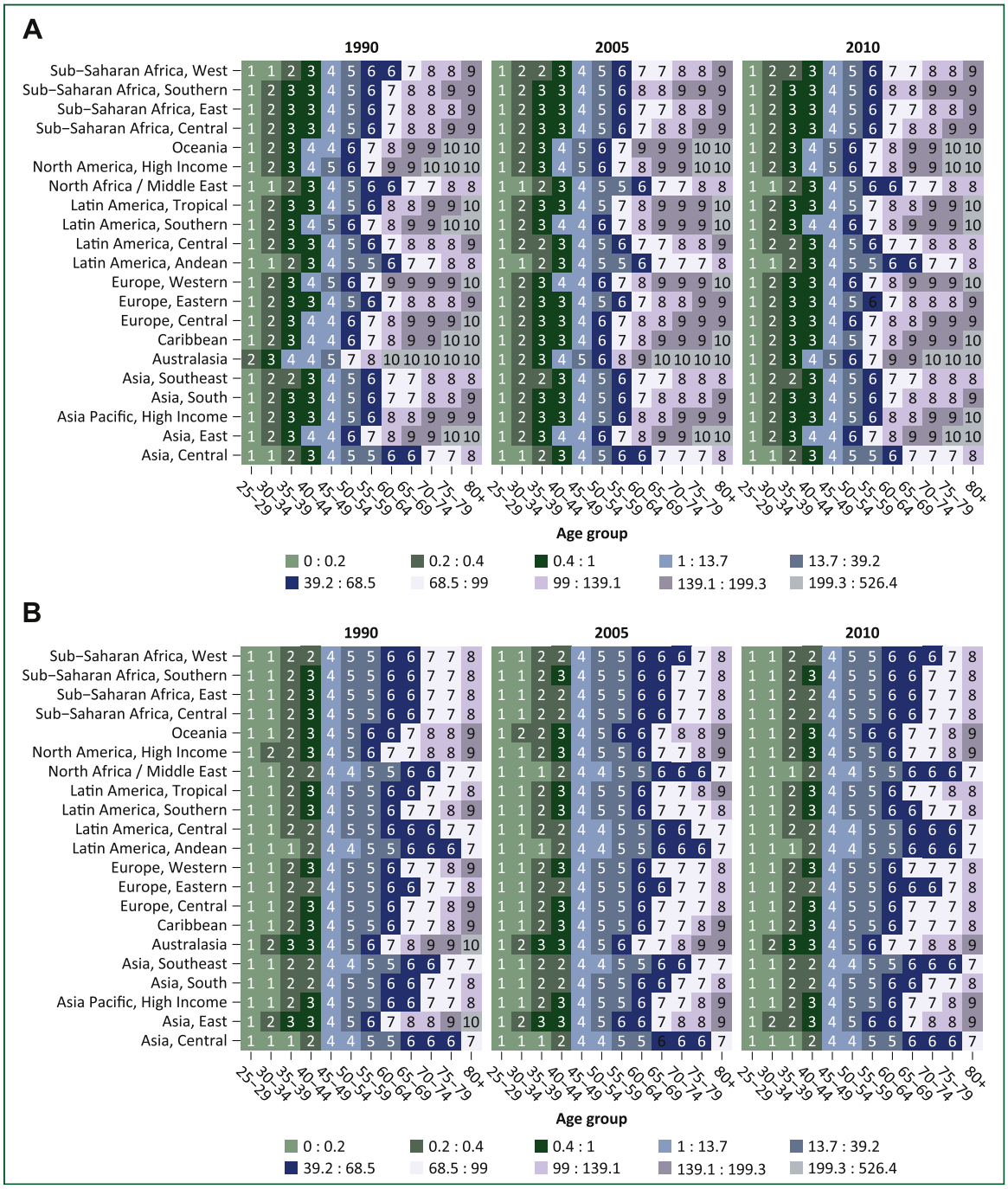

FIGURE 5. AAA annual incidence rates by GBD region and age group in 1990, 2005, and 2010. (A) Total population. (B) Women. (C) Men. The charts delineate estimates of age-specific annual incidence rates of AAA per 100,000 population for all GBD regions. Each color-coded box represents a range of age-specific incidence rates for a GBD region. Color gradations (also delineated by numbers within the color-coded boxes) represent different tiers of incidence rates. The color gradient from green to blue to purple to gray (or increasing numbers) observed with increasing age indicates an increase in AAA incidence by age within each region in 1990, 2005, and 2010. Age groups are in years. Abbreviations as in Figure 1.

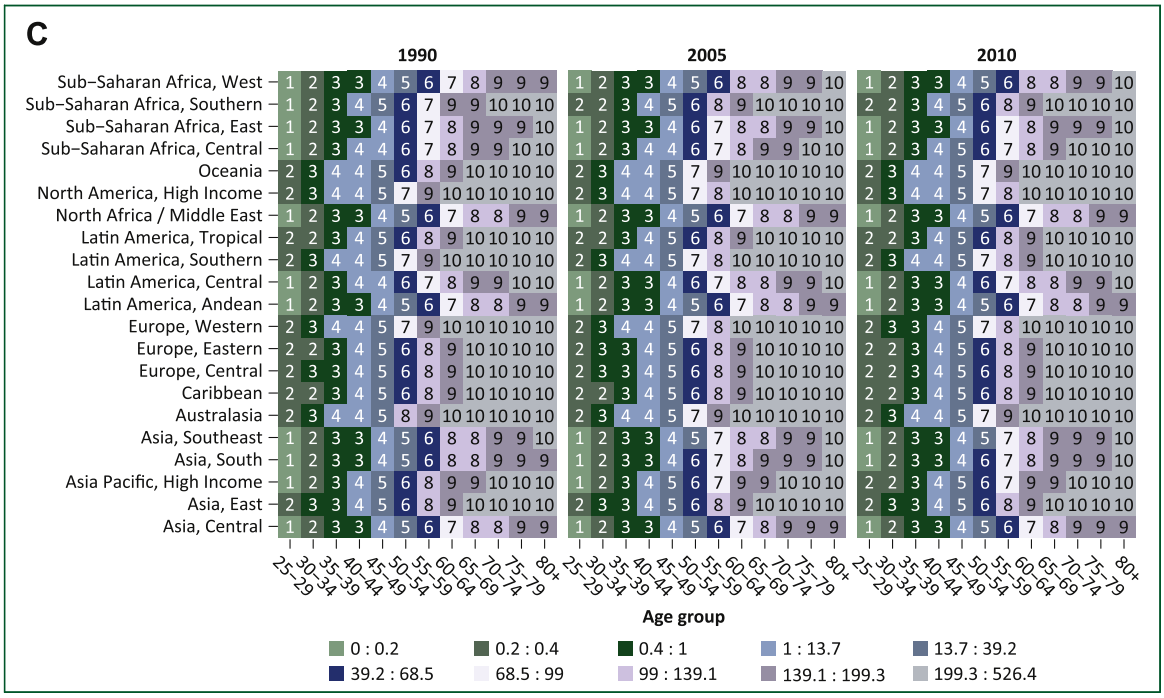

FIGURE 5. (*continued*).

developing nations. However, regional assessments reveal increases in prevalence for some regions, notably Oceania, tropical Latin America, Asia Pacific high income, Southern SSA, Central SSA, South Asia, West SSA, and Central Asia. The insight that this study provides may have implications for future surveillance efforts and intervention.

Australasia, North America high income, and Western Europe had the most appreciable decline in AAA prevalence and incidence rates. Such improvements in epidemiological pattern may be attributed to increases in risk factor control such as smoking cessation programs afforded by the health systems in these regions. Evidence of a decline in AAA in the high-income regions plus the scarcity of data in developing regions had the potential to create a false impression of overall global decline. However, our data and methods were robust enough to detect an increasing trend in AAA in a number of regions. Adverse trends in these regions are concerning and raise 2 fundamental questions. What is responsible for the worsening picture, and what is a reasonable response strategy? Increasing burden [49,52] of risk factors for atherosclerotic cardiovascular disease is worth considering. In this context, smoking cessation programs or policies to lower tobacco consumption may eventually provide good return on investment—akin to a World Health Organization "best buy" [53]—in regions with adverse trends in AAA prevalence and incidence, mostly in developing countries.

Smoking is an important target because multiple studies have identified smoking as the most important modifiable risk factor for AAA [44,47,54,55]. Current smoking, specifically, appears to have the greatest effect, with evidence of a dose response whereby higher daily cigarette intake is associated with higher risk of AAA [56]. Although the mechanisms through which smoking increases AAA formation are unclear, multifactorial effects on atherosclerosis and overall vascular homeostasis may be implicated [57–63]. It is important to note that approximately 900 million smokers live in developing nations, accounting for 70% of global consumption, which stems from the aggressive marketing activities of tobacco companies in these areas [64]. Other strategies for reducing the burden of AAA could include improvements in diagnosis, treatment, and overall disease surveillance. However, these are resource intense and may not be routinely feasible in low- to middle-income regions.

It is important to recognize a major limitation of this study, which is the fact that we may have underestimated the global and regional trends in the incidence and prevalence of AAA due to scarcity of data in some regions. Given limited data for specific regions, it is uncertain as to how reasonable it is to project from other regions. Furthermore, the strength of our systematic analysis rests on the quality of the included studies. These are all factors that make apparent the need for improved global surveillance data to improve future assessments of disease burden.

SUMMARY

AAA global prevalence and incidence rates have decreased over the last 20 years. However, regional evaluation revealed rising AAA rates in many regions of the world,

which highlights the need to improve prevention, diagnosis and treatment, and collection of disease surveillance data globally.

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