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Burden of antimicrobial resistance in the WHO Southeast Asia and Western Pacific Regions, 1990–2021: a cross-country systematic analysis with forecasts to 2050

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Abstract

Background: Antimicrobial resistance (AMR) constitutes a critical global health challenge with major implications for public health and economic stability, increasing infection- and sepsis-related mortality. Despite growing evidence on its contribution to disease burden, comprehensive assessments of long-term trends at the regional level remain limited in the World Health Organization (WHO) Southeast Asia Region (SEAR) and Western Pacific Region (WPR).

Methods: We used data from the Global Research on Antimicrobial Resistance (GRAM) Project to evaluate sepsis- and AMR-related deaths and disability-adjusted life-years (DALYs) for 11 infectious syndromes, 22 pathogens, and 84 pathogen-drug combinations across 42 countries and territories in the WHO SEAR and WPR from 1990 to 2021. AMR burden was estimated under two counterfactual scenarios: deaths and DALYs attributable to AMR (representing the burden if drug-resistant infections were replaced by drug-susceptible infections), and deaths and DALYs associated with AMR (representing the burden if infections did not occur at all). We reported numbers, crude rates, and age-standardized rates, and generated forecasts of AMR burden to 2050 using an autoregressive integrated moving average model.

Results: In SEAR and WPR, there were 8.36×10^6 [95% uncertainty interval (UI) 7.93–8.79] sepsis-related deaths in 1990, which decreased to 6.03×10^6 (95% UI 5.68–6.39) in 2019 before increasing to 8.31×10^6 (95% UI 7.86–8.76) in 2021. The number of deaths associated with AMR ranged from 2,445,875 (95% UI 2,221,769–2,670,192) in 1990 to 2,358,190 (95% UI 2,173,521–2,545,190) in 2021, while deaths attributable to AMR ranged from 546,479 (95% UI 487,669–605,277) to 587,103 (95% UI 534,165–639,903) over the same period. From 1990 to 2021, deaths attributable to AMR decreased among people <25 years, with a 76.1% [95% confidence interval (CI) 70.6–81.6] reduction occurring among children <5 years, while those among adults aged ≥70 years more than doubled, increasing from 133,013 (95% UI 124,066–141,922) to 298,366 (95% UI 284,023–312,475). The largest increase in the number of deaths attributable to AMR was caused by methicillin-resistant Staphylococcus aureus [from 30,168 (95% UI 24,956–35,351) in 1990 to 66,946 (95% UI 57,544–76,479) in 2021]. In 2021, Kiribati had the highest age-standardized mortality rate (per 100,000 person-years) attributable to AMR [30.9 (95% UI 24.1–37.8)], whereas New Zealand had the lowest [3.2 (95% UI 2.6–3.8)] among the two regions. By 2050, the number of deaths associated with AMR is predicted to reach 3,875,753 (95% UI 1,502,402–9,998,297) in these two regions, of which 952,592 (95% UI 766,353–1,184,090) deaths are attributable to AMR.

Conclusions: This study highlights the escalating burden of AMR in SEAR and WPR, emphasizing the urgent need for attention to this persistent and growing crisis. Our analyses underscore the dual challenge of sustaining gains among people <25 years while addressing the alarming increase of AMR in elderly populations. Given the high variability of AMR burden by pathogen, age group, and country, strengthened surveillance and improved laboratory capacity are essential to accurately characterize resistance patterns and guide clinical decision-making.

Key words Antimicrobial resistance, Burden, Southeast Asia Region (SEAR), Western Pacific Region (WPR)

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Background

Antimicrobial resistance (AMR) is a major global public health challenge and one of the most significant threats in the 21st century, characterized by its complex interplay of biological, socioeconomic, and ecological drivers [1-2]. In clinical practice, the emergence and spread of resistant bacterial pathogens compromise the effectiveness of standard antimicrobial therapy, leading to treatment failure, persistent or recurrent infections, and substantially increased mortality. Sepsis represents the most severe clinical manifestation of these processes. In 2021, an estimated 4.71 million (22.0%) of 21.4 million sepsis-related deaths worldwide were associated with bacterial AMR, with a disproportionate burden observed among aging populations [3]. A substantial proportion of this burden is driven by a limited number of high-impact pathogens, known as the "ESKAPE" organisms (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacterales*), which dominate resistant infections in healthcare settings [4]. Beyond these well-recognized organisms, the continued emergence of multidrug- and extensively drug-resistant bacteria further complicates clinical management and challenges accurate estimation of the true burden of bacterial AMR [5]. Moreover, the impact of AMR extends beyond the clinical settings, representing a complex threat that requires rigorous surveillance and interventions across multiple sectors [6].

The World Health Organization (WHO) Southeast Asia Region (SEAR) and Western Pacific Region (WPR), which encompass nearly half of the global population, present a critical nexus in the AMR crisis. These two regions comprise many low- and middle-income countries (LMICs) with the following intersecting vulnerabilities: fragmented health systems, limited surveillance networks, and persistently high burdens of communicable diseases [7,8]. Compounded by overcrowded healthcare facilities and suboptimal infection control protocols, these conditions increase nosocomial infection rates to 2–3 times higher than global averages, creating fertile grounds for resistant pathogen transmission [9]. This elevated risk is amplified by systemic drivers unique to both regions, including widespread empirical antibiotic use for undifferentiated febrile illnesses [10] and vaccination coverage for preventable diseases that remains below regional targets [11]. Together, these factors not only maintain high transmission pressure within healthcare settings, where pan-resistant *Klebsiella pneumonia* [12] and carbapenem-resistant *Enterobacterales* strains [13] have already become endemic, but also accelerate the selection and cross-border dissemination of AMR at the genomic level [14]. Furthermore, metagenomic surveillance reveals heterogeneous yet escalating distributions of mobile genetic elements (e.g., *bla_NDM* and *mcr-1*) across SEAR and WPR countries, signaling the imminent threat of novel resistance mechanisms transcending national borders [15-17].

The 2024 Accelerate Action to Fight AMR initiative represents a pivotal commitment in the Asia-Pacific region, advocating for harmonized surveillance, antimicrobial stewardship, and cross-border pathogen tracking to strengthen the response against AMR [18]. Despite the implementation of national action plans (NAPs) across the region, the dynamic evolution of resistant organisms and their ability to spread across borders and sectors pose significant challenges in tackling AMR. Therefore, there is an urgent need for comprehensive estimates of AMR across diverse settings to inform effective strategies that reflect the unique epidemiological and socioeconomic contexts of each region. However, current estimates of AMR burden in these two regions are primarily informed by fragmented hospital-based data, and no study has systematically assessed the national-level AMR burden across these countries. To inform targeted interventions and policy development, we present a comprehensive regional and national-level sepsis-related and AMR estimates for the WHO SEAR and WPR from 1990 to 2021, together with projections of the AMR burden through 2050, encompassing an extensive set of infectious syndromes, pathogens, and pathogen-antibiotic combinations.

Methods

Data sources

The Global Research on Antimicrobial Resistance (GRAM) Project 2021 provides the most comprehensive estimates of deaths and disability-adjusted life-years (DALYs) associated with and attributable to bacterial AMR for 11 of the 22 modelled infectious syndromes, 22 pathogens, and 84 pathogen-drug combinations in 204 countries and territories between 1990 and 2021 [3]. The raw data for the GRAM 2021 comprise about 520 million individual records or isolates covering 19,513 study-location-years obtained from multiple datasets, including causes of death, hospital charge, microbiology data with and without patient outcome, studies published in scientific journals, reports from networks that monitor bacteria resistant to antibiotics, pharmaceutical sales, antibiotic use surveys, mortality surveillance, linkage data, outpatient and inpatient linked insurance claims data, and publicly available data [3]. The detailed methodology, input data, and the estimation of the burden of infectious syndromes and AMR for GRAM 2021 have been reported elsewhere [3]. The estimation processes and methods are displayed in the Additional file 1: Methods and Fig. S1, and Additional file 2: Table S1. Building on the GRAM 2021 study, this paper presents a detailed cross-country analysis of AMR and infectious syndrome data on deaths and DALYs for all age groups in the WHO SEAR (11 countries: Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand, and Timor-Lest) and WPR [31 countries and territories: American Samoa, Australia, Brunei Darussalam, Cambodia, China, Cook Islands, Fiji, Guam, Japan, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, New Zealand, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Singapore, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Viet Nam] from 1990 to 2021.

The evaluation of multi-sector and One Health collaboration/coordination was based on data from the WHO Tripartite Antimicrobial Resistance Country Self-Assessment Survey (TrACSS, https://amrcountryprogress.org/). The TrACSS aims to monitor the implementation of NAPs, with a particular emphasis on the extent of cross-sectoral engagement, which encompasses the health sectors of human, environmental, animal, and food and agriculture in national AMR governance structures. For each country, we extracted the self-reported status of establishing and operationalizing multi-sectoral coordination mechanisms for AMR in 2024 across the WHO SEAR and WPR. In the TrACSS, the highest level of such governance corresponds to integrated approaches, which emphasize coordinated actions through cross-sectoral platforms that jointly plan and implement NAPs, supported by clear governance structures, costed operational plans, and sustainable resource mobilization. Notably, 8 countries or territories, i.e., Guam, Niue, the Northern Mariana Islands, Tokelau, American Samoa, the Marshall Islands, Micronesia, and Samoa, did not submit data to TrACSS 2024 and were excluded from the analysis.

Definitions and burden estimation

Sepsis-related deaths are defined according to the Sepsis-3 criteria as life-threatening organ dysfunction due to a dysregulated host response to infection [19] and are modeled based on Global Burden of Disease (GBD) 2021 cause-of-death estimates [20] to identify deaths from infection in the causal pathway [21]. In the GRAM 2021 study, two counterfactual scenarios were used to estimate the disease burden of AMR [3]. Deaths attributable to AMR are defined as those directly resulting from drug-sensitive infections due to treatment failure [3]. In a hypothetical scenario in which all drug-resistant infections were substituted with drug-susceptible infections, these deaths would not have occurred. Deaths associated with AMR refer to deaths in which a drug-resistant infection was present, regardless of whether resistance was the direct cause of death. In this scenario, the counterfactual assumes that no infection occurred; thus, these deaths would have been avoided if there had been no infection at all [3].

Years of life lost (YLLs) values were calculated by multiplying the number of AMR-related deaths by the GBD 2021 standard life expectancy at the age of death. Years lived with disability (YLDs) were estimated from the prevalence of nonfatal AMR infections, which was derived from syndrome incidence and resistance fractions using DisMod-MR 2.1, multiplied by disability weights for health states such as acute sepsis sequelae. DALYs were calculated by summing YLLs and YLDs, with attributable DALYs capturing the excess burden under the susceptible-organism counterfactual. DALY rates were expressed as the number of DALYs per 100,000 population.

Statistical analysis

All the data analyses were conducted at the regional and national levels, with the data stratified by age group and year. Age groups were defined according to WHO life-stage classifications to ensure comparability across populations and to capture meaningful differences in AMR burden across different stages of life [22]. First, we described the temporal trends in infectious syndromes from 1990 to 2021, including the total number of sepsis-related deaths and the number and rate of 11 infectious syndromes associated with and attributable to AMR death and DALYs. Second, we reported the overall fatal burden caused by pathogens and pathogens associated with and attributable to AMR in different infection syndromes. Third, we described the mortality and DALYs burden of pathogen-antibiotic class combinations associated with and attributable to AMR, and calculated their percentage changes as follows: [100%×(number in 2021−number in 1990)/(number in 1990)] for each pathogen-antibiotic class combination. Fourth, the age-standardized mortality rates (ASMRs) associated with and attributable to AMR for each country were further reported. These rates were determined on the basis of the direct method of standardization and were weighted using the GBD 2021 world standard population [23]. Fifth, we compared the ASMRs of AMR with countries' progress in developing multi-sector collaborations across SEAR and WPR. Finally, an autoregressive integrated moving average (ARIMA) model was applied to forecast the number of sepsis-related deaths and AMR under the baseline scenario through 2050. The models were fitted using the natural logarithms of three key mortality ratios: the ratio of sepsis-related deaths to total deaths, the ratio of AMR-associated deaths to sepsis-related deaths, and the ratio of AMR-attributable deaths to AMR-associated deaths [24]. Log transformation was used to stabilize variance, account for nonlinear trends, and improve model fit over time. ARIMA model identification was performed using the "auto.arima" procedure in the forecast package (version 8.24.0), which selects the optimal (p, d, q) combination by minimizing the corrected Akaike Information Criterion after determining the appropriate differencing order via stationarity tests. Residual analyses of different models were conducted to assess model adequacy. Estimates of total deaths from 1990 to 2050 were obtained from the Global Health Data Exchange (https://ghdx.healthdata.org/record/ihme-data/global-population-forecasts-2017-2100).

Uncertainty for country-level historical estimates was propagated by the GRAM 2021 data, combining 100 draws for each metric from the posterior distribution of the estimation process into the final estimates of AMR deaths. The 95% uncertainty intervals (UIs) were calculated as 1.96 standard deviations below and above the mean value, as determined by GBD [3]. Regional totals were then aggregated at the posterior-draw level, with 10,000 bootstrap resamples to propagate uncertainty. For future projections, UIs were derived from the 2.5th and 97.5th percentiles of the ARIMA predictive distributions. Percentage changes in metrics over time were considered statistically significant if the 95% confidence intervals (CIs) excluded zero; otherwise, non-overlapping 95% UIs between burden estimates were used as a conservative indicator of difference. Statistical significance was defined as $P<0.05$ (two-tailed). All analyses and visualizations were performed using R software (version 4.3.1).

Results

Sepsis-related burden in the WHO SEAR and WPR

In the SEAR and WPR, sepsis-related deaths with 22 infectious syndromes decreased from 8.36×10^6 (95% UI 7.93–8.79) in 1990 to 6.03×10^6 (95% UI 5.68–6.39) in 2019, before increasing to 8.31×10^6 (95% UI 7.86–8.76) in 2021 (Fig. 1a). The corresponding all-age mortality rate per 100,000 population followed a similar pattern, declining consistently until 2019 [151.1 (95% UI 144.2–162.2)] and then showing a temporary increase from 2020 [179.3 (95% UI 170.0–188.6)] to 2021 [208.4 (95% UI 197.1–219.6)]. This pattern reflects contrasting age-specific trends over the past three decades: deaths among children <5 years declined by 83.5% (95% CI 82.0–85.0), whereas deaths among adults aged ≥25 years increased by 81.1% (95% CI 64.8–97.4) and accounted for more than 90% of all sepsis-related deaths in 2021. A decomposition analysis indicated that the majority of the 2021 rebound in sepsis-related deaths was attributable to true epidemiological changes [86.0% (95% CI 81.1–90.9)], with smaller contributions from population aging [4.0% (95% CI 1.4–6.9)] and population growth [10.0% (95% CI 8.9–11.1), Additional file 1: Fig. S2]. At the country level, India remained the country with the highest number of sepsis-related deaths in 2021 [4,326,299 (95% UI 4,027,610–4,624,988)], approximately triple that of China [1,400,419 (95% UI 1,156,101–1,644,737)], the country with the second-highest burden (Additional file 1: Fig. S3).

AMR burden by infectious syndromes in the WHO SEAR and WPR

Among all sepsis-related deaths, deaths associated with AMR ranged from 2,445,875 (95% UI 2,221,769–2,670,192) in 1990 to 2,358,190 (95% UI 2,173,521–2,545,190) in 2021, while deaths attributable to AMR ranged from 546,479 (95% UI 487,669–605,277) in 1990 to 606,644 (95% UI 554,008–659,542) in 2019 and 587,103 (95% UI 534,165–639,903) in 2021 (Table 1). The regional associated and attributable AMR death rates (per 100,000) decreased from 86.0 (95% UI 78.1–93.9) and 19.2 (95% UI 17.1–21.3) in 1990 to 59.1 (95% UI 54.4–63.8) and 14.7 (95% UI 13.4–16.0) in 2021, respectively (Table 1). However, the percentage of sepsis-related deaths attributable to AMR increased from 6.5% (95% CI 5.6–7.7) in 1990 to 10.1% (95% CI 8.7–11.6) in 2019, before decreasing to 7.1% (95% CI 6.1–8.1) in 2021 (Additional file 2: Table S2), accounting for 51.5% (95% CI 43.8–59.2) of global AMR-attributable deaths in 2021 [1,141,416 (95% UI 1,003,460–1,279,372)]. During the same period, the regional number of DALYs associated with AMR decreased from 145,973,145 (95% UI 130,829,953–160,502,386) in 1990 to 75,633,528 (95% UI 69,225,726–81,956,128) in 2021; likewise, DALYs attributable to AMR also decreased from 31,722,066 (95% UI 28,048,785–35,451,404) in 1990 to 18,780,988 (95% UI 16,950,565–20,585,307) in 2021 (Table 2). In 2021, the regional AMR-associated and AMR-attributable DALY rates per 100,000 population were 1896 (95% UI 1735–2055) and 471 (95% UI 425–516), respectively (Table 2). Among the 11 specific infectious syndromes related to AMR, deaths associated with and attributable to AMR decreased among 4 infectious diseases (lower respiratory infections; diarrhoea; typhoid, paratyphoid, and invasive non-typhoidal *Salmonella*; and meningitis) and increased among 7 infectious diseases

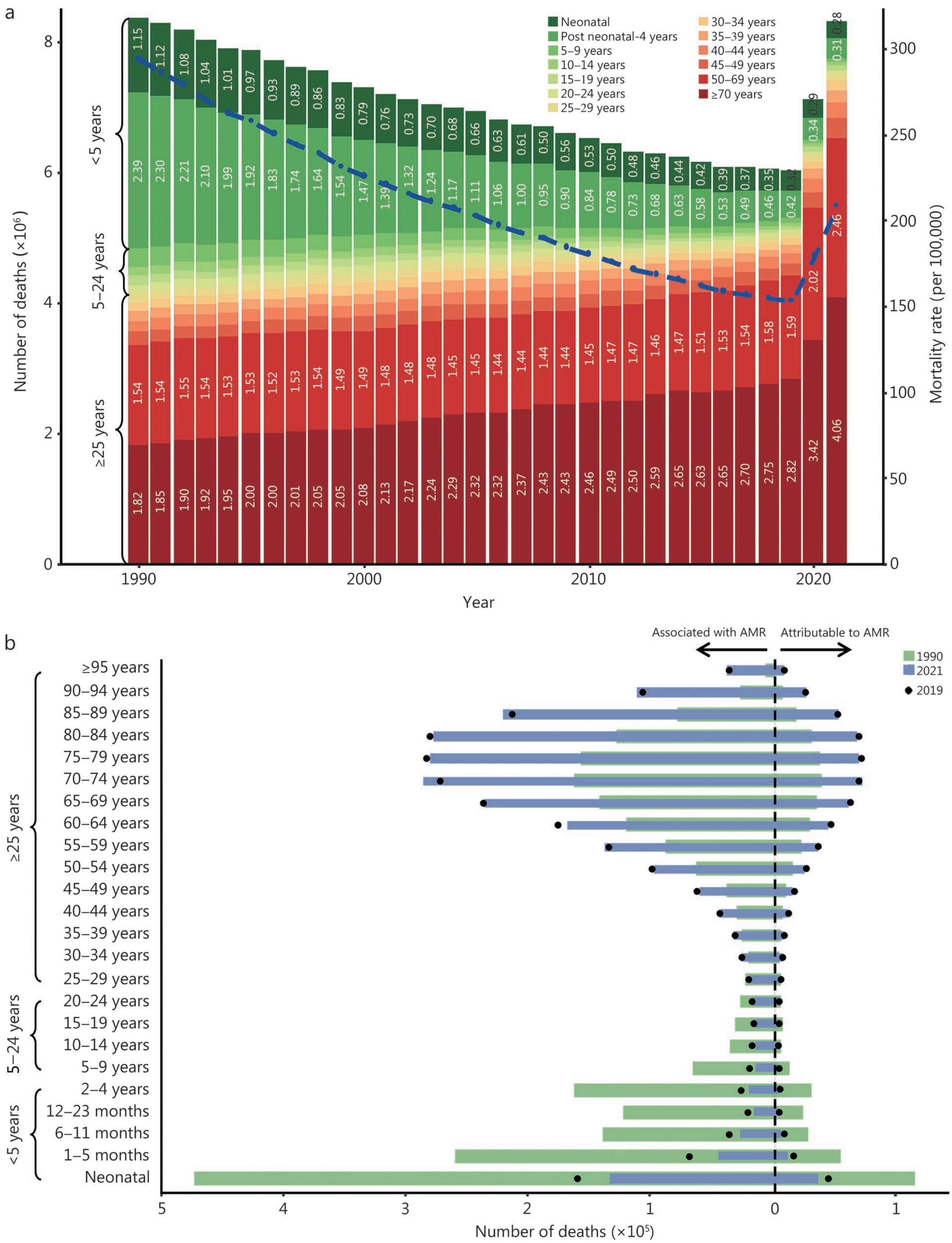

Fig. 1 Time trend of sepsis-related deaths and mortality rate (a) and AMR-related deaths (b) by age for countries in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 1990-2021.

Bars represent the number of deaths (left y-axis), and the blue dotted line represents the mortality rate (right y-axis) in **a**. Bars represent ARM estimates for 1990 (green) and 2021 (blue), with black dots indicating the 2019 estimates in **b**. AMR. Antimicrobial resistance

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Table 1 Deaths (in numbers and all-age rates) attributable to and associated with antimicrobial resistance per country in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), for 1990, 2019, and 2021

Parameter	Number of associated deaths			Associated death rate (per 100,000)			Number of attributable deaths			Attributable death rate (per 100,000)		
	1990	2019	2021	1990	2019	2021	1990	2019	2021	1990	2019	2021
All countries	2,445,875 (2,221,769–2,670,192)	2,419,974 (2,243,336–2,596,571)	2,358,190 (2,173,521–2,545,190)	86.0 (78.1–93.9)	61.5 (57.0–66.0)	59.1 (54.4–63.8)	546,479 (487,669–605,277)	606,644 (554,008–659,542)	587,103 (534,165–639,903)	19.2 (17.1–21.3)	15.4 (14.1–16.8)	14.7 (13.4–16.0)
SEAR (*n*=11)												
Bangladesh	192,224 (158,806–225,642)	102,319 (82,206–122,432)	96,878 (76,464–117,293)	176.2 (145.5–206.8)	63.1 (50.7–75.5)	58.8 (46.4–71.2)	40,933 (31,811–50,056)	24,558 (19,045–30,070)	23,454 (17,888–29,019)	37.5 (29.2–45.9)	15.1 (11.7–18.5)	14.2 (10.9–17.6)
Bhutan	734 (481–987)	425 (321–529)	410 (310–510)	116.5 (76.3–156.6)	56.0 (42.2–69.7)	54.2 (41.0–67.4)	157 (102–212)	104 (77–132)	101 (74–128)	24.9 (16.2–33.6)	13.8 (10.1–17.4)	13.3 (9.7–16.9)
Democratic People's Republic of Korea	12,135 (9182–15,089)	17,676 (13,416–21,936)	17,474 (13,100–21,848)	58.9 (44.6–73.3)	67.3 (51.1–83.5)	66.2 (49.6–82.8)	2827 (2000–3655)	4412 (3067–5758)	4371 (3012–5730)	13.7 (9.7–17.8)	16.8 (11.7–21.9)	16.6 (11.4–21.7)
India	1,020,272 (850,730–1,189,813)	1,050,811 (928,811–1,172,812)	987,254 (854,794–1,119,715)	119.6 (99.7–139.5)	75.7 (66.9–84.5)	69.8 (60.4–79.2)	228,265 (185,109–271,420)	283,556 (240,590–326,522)	266,734 (223,662–309,806)	26.8 (21.7–31.8)	20.4 (17.3–23.5)	18.9 (15.8–21.9)
Indonesia	153,043 (128,535–177,551)	147,310 (122,776–171,844	146,531 (122,022–171,039)	82.7 (69.5–96.0)	54.0 (45.0–63.0)	52.5 (43.7–61.3)	31,895 (25,149–38,641)	36,487 (29,905–43,070)	36,508 (29,994–43,021)	17.2 (13.6–20.9)	13.4 (11.0–15.8)	13.1 (10.8–15.4)
Maldives	149 (117–182)	100 (76–124)	99 (74–124)	67.2 (52.8–81.7)	20.5 (15.6–25.4)	19.1 (14.2–24.0)	37 (27–46)	24 (17–31)	24 (17–31)	16.4 (12.3–20.6)	5.0 (3.5–6.4)	4.7 (3.2–6.1)
Myanmar	59,475 (44,485–74,464)	44,564 (35,409–53,719)	42,496 (33,404–51,589)	147.1 (110.0–184.1)	80.6 (64.0–97.1)	75.3 (59.2–91.4)	13,322 (9592–17,052)	11507 (8827–14,187)	11071 (8472–13,670)	32.9 (23.7–42.2)	20.8 (16.0–25.7)	19.6 (15.0–24.2)
Nepal	37,788 (30,213–45,362)	20,543 (16,216–24,870)	19,579 (15,432–23,726)	194.1 (155.2–233.0)	67.3 (53.1–81.5)	62.9 (49.6–76.2)	8198 (6287–10,110)	4912 (3795–6029)	4707 (3607–5806)	42.1 (32.3–51.9)	16.1 (12.4–19.8)	15.1 (11.6–18.7)
Sri Lanka	8231 (6727–9735)	10,409 (7520–13,297)	10,039 (6613–13,465)	48.0 (39.3–56.8)	47.3 (34.2–60.4)	45.1 (29.7–60.5)	1909 (1476–2342)	2695 (1965–3425)	2607 (1750–3465)	11.1 (8.6–13.7)	12.2 (8.9–15.6)	11.7 (7.9–15.6)
Thailand	24,556 (20,224–28,888)	53,769 (44,726–62,811)	55,693 (41,609–69,777)	43.3 (35.6–50.9)	80.6 (67.0–94.1)	83.5 (62.4–104.6)	5678 (4405–6952)	13,432 (10,934–15,930)	13,901 (10,441–17,361)	10.0 (7.8–12.2)	20.1 (16.4–23.9)	20.8 (15.7–26.0)
Timor-Leste	1308 (1004–1612)	866 (661–1070)	840 (637–1042)	167.4 (128.5–206.4)	64.5 (49.3–79.8)	60.1 (45.6–74.5)	260 (183–337)	193 (138–248)	192 (136–248)	33.3 (23.5–43.2)	14.4 (10.3–18.5)	13.7 (9.7–17.7)
WPR (*n*=31)												
American Samoa	22 (19–26)	33 (25–40)	32 (25–40)	46.1 (38.5–53.6)	63.5 (49.7–77.4)	65.2 (50.1–80.2)	5 (4–6)	9 (7–11)	9 (6–11)	10.7 (8.1–13.2)	17.0 (12.9–21.1)	17.3 (13.0–21.7)
Australia	5164 (3920–6409)	7641 (6727–8555)	7841 (6846–8835)	30.6 (23.3–38.0)	30.6 (27.0–34.3)	30.4 (26.5–34.3)	1100 (801–1400)	1693 (1438–1949)	1696 (1418–1974)	6.5 (4.7–8.3)	6.8 (5.8–7.8)	6.6 (5.5–7.7)
Brunei Darussalam	83 (67–99)	142 (115–169)	136 (111–162)	32.2 (26.0–38.4)	32.1 (26.0–38.3)	30.2 (24.6–35.9)	21 (15–26)	35 (27–43)	34 (27–42)	8.0 (6.0–9.9)	7.9 (6.2–9.7)	7.6 (5.9–9.2)
Cambodia	18,684 (13,933–23,434)	12,799 (9989–15,609)	11,868 (9236–14,501)	181.9 (135.6–228.1)	77.1 (60.2–94.1)	69.6 (54.2–85.1)	3895 (2804–4987)	2985 (2278–3692)	2809 (2152–3466)	37.9 (27.3–48.5)	18.0 (13.7–22.2)	16.5 (12.6–20.3)
China	718,647 (583,250–854,044)	692,245 (573,159–811,331)	711,852 (58,6447–837,256)	61.1 (49.6–72.6)	48.9 (40.5–57.4)	50.0 (41.2–58.8)	164,317 (127,009–201,626)	159,390 (131,929–186,852)	160,268 (132,375–188,161)	14.0 (10.8–17.1)	11.3 (9.3–13.2)	11.3 (9.3–13.2)
Cook Islands	11 (9–14)	11 (9–14)	12 (9–15)	60.0 (48.8–71.2)	64.5 (49.3–79.8)	67.7 (51.4–84.1)	3 (2–3)	3 (2–4)	3 (2–4)	14.7 (11.1–18.3)	17.1 (12.6–21.7)	17.9 (13.1–22.7)
Fiji	381 (303–458)	511 (368–654)	491 (344–638)	50.2 (40.0–60.4)	55.7 (40.1–71.3)	53.1 (37.2–69.0)	89 (67–111)	131 (94–169)	127 (90–165)	11.7 (8.8–14.7)	14.3 (10.2–18.4)	13.8 (9.7–17.8)
Guam	39 (32–47)	70 (58–83)	57 (46–68)	28.7 (23.4–34.0)	43.8 (36.3–51.4)	35.9 (29.0–42.8)	9 (7–11)	16 (12–20)	13 (10–17)	6.5 (4.8–8.2)	10.1 (7.7–12.6)	8.3 (6.2–10.4)
Japan	64,263 (52,349–76,178)	87,256 (73,848–100,665)	83,850 (70,271–97,429)	51.1 (41.6–60.5)	68.0 (57.5–78.4)	65.7 (55.0–76.3)	14,953 (11,304–18,602)	18,273 (15,433–21,112)	17,429 (14,634–20,233)	11.9 (9.0–14.8)	14.2 (12.0–16.4)	13.6 (11.5–15.8)
Kiribati	79 (64–94)	83 (65–101)	83 (65–102)	106.4 (86.4–126.3)	70.5 (55.2–85.7)	68.7 (53.6–83.9)	18 (13–22)	21 (16–26)	21 (16–26)	23.9 (18.0–29.9)	18.0 (13.8–22.2)	17.6 (13.5–21.8)
Lao People's Democratic Republic	7956 (5762–10,150)	4106 (2946–5266)	3811 (2744–4879)	190.8 (138.2–243.4)	57.2 (41.0–73.3)	51.7 (37.2–66.1)	1635 (1166–2104)	910 (641–1180)	838 (591–1085)	39.2 (28.0–50.5)	12.7 (8.9–16.4)	11.4 (8.0–14.7)

(Continued)

Parameter	Number of associated deaths			Associated death rate (per 100,000)			Number of attributable deaths			Attributable death rate (per 100,000)		
	1990	2019	2021	1990	2019	2021	1990	2019	2021	1990	2019	2021
Malaysia	7223 (5769–8677)	17,104 (15,495–18,712)	17,154 (15,487–18,821)	40.9 (32.7–49.1)	54.8 (49.6–59.9)	53.9 (48.7–59.2)	1778 (1354–2201)	4044 (3515–4573)	4023 (3470–4577)	10.1 (7.7–12.5)	12.9 (11.3–14.6)	12.6 (10.9–14.4)
Marshall Islands	30 (25–34)	31 (24–39)	32 (23–40)	65.0 (54.6–75.5)	56.2 (42.0–70.4)	56.1 (41.1–71.1)	7 (5–8)	8 (6–11)	8 (6–11)	15.1 (11.5–18.7)	15.0 (10.9–19.1)	14.8 (10.4–19.1)
Micronesia (Federated States of)	88 (68–107)	58 (43–72)	57 (46–72)	84.6 (65.5–103.6)	55.9 (41.6–70.2)	56.0 (41.4–70.6)	21 (15–26)	14 (10–18)	14 (10–18)	19.9 (14.3–25.4)	13.9 (10.1–17.7)	13.8 (10.0–17.6)
Mongolia	2911 (2441–3381)	1595 (1328–1862)	1462 (1218–1706)	134.9 (113.1–156.7)	49.5 (41.2–57.8)	43.8 (36.5–51.1)	686 (516–855)	407 (288–526)	374 (266–481)	31.8 (23.9–39.6)	12.6 (8.9–16.3)	11.2 (8.0–14.4)
Nauru	8 (6–10)	7 (5–9)	7 (5–9)	76.5 (57.9–95.0)	64.7 (47.8–81.6)	62.4 (45.0–79.7)	2 (1–2)	2 (1–2)	2 (1–2)	17.7 (12.3–23.1)	17.0 (12.3–21.7)	16.3 (11.5–21.0)
New Zealand	1071 (863–1279)	1305 (1104–1506)	1297 (1085–1509)	31.3 (25.3–37.4)	26.2 (22.1–30.2)	25.1 (21.0–29.2)	226 (171–281)	280 (226–335)	278 (222–334)	6.6 (5.0–8.2)	5.6 (4.5–6.7)	5.4 (4.3–6.5)
Niue	2 (2–3)	1 (1–2)	1 (1–2)	97.3 (77.7–116.8)	79.3 (58.9–99.7)	86.3 (66.2–106.4)	1 (0–1)	0 (0–0)	0 (0–0)	23.9 (18.0–29.8)	19.7 (14.0–25.3)	21.2 (15.5–26.8)
Northern Mariana Islands	14 (10–17)	26 (20–32)	26 (22–30)	30.8 (23.0–38.7)	53.7 (41.7–65.8)	53.4 (44.7–62.0)	3 (2–4)	6 (5–8)	6 (5–8)	7.2 (5.1–9.3)	12.9 (9.4–16.4)	13.1 (10.3–16.0)
Palau	11 (8–13)	12 (9–15)	12 (9–16)	69.2 (52.6–85.8)	66.8 (49.2–84.4)	68.5 (50.5–86.5)	3 (2–3)	3 (2–4)	3 (2–4)	16.5 (12.0–21.0)	17.5 (12.5–22.5)	17.8 (12.7–22.9)
Papua New Guinea	4516 (3443–5590)	7601 (5757–9444)	7060 (5423–8697)	110.1 (83.9–136.2)	76.9 (58.2–95.5)	67.5 (51.8–83.1)	977 (683–1270)	1744 (1229–2258)	1636 (1168–2105)	23.8 (16.6–31.0)	17.6 (12.4–22.8)	15.6 (11.2–20.1)
Philippines	38,497 (28,282–48,711)	55,609 (49,711–61,507)	51,829 (44,316–59,342)	61.1 (44.9–77.3)	50.4 (45.0–55.7)	45.8 (39.1–52.4)	8241 (5908–10,573)	13,759 (12,008–15,509)	12,964 (10,893–15,034)	13.1 (9.4–16.8)	12.5 (10.9–14.0)	11.4 (9.6–13.3)
Republic of Korea	17,781 (15,485–20,076)	22,462 (19,150–25,775)	22,658 (19,305–26,010)	40.2 (35.0–45.4)	43.3 (36.9–49.7)	43.9 (37.4–50.4)	4523 (3574–5471)	5726 (4771–6682)	5817 (4856–6777)	10.2 (8.1–12.4)	11.0 (9.2–12.9)	11.3 (9.4–13.1)
Samoa	103 (82–124)	111 (86–135)	112 (87–136)	60.8 (48.4–73.3)	53.1 (41.4–64.7)	52.2 (40.9–63.6)	24 (18–31)	30 (22–38)	30 (24–38)	14.5 (10.7–18.2)	14.4 (10.8–18.0)	14.2 (10.7–17.7)
Singapore	1330 (1105–1554)	2144 (1828–2461)	2024 (1703–2344)	43.6 (36.3–51.0)	37.8 (32.2–43.4)	35.3 (29.7–40.9)	324 (250–398)	462 (375–549)	437 (352–521)	10.6 (8.2–13.1)	8.2 (6.6–9.7)	7.6 (6.1–9.1)
Solomon Islands	321 (227–414)	431 (328–533)	421 (318–525)	94.6 (67.0–122.2)	65.5 (49.9–81.0)	61.7 (46.5–76.8)	72 (48–97)	101 (73–130)	98 (70–126)	21.3 (14.1–28.5)	15.4 (11.1–19.8)	14.3 (10.2–18.5)
Tokelau	1 (1–2)	1 (1–1)	1 (1–2)	92.0 (71.7–112.3)	70.5 (52.4–88.7)	90.8 (70.8–110.7)	0 (0–0)	0 (0–0)	0 (0–0)	21.6 (15.4–27.7)	18.0 (12.8–23.2)	23.0 (17.1–28.9)
Tonga	61 (50–72)	65 (48–82)	64 (46–81)	62.0 (50.7–73.2)	61.2 (44.9–77.4)	59.9 (43.4–76.5)	14 (11–18)	17 (12–22)	17 (12–22)	14.6 (11.0–18.3)	16.2 (11.5–20.8)	15.6 (11.0–20.2)
Tuvalu	13 (10–16)	8 (6–10)	8 (6–10)	133.5 (104.0–163.0)	67.5 (51.9–83.2)	64.9 (50.0–79.8)	3 (2–4)	2 (2–3)	2 (1–3)	31.4 (23.0–39.9)	17.2 (12.5–21.8)	16.4 (12.1–20.8)
Vanuatu	100 (77–123)	177 (147–207)	172 (143–201)	65.7 (50.7–80.8)	58.9 (48.8–69.1)	55.0 (45.7–64.3)	23 (17–30)	44 (34–38)	43 (33–52)	15.3 (11.1–19.6)	14.5 (11.2–17.9)	13.7 (10.6–16.8)
Viet Nam	46,552 (39,107–53,998)	57,538 (48,206–66,869)	56,466 (46,927–66,004)	68.2 (57.3–79.1)	58.4 (49.0–67.9)	56.3 (46.8–65.8)	10,025 (7840–12,209)	14,644 (12,034–17,254)	14,434 (11,824–17,044)	14.7 (11.5–17.9)	14.9 (12.2–17.5)	14.4 (11.8–17.0)

Table 2 DALYs (in numbers and all-age rates) attributable to and associated with antimicrobial resistance per country in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), for 1990, 2019, and 2021

Parameter	Number of associated DALYs			Associated DALY rate (per 100,000)			Number of attributable DALYs			Attributable DALY rate (per 100,000)		
	1990	2019	2021	1990	2019	2021	1990	2019	2021	1990	2019	2021
All countries	145,973,145 (130,829,953–160,502,386)	82,246,039 (75,395,671–89,146,646)	75,633,528 (69,225,726–81,956,128)	5131 (4599–5642)	2089 (1915–2264)	1896 (1735–2055)	31,722,066 (28,048,785–35,451,404)	20,443,971 (18,515,767–22,361,945)	18,780,988 (16,950,565–20,585,307)	1115 (986–1246)	519 (470–568)	471 (425–516)
SEAR (n=11)												
Bangladesh	14,368,063 (1,686,693–170,494,341)	4,512,941 (3,553,251–5,472,632)	3,938,745 (3,043,098–4,834,391)	13,167 (10,710–15,624)	2783 (2191–3375)	2392 (1848–2936)	3,016,722 (2,310,127–3,723,317)	1,033,646 (789,616–1,277,676)	907,534 (678,513–1,136,555)	2765 (2117–3412)	637 (487–788)	551 (412–690)
Bhutan	55,535 (35,086–75,983)	16,362 (11,481–21,244)	14,856 (10,401–19,310)	8814 (5569–12,060)	2154 (1511–2797)	1963 (1374–2551)	11,762 (7407–16,117)	3866 (2652–5080)	3514 (2391–4637)	1867 (1176–2558)	509 (349–669)	464 (316–613)
Democratic People's Republic of Korea	548,367 (402,224–694,510)	473,969 (343,468–604,469)	456,886 (327,663–586,110)	2663 (1953–3373)	1804 (1307–2300)	1731 (1242–2221)	126,662 (87,163–166,162)	118,213 (78,128–158,298)	114,353 (75,090–153,616)	615 (423–807)	450 (297–602)	433 (285–582)
India	68,233,488 (55,528,431–80,938,546)	42,673,399 (36,627,000–48,719,798)	37,733,199 (32,227,727–43,238,670)	7999 (6509–9488)	3073 (2638–3508)	2668 (2278–3057)	14,930,855 (11,863,848–17,997,861)	11,110,374 (9,338,728–12,882,021)	9,880,982 (8,256,758–11,505,206)	1750 (1391–2110)	800 (673–928)	699 (584–813)
Indonesia	9,279,605 (7,696,941–10,862,270)	5,331,878 (4,484,875–6,178,882)	5,107,775 (4,257,648–5,957,902)	5016 (4161–5872)	1956 (1645–2266)	1831 (1527–2136)	1,877,152 (1,458,564–2,295,741)	1,297,449 (1,076,851–1,518,047)	1,255,669 (1,034,875–1,476,463)	1015 (788–1241)	476 (395–557)	450 (371–529)
Maldives	10,092 (7713–12,470)	3558 (2682–4434)	3413 (2528–4299)	4541 (3471–5611)	729 (550–909)	660 (489–831)	2440 (1788–3092)	865 (613–1117)	831 (579–1083)	1098 (805–1391)	177 (126–229)	161 (112–209)
Myanmar	3,957,646 (2,849,916–5,065,375)	1,929,172 (1,530,765–2,327,578)	1,759,181 (1,372,800–2,145,561)	9787 (7048–12526)	3489 (2768–4209)	3118 (2433–3803)	856,789 (595,114–1,118,463)	484,633 (372,652–596,613)	448,002 (340,544–555,460)	2119 (1472–2766)	876 (674–1079)	794 (604–985)
Nepal	2,852,605 (2,237,141–3,468,069)	879,241 (676,591–1,081,892)	799,038 (616,589–981,487)	14,652 (11,491–17,813)	2881 (2217–3545)	2567 (1981–3153)	609,648 (458,201–761,095)	202,185 (152,986–251,384)	184,863 (139,314–230,412)	3131 (2353–3909)	663 (501–824)	594 (448–740)
Sri Lanka	338,741 (271,964–405,518)	290,298 (207,640–372,956)	269,891 (176,183–363,599)	1977 (1588–2367)	1319 (944–1695)	1212 (791–1633)	77,307 (59,164–95,449)	75,036 (54,223–95,850)	70,132 (46,612–93,652)	451 (345–557)	341 (246–436)	315 (209–421)
Thailand	1,047,286 (864,018–1,230,553)	1,383,310 (1,170,402–1,596,217)	1,396,692 (1,052,108–1,741,277)	1845 (1522–2168)	2073 (1754–2392)	2095 (1578–2611)	239,920 (187,141–292,699)	351,603 (290,981–412,225)	355,409 (268,805–442,013)	423 (330–516)	527 (436–618)	533 (403–663)
Timor-Leste	105,120 (79,801–130,439)	43,620 (33,212–54,028)	41,126 (30,855–51,397)	13,457 (10,216–16,699)	3252 (2476–4028)	2942 (2208–3677)	20,675 (14,357–26,993)	9520 (6796–12,244)	9214 (6455–11,973)	2647 (1838–3456)	710 (507–913)	659 (462–857)
WPR (n=31)												
American Samoa	1103 (915–1292)	1056 (813–1298)	1028 (775–1281)	2274 (1886–2663)	2064 (1590–2539)	2066 (1558–2575)	251 (189–313)	285 (215–356)	276 (205–348)	518 (390–645)	558 (419–696)	555 (412–699)
Australia	127,057 (97,094–157,020)	161,273 (144,986–177,561)	163,871 (146,061–181,682)	754 (576–931)	647 (581–712)	635 (566–704)	27,564 (20,121–35,007)	36,688 (31,698–41,678)	36,564 (31,139–41,989)	163 (119–208)	147 (127–167)	142 (121–163)
Brunei Darussalam	3073 (2499–3647)	4545 (3676–5414)	4328 (3532–5125)	1185 (964–1407)	1029 (832–1225)	959 (783–1136)	768 (581–954)	1146 (900–1391)	1110 (872–1347)	296 (224–368)	259 (204–315)	246 (193–299)
Cambodia	1,367,853 (1,003,534–1,732,173)	541,808 (414,781–668,835)	478,582 (362,391–594,773)	13315 (9769–16862)	3265 (2500–4030)	2808 (2126–3490)	280,900 (199,520–362,281)	123,931 (92,803–155,059)	111,226 (82,872–139,580)	2734 (1942–3527)	747 (559–934)	653 (486–819)
China	35,115,606 (27,921,168–42,310,043)	16,755,749 (14,082,313–19,429,186)	16,689,500 (13,814,904–19,564,097)	2985 (2373–3596)	1185 (996–1374)	1173 (971–1375)	7,776,301 (5,904,912–9,647,690)	3,868,990 (3,239,403–4,498,578)	3,777,893 (3,119,612–4,436,173)	661 (502–820)	274 (229–318)	266 (219–312)
Cook Islands	463 (560–367)	288 (216–359)	308 (232–384)	2449 (1938–2961)	1619 (1217–2021)	1735 (1305–2165)	111 (82–141)	77 (56–98)	82 (60–104)	589 (434–743)	434 (315–552)	462 (336–588)
Fiji	18,638 (14,660–22,617)	18,896 (13,307–24,484)	17,529 (12,005–23,053)	2458 (1933–2982)	2061 (1452–2671)	1896 (1299–2494)	4291 (3183–5399)	4843 (3406–6280)	4547 (3144–5949)	566 (420–712)	528 (372–685)	492 (340–644)
Guam	1697 (1368–2026)	2397 (1989–2805)	1928 (1556–2300)	1240 (1000–1481)	1492 (1238–1747)	1211 (977–1445)	378 (277–478)	556 (426–687)	450 (338–561)	276 (202–350)	347 (265–428)	283 (212–353)
Japan	1,366,470 (1,117,439–1,615,500)	1,395,052 (1,231,414–1,558,690)	1,336,844 (1,167,253–1,506,435)	1086 (888–1284)	1086 (959–1214)	1047 (914–1180)	319,442 (240,733–398,151)	294,530 (257,760–331,300)	280,426 (243,662–317,191)	254 (191–316)	229 (201–258)	220 (191–248)

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Parameter	Number of associated DALYs			Associated DALY rate (per 100,000)			Number of attributable DALYs			Attributable DALY rate (per 100,000)		
	1990	2019	2021	1990	2019	2021	1990	2019	2021	1990	2019	2021
Kiribati	4962 (3929–5995)	3888 (2990–4785)	3805 (2904–4705)	6669 (5281–8057)	3289 (2530–4049)	3140 (2397–3883)	1094 (803–1386)	984 (741–1227)	970 (727–1213)	1471 (1079–1863)	833 (627–1038)	800 (600–1001)
Lao People's Democratic Republic	591,552 (416,315–766,790)	207,321 (142,403–272,238)	183,960 (126,984–240,936)	14,188 (9985–18,390)	2887 (1983–3791)	2494 (1721–3266)	119,978 (83,320–156,635)	45,523 (30,677–60,370)	40,150 (27,162–53,138)	2878 (1998–3757)	634 (427–841)	544 (368–720)
Malaysia	295,846 (234,253–357,439)	500,598 (456,976–544,220)	489,215 (444,216–534,214)	1675 (1326–2023)	1603 (1463–1742)	1538 (1396–1679)	72,076 (54,760–89,391)	120,521 (106,236–134,806)	117,342 (102,433–132,252)	408 (310–506)	386 (340–432)	369 (322–416)
Marshall Islands	1665 (1360–1970)	1362 (997–1728)	1328 (953–1703)	3665 (2994–4337)	2435 (1782–3088)	2359 (1693–3026)	378 (281–475)	362 (258–465)	348 (242–455)	832 (618–1047)	647 (462–831)	619 (430–808)
Micronesia (Federated States of)	4677 (3593–5760)	2163 (1589–2737)	2103 (1536–2669)	4519 (3472–5567)	2103 (1545–2661)	2050 (1498–2602)	1074 (767–1381)	536 (385–687)	519 (371–666)	1038 (741–1335)	521 (374–668)	506 (362–649)
Mongolia	214,719 (177,632–251,805)	71,083 (58,562–83,604)	60,432 (49,939–70,925)	9951 (8232–11669)	2206 (1817–2594)	1811 (1497–2126)	50,687 (37,836–63,538)	18,041 (12,559–23,523)	15,388 (10,691–20,085)	2349 (1753–2945)	560 (390–730)	461 (320–602)
Nauru	435 (327–542)	331 (237–425)	314 (218–411)	4258 (3207–5308)	3038 (2172–3904)	2849 (1975–3724)	99 (68–129)	87 (61–113)	82 (56–108)	966 (663–1268)	798 (558–1038)	742 (506–978)
New Zealand	25,144 (20,407–29,880)	27,117 (23,430–30,804)	26,995 (23,083–30,907)	736 (597–874)	544 (470–618)	522 (447–598)	5404 (4114–6694)	5957 (4900–7014)	5932 (4834–7029)	158 (120–196)	119 (98–141)	115 (94–136)
Niue	69 (54–84)	36 (26–47)	50 (38–61)	2984 (2326–3642)	2192 (1547–2837)	2977 (2300–3653)	17 (12–21)	9 (6–12)	12 (9–15)	723 (533–913)	549 (377–722)	730 (539–920)
Northern Mariana Islands	646 (470–823)	837 (632–1043)	795 (663–926)	1432 (1041–1824)	1709 (1290–2129)	1639 (1367–1910)	150 (103–197)	204 (146–262)	198 (155–241)	333 (229–437)	416 (297–534)	408 (319–497)
Palau	456 (334–577)	385 (280–489)	386 (282–490)	3001 (2202–3801)	2129 (1549–2709)	2133 (1556–2709)	106 (74–137)	101 (72–131)	101 (72–130)	697 (490–904)	560 (397–723)	557 (396–718)
Papua New Guinea	331,000 (248,864–413,137)	500,175 (368,222–632,128)	449,326 (338,410–560,241)	8067 (6065–10069)	5059 (3725–6394)	4295 (3235–5355)	70,774 (48,651–92,897)	112,025 (76,747–147,303)	101,547 (71,499–131,595)	1725 (1186–2264)	1133 (776–1490)	971 (683–1258)
Philippines	2,550,469 (1,834,266–3,266,673)	2,196,835 (1,946,148–2,447,522)	1,971,567 (1,712,389–2,230,744)	4048 (2911–5184)	1989 (1762–2216)	1741 (1512–1970)	536,298 (377,927–694,669)	538,224 (467,083–609,365)	489,965 (416,676–563,254)	851 (600–1103)	487 (423–552)	433 (368–497)
Republic of Korea	567,064 (493,120–641,009)	486,946 (431,154–542,738)	486,373 (427,703–545,043)	1282 (1115–1449)	939 (832–1047)	943 (829–1057)	144,634 (114,242–175,026)	124,291 (106,709–141,873)	125,088 (106,899–143,278)	327 (258–396)	240 (206–274)	243 (207–278)
Samoa	5224 (3982–6466)	4095 (3072–5119)	4068 (3079–5056)	3092 (2357–3828)	1965 (1474–2456)	1904 (1441–2367)	1219 (873–1565)	1109 (802–1416)	1105 (808–1403)	722 (517–926)	532 (385–680)	517 (378–657)
Singapore	37,818 (31,601–44,036)	42,996 (37,607–48,385)	40,290 (34,787–45,793)	1241 (1037–1445)	759 (664–854)	703 (607–800)	9361 (7254–11,468)	9581 (7981–11,180)	9010 (7449–10,571)	307 (238–376)	169 (141–197)	157 (130–185)
Solomon Islands	19,605 (13,856–25,354)	19,819 (15,096–24,543)	18,935 (14,237–23,633)	5782 (4086–7478)	3014 (2295–3732)	2770 (2083–3457)	4353 (2880–5826)	4624 (3319–5929)	4372 (3096–5647)	1284 (849–1718)	703 (505–901)	640 (453–826)
Tokelau	55 (42–68)	25 (17–32)	50 (40–60)	3455 (2633–4277)	1820 (1287–2352)	3640 (2889–4391)	13 (9–16)	6 (4–8)	12 (9–16)	789 (552–1025)	465 (318–612)	908 (681–1134)
Tonga	2941 (2323–3560)	2163 (1542–2783)	2090 (1465–2714)	2976 (2350–3601)	2043 (1457–2628)	1966 (1378–2553)	682 (493–870)	573 (398–747)	546 (374–717)	690 (499–881)	541 (376–706)	513 (352–675)
Tuvalu	780 (583–977)	292 (215–368)	281 (209–354)	8199 (6129–10270)	2418 (1786–3050)	2274 (1686–2862)	180 (127–233)	74 (52–96)	71 (50–92)	1894 (1334–2454)	612 (429–794)	573 (405–741)
Vanuatu	5960 (4497–7424)	8291 (6727–9855)	7696 (6244–9148)	3916 (2954–4877)	2763 (2242–3284)	2459 (1995–2923)	1370 (973–1767)	2014 (1523–2505)	1893 (1439–2347)	900 (639–1161)	671 (508–835)	605 (460–750)
Viet Nam	2,513,548 (2,108,305–2,918,791)	1,750,469 (1,448,912–2,052,026)	1,668,750 (1,368,387–1,969,113)	3684 (3090–4278)	1778 (1472–2084)	1664 (1365–1964)	522,182 (409,293–635,070)	440,690 (358,009–523,372)	423,261 (342,053–504,468)	765 (600–931)	448 (364–532)	422 (341–503)

DALY. Disability-adjusted life year

(bloodstream infections; peritoneal and intra-abdominal infections; urinary tract infections and pyelonephritis; infections of the skin and subcutaneous systems; tuberculosis; edocarditis; and infections of bones, joints, and related organs) between 1990 and 2021 (Fig. 2). The largest fatal burden attributable to AMR shifted from lower respiratory infections [246,672 (95% UI 234,420–260,309) deaths in 1990 and 214,641 (95% UI 199,729–231,361) deaths in 2021] to bloodstream infections [186,165 (95% UI 176,918–196,457) deaths in 1990 and 230,309 (95% UI 214,309–248,249)

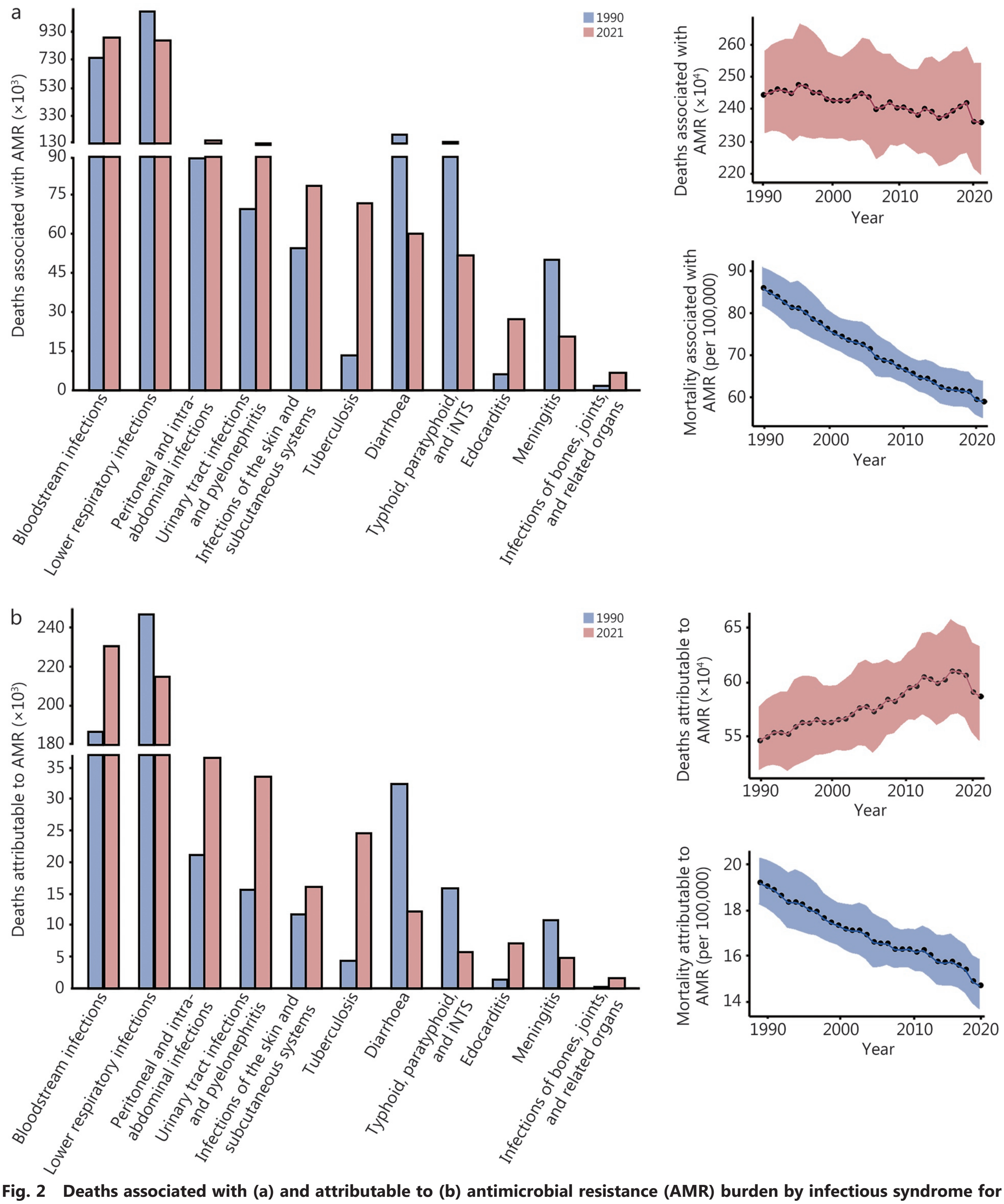

Fig. 2 Deaths associated with (a) and attributable to (b) antimicrobial resistance (AMR) burden by infectious syndrome for countries in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 1990–2021.
The red and blue lines depict the trends in AMR deaths and mortality rates (per 100,000 population) from 1990 to 2021, respectively

deaths in 2021]; these two infectious syndromes accounted for 75.8% (95% CI 64.7–89.8) of the total AMR burden in 2021 (Fig. 2; Additional file 1: Fig. S4; Additional file 2: Tables S2-S3). A similar pattern was observed in terms of DALYs, where lower respiratory infections and bloodstream infections collectively contributed the largest AMR burden in 2021, as detailed in Additional file 2: Table S4, underscoring the substantial mortality impact of these two infectious syndromes. Notably, lower respiratory infections contributed the most to the overall regional reduction in AMR-attributable deaths between 2019 [229,255 (95% UI 214,350–245,714)] and 2021 (Additional file 2: Table S2). In 2021, *Staphylococcus aureus* and *Streptococcus pneumoniae* were the leading causes of death attributable to bacterial AMR from bloodstream infections and lower respiratory infections, respectively (Additional file 1: Fig. S5).

Age-stratified AMR burden in the WHO SEAR and WPR

From 1990 to 2021, the trends of deaths associated with and attributable to AMR differed markedly across age groups (Fig. 1b). The AMR burden decreased markedly among people <25 years, with deaths among children <5 years declining by 78.9% (95% CI 74.4–83.5) for AMR-associated deaths [from 1,162,883 (95% UI 1,032,285–1,297,413) to 244,910 (95% UI 200,633–290,221)] and by 76.1% (95% CI 70.6–81.6) for AMR-attributable deaths [from 250,300 (95% UI 218,110–283,407) to 59,733 (95% UI 48,521–71,164)]. Within this group, neonatal AMR-associated deaths decreased from 474,285 (95% UI 416,430–532,824) to 133,751 (95% UI 104,026–163,487), and AMR-attributable deaths decreased from 114,455 (95% UI 98,951–130,128) to 36,400 (95% UI 28,268–44,520) between 1990 and 2021, accounting for 61.0% (95% CI 43.1–78.8) of AMR-attributable deaths in children <5 years in 2021. Among individuals aged 5–24 years, AMR caused 65,259 (95% UI 59,745–70,829) associated deaths and 13,955 (95% UI 12,774–15,148) attributable deaths in 2021. Compared with 1990, this represents a 59.7% decrease (95% CI –65.6 to –53.8) in AMR-associated deaths and a 53.8% decrease (95% CI –59.0 to –48.0) in AMR-attributable deaths. In contrast, adults aged ≥25 years experienced a pronounced increase, accounting for 2,048,021 (95% UI 1,979,726–2,117,852) AMR-associated and 513,415 (95% UI 495,713–531,232) AMR-attributable deaths in 2021, nearly double that of 1990. Within this group, adults aged 25–69 years experienced a gradual increase in both AMR-associated [49.0% (95% CI 39.0–59.0)] and AMR-attributable [61.7% (95% CI 50.0–73.8)] deaths, whereas adults aged ≥70 years experienced a more than 2-fold increase in both associated [from 564,530 (95% UI 530,363–598,223) to 1,219,157 (95% UI 1,161,807–1,275,827)] and attributable [from 133,013 (95% UI 124,066–141,922) to 298,366 (95% UI 284,023–312,475)] AMR deaths between 1990 and 2021.

AMR burden by pathogen in the WHO SEAR and WPR

In 2021, 6 pathogens were each responsible for more than 300,000 deaths in the SEAR and WPR (Additional file 1: Figs. S6-S7): *Mycobacterium tuberculosis* [668,041 (95% UI 589,666–745,638) deaths], *Streptococcus pneumoniae* [547,722 (95% UI 509,140–586,367)], *Staphylococcus aureus* [535,236 (95% UI 491,883–579,049)], *Escherichia coli* [375,614 (95% UI 347,805–404,221)], *Klebsiella pneumoniae* [325,773 (95% UI 306,388–345,560)], and *Pseudomonas aeruginosa* [307,779 (95% UI 286,738–328,825)]. In 2021, among deaths attributable to AMR from drug-resistant pathogens, Gram-negative bacteria accounted for 354,915 (95% UI 341,381–368,539) deaths, and Gram-positive bacteria for 232,188 (95% UI 207,010–260,199) deaths, representing 60.5% (95% CI 58.2–62.8) and 39.5% (95% CI 35.0–44.0) of the total, respectively (Additional file 1: Fig. S8). Between 1990 and 2021, deaths attributable to AMR from 12 pathogens decreased (Figs. 3-4; Additional file 1: Fig. S9; Additional file 2: Table S5), with the largest reduction observed for *Streptococcus pneumoniae*, from 127,682 (95% UI 105,976–149,689) deaths in 1990 to 83,710 (95% UI 72,479–95,119) deaths in 2021. Among the other 9 pathogens, *Staphylococcus aureus* increased most, with deaths attributable to AMR doubling from 51,355 (95% UI 45,059–57,612) in 1990 to 101,774 (95% UI 92,259–111,194) in 2021 (Figs. 3-4; Additional file 1: Fig. S9), and contributing to 2,795,549 (95% UI 2,529,714–3,058,973) DALYs attributable to AMR in 2021 (Additional file 2: Table S6). From 1990 to 2021, deaths attributable to AMR decreased in children <5 years for all pathogens. Among them, 6 pathogens experienced a decline of more than 80%: Group A *Streptococcus*, *Haemophilus influenzae*, *Non-typhoidal Salmonella*, *Serratia* spp., *Shigella* spp., and *Streptococcus pneumoniae* (Additional file 2: Table S7). Conversely, deaths attributable to AMR in adults ≥25 years increased in all but 4 pathogens: *Salmonella enterica serovar Typhi*, *Salmonella enterica serovar Paratyphi*, *Non-typhoidal Salmonella*, and *Serratia* spp. (Additional file 2: Table S7). In 2021, the pathogen with the largest number of deaths attributable to AMR was *Streptococcus pneumoniae* in children <5 years [11,290 (95% UI 10,474–12,133)], *Acinetobacter baumannii* [2077 (95% UI 1927–2232)] in people aged 5–24 years, and *Staphylococcus aureus* [94,080 (95% UI 87,281–101,104)] in those ≥25 years (Fig. 3).

AMR burden by pathogen-drug combinations in the WHO SEAR and WPR

In 2021, macrolide-resistant *Streptococcus pneumoniae* predominated as the leading pathogen-drug combination for causing deaths associated with AMR [338,267 (95% UI 304,862–372,456)], followed by aminopenicillin-resistant *Escherichia coli* [315,166 (95% UI 289,205–341,945)] (Additional file 1: Fig. S10). With respect to deaths attributable to AMR, methicillin-resistant *Staphylococcus aureus* (MRSA) replaced carbapenem-resistant *Streptococcus pneumoniae* as the leading pathogen-drug combination in 2021, with the latter predominating the AMR death burden in 80% of countries in

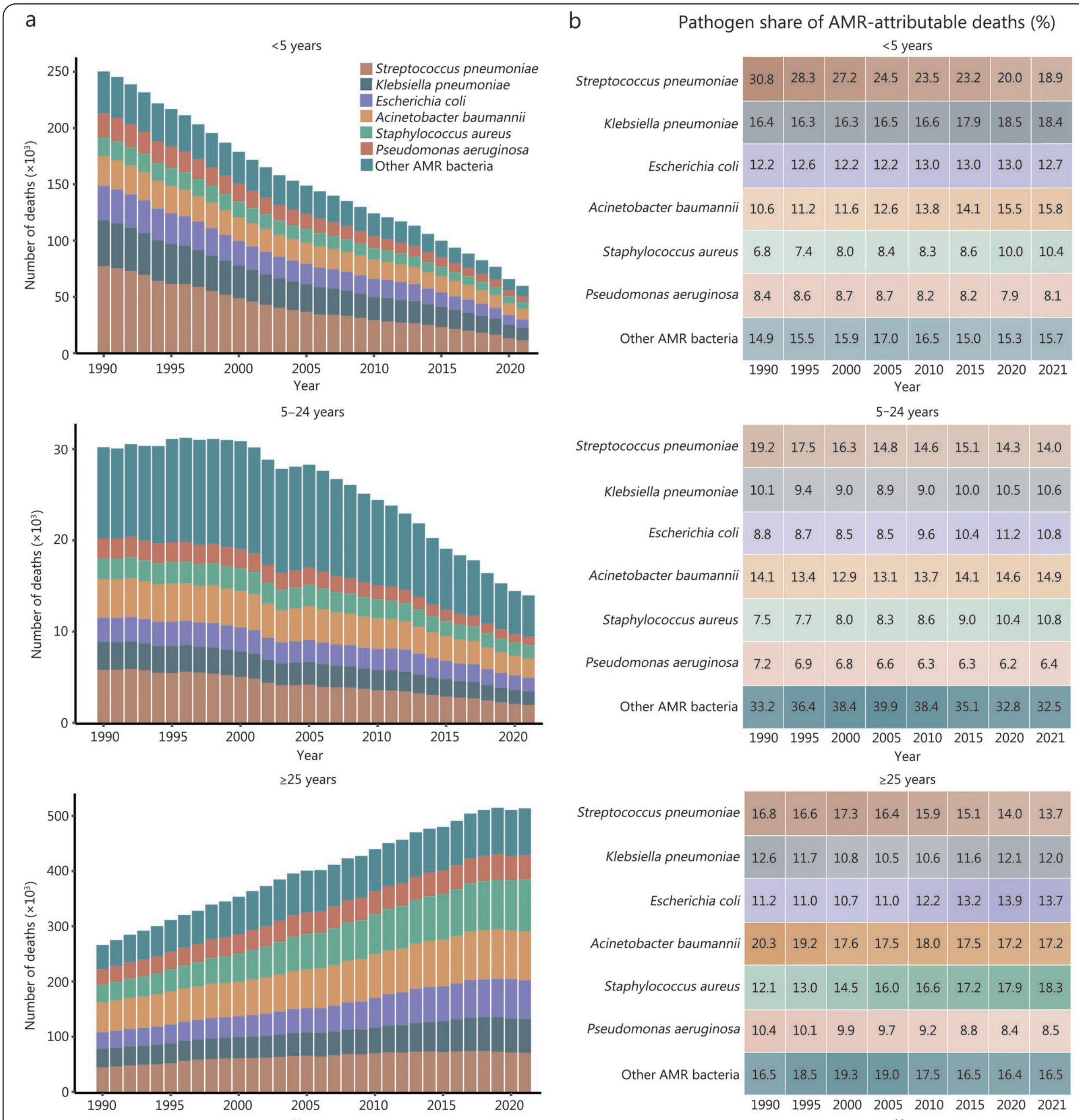

Fig. 3 Deaths attributable to antimicrobial resistance (AMR) by pathogen for people <5 years, 5-24 years, and ≥25 years in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 1990–2021.
a The total AMR-attributable deaths by pathogen. **b** The proportion (%) of total AMR deaths attributable to each pathogen. Other AMR bacteria are *Citrobacter* spp., *Enterobacter* spp., *Enterococcus faecalis*, *Enterococcus faecium*, *Haemophilus influenzae*, *Morganella* spp., *Mycobacterium tuberculosis*, *Proteus* spp., *Non-typhoidal Salmonella*, *Salmonella enterica serovar Typhi*, *Salmonella enterica serovar Paratyphi*, *Serratia* spp., *Shigella* spp., Group A *Streptococcus* (*Streptococcus pyogenes*), and Group B *Streptococcus* (*Streptococcus agalactiae*)

the two regions in 1990 (Fig. 4; Additional file 2: Tables S8-S9). A similar distribution was observed in DALYs attributable to AMR for pathogen-drug combinations (Additional file 1: Figs. S11-S12; Additional file 2: Tables S10-S11). Specifically,

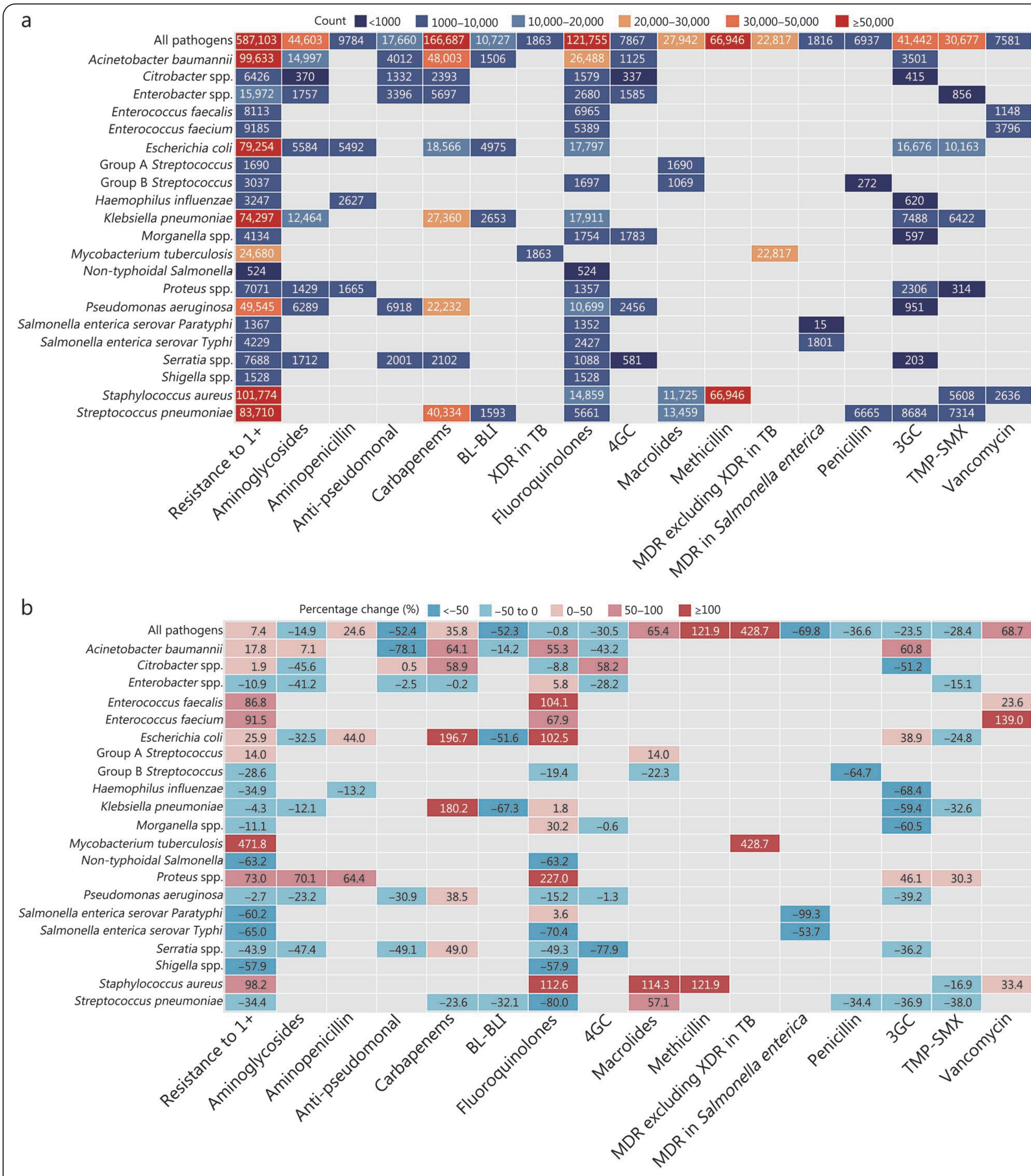

Fig. 4 Heatmap representing number of deaths in 2021 (a) and percentage change from 1990 to 2021 (b) attributable to antimicrobial resistance (AMR) by pathogen-drug combination in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR).

Group A *Streptococcus* pertains to *Streptococcus* pyogenes, and Group B *Streptococcus* pertains to *Streptococcus* agalactiae. Resistance to 1+. Resistance to one or more drugs; BL-BLI. Beta lactam/beta-lactamase inhibitors; 3GC. third-generation cephalosporins; 4GC. Fourth-generation cephalosporins; Anti-pseudomonal. Anti-pseudomonal penicillins with or without β-lactamase inhibitors; MDR. Multidrug resistance; XDR. Extensive drug resistance, TMP-SMX. Trimethoprim-sulfamethoxazole

MRSA was the combination with the highest number of deaths attributable to AMR in 2021, representing a 121.9% increase (95% CI 72.4–171.4) from 30,168 (95% UI 24,956–35,351) in 1990 to 66,946 (95% UI 57,544–76,479), and also showed the largest absolute increase among *Staphylococcus aureus*-related AMR-attributable death during the study period (Fig. 4; Additional file 1: Fig. S9). In Gram-negative organisms, the number of deaths attributable to carbapenem-resistance ranged from 122,723 (95% UI 97,179–148,718) in 1990 to 166,687 (95% UI 143,777–190,429) in 2021, accounting for more deaths than any other antibiotic class during this period (Fig. 4; Additional file 1: Fig. S9).

National comparisons of AMR burden in the WHO SEAR and WPR

Between 1990 and 2021, deaths attributable to AMR decreased in 15 countries but increased in 27 countries (Table 1). Among those 27 countries, 2 experienced an increase of more than 8000 AMR-attributable deaths (point estimates): India [from 228,265 (95% UI 185,109–271,420) to 266,734 (95% UI 223,662–309,806)] and Thailand [from 5678 (95% UI 4405–6952) to 13,901 (95% UI 10,441–17,361)]. However, the percentage change in ASMR attributable to AMR varied widely across all countries for the general population from 1990 to 2021, ranging from –3.2% (95% CI –36.5 to 30.1) in American Samoa to –68.7% (95% CI –78.2 to –59.2) in Singapore (Additional file 1: Fig. S13). In 2021, Kiribati [30.9 (95% UI 24.1–37.8)] and Nauru [30.6 (95% UI 22.4–38.7)] exhibited ASMRs attributable to AMR greater than 30 deaths per 100,000 person-years, whereas New Zealand [3.2 (95% UI 2.6–3.8)], Australia [3.5 (95% UI 3.0–4.1)], and Japan [3.7 (95% UI 3.2–4.1)] had the lowest ASMRs of less than 5 deaths per 100,000 person-years (Fig. 5). In addition, 7 countries had AMR-associated ASMRs of more than 100 deaths per 100,000 person-years in 2021. These countries in descending order were as follows: Solomon Islands [123.2 (95% UI 90.0–149.6)], Kiribati [120.7 (95% UI 96.5–145.0)], Nauru [117.2 (95% UI 88.4–146.0)], Cambodia [106.6 (95% UI 84.7–128.5)], Marshall Islands [103.0 (95% UI 78.5–127.5)], Vanuatu [101.1 (95% UI 84.7–117.6)], and Papua New Guinea [100.8 (95% UI 77.6–123.9)].

Comparisons between AMR mortality rates and countries' progress in the development of multi-sectoral collaboration against AMR are shown in Fig. 5. None of the 15 countries

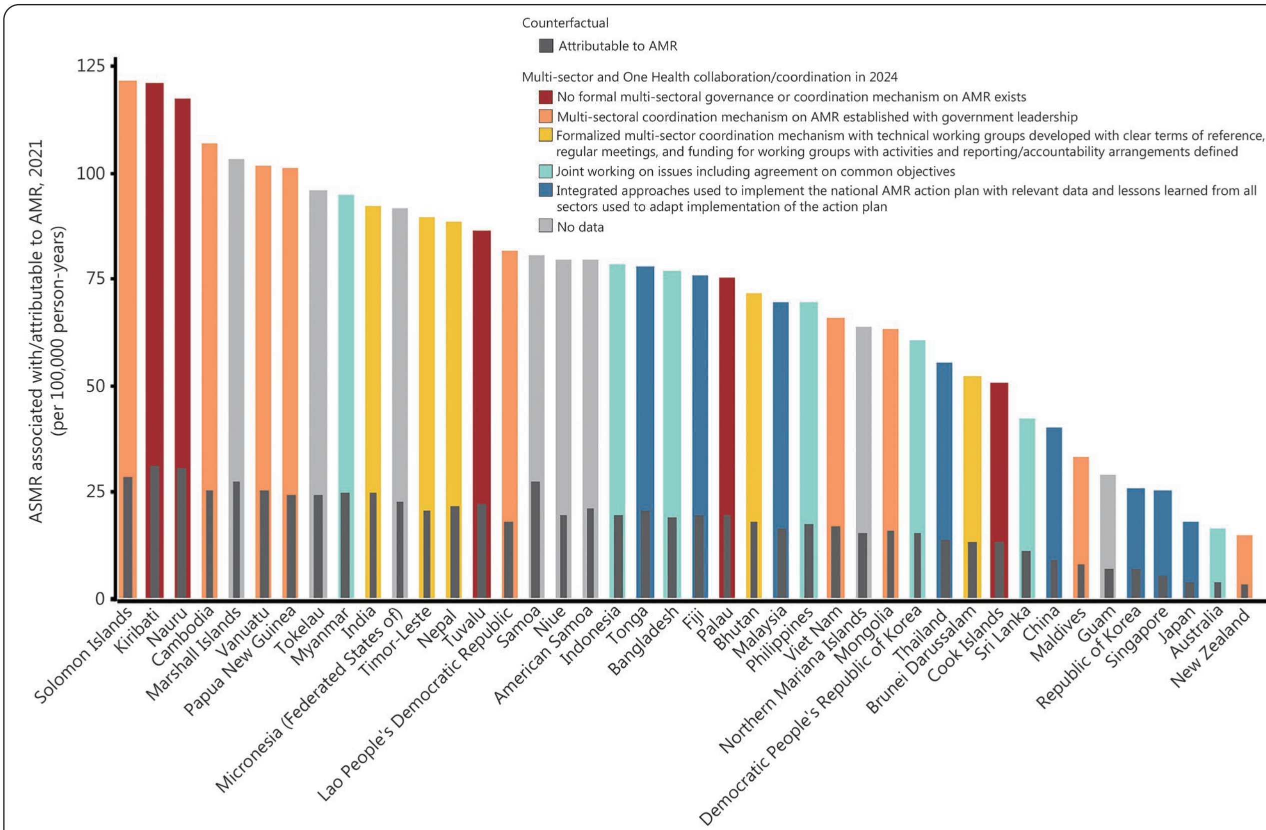

Fig. 5 Age-standardized mortality rate (ASMR) associated with and attributable to antimicrobial resistance (AMR) with the status of multi-sectoral and One Health collaboration for the countries in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 2021

exhibiting the highest ASMRs associated with or attributable to AMR have adopted integrated implementation approaches for their national AMR NAPs; they have failed to systematically incorporate multi-sectoral data and lessons learned from all sectors to refine their NAPs. Japan, Singapore, Republic of Korea, and China were 4 of the 8 countries that implemented NAPs with an integrated approach in 2024; these countries were all situated in the lower 20th percentile of ASMRs that were attributable to and associated with AMR.

AMR burden forecasts in the WHO SEAR and WPR

The adequacy of the ARIMA model was confirmed through residual diagnostics, as shown in Additional file 1: Figs. S14-S16. According to current trends, the number of sepsis-related deaths and AMR burden in the SEAR and WPR is projected to increase steadily in the next 25 years (Fig. 6; Additional file 2: Table S12). By 2050, sepsis-related deaths are projected to reach 13,732,757 (95% UI 5,621,498–33,547,750), accounting for approximately 28.4% (95% CI 22.1–36.4) of all-cause deaths [48,361,978 (95% UI 46,673,206–50,059,320)] in the

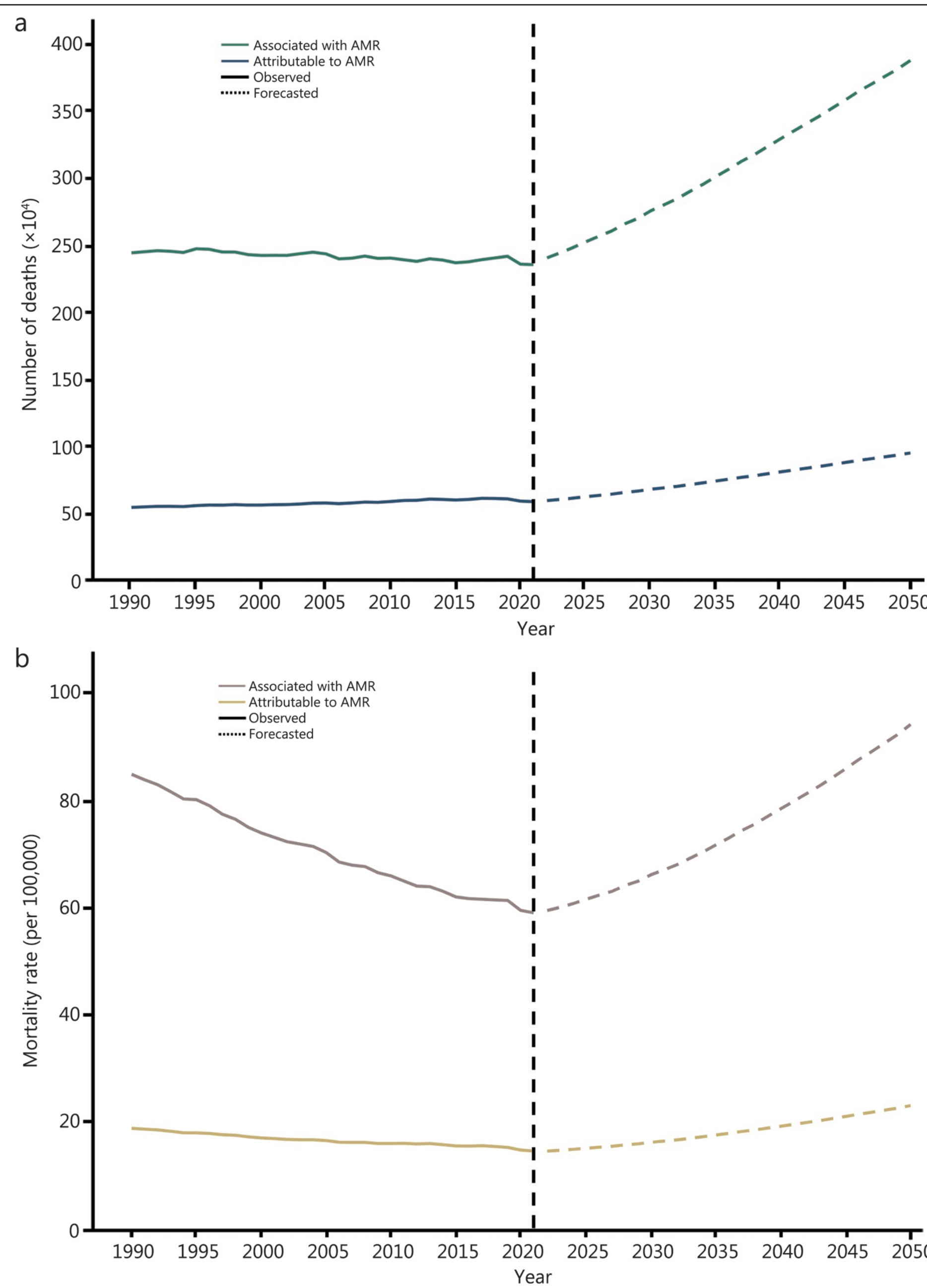

Fig. 6 Projected deaths (a) and mortality rates (b) associated with and attributable to antimicrobial resistance (AMR) in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 1990–2050.
The black vertical dashed line indicates the separation between the observed historical data and the projected period

studied regions. In addition, an estimated 3,875,753 (95% UI 1,502,402–9,998,297) deaths will be associated with AMR, of which 952,592 (95% UI 766,353–1,184,090) will be directly attributable to AMR. This corresponds to a 1.62-fold increase (95% CI 1.24–2.01) compared with attributable AMR deaths in 2021.

Discussion

This study provides a comprehensive assessment of sepsis-related and AMR burden across infectious syndromes, pathogens, and pathogen-drug combinations in the SEAR and WPR (1990–2021), with forecasts to 2050 and a critical evaluation of progress in regional AMR governance. Our analysis showed that despite overall sepsis-related mortality decline, the percentage of sepsis-related deaths that were attributable to AMR increased from 1990 to 2019. Alarmingly, these two regions accounted for 587,103 AMR-attributable deaths in 2021, representing 51.5% of the global total of such deaths, positioning the SEAR and WPR as the epicenter of the AMR crisis. Notably, age-stratified trends highlight divergent trajectories; that is, the 76.1% reduction in under-5 mortality contrasts sharply with AMR-attributable deaths among adults ≥70 years more than doubling, underscoring vulnerabilities in aging populations with comorbidities. Pathogen-specific analyses revealed that MRSA was the dominant driver, with deaths attributable to AMR increasing by 121.9% since 1990.

Between 2020 and 2021, we determined that sepsis-related deaths increased while AMR burden decreased in the SEAR and WPR, which was likely driven by nonpharmaceutical interventions that temporarily reduced bacterial transmission during the coronavirus disease 2019 (COVID-19) pandemic [25]. Beyond these short-term fluctuations, the long-term trend reveals a pronounced decline in AMR mortality among people <25 years, highlighting the success of preventive strategies. This reduction is primarily attributable to a decrease in mortality from vaccine-preventable bacterial infections, including lower respiratory infections and diarrhea caused by *Streptococcus pneumoniae*, *Haemophilus influenzae*, and fecal-oral-transmitted pathogens such as *Salmonella enterica serotypes Typhi* and *Shigella*. The widespread introduction of pneumococcal conjugate vaccines has contributed not only to lowering disease incidence but also to reducing the prevalence of antibiotic-resistant *Streptococcus pneumoniae* strains [26]. Vaccines thus represent powerful tools against AMR by both directly reducing the circulation of resistant pathogens and indirectly decreasing antibiotic use [27]. Further gains can be achieved by expanding universal access to high-quality water, sanitation, and hygiene (WASH) and by strengthening infection prevention and control (IPC). These measures limit the release of resistance genes into the environment and reduce AMR transmission across humans, animals, and ecosystems [28,29]. However, despite the overall reduction in AMR deaths, the proportion of deaths associated with AMR increased among children <5 years who died from sepsis in the two regions. These findings suggest that the currently available antibiotics to treat these infections may be ineffective in children [8], and there is an urgent need to focus limited resources on the most appropriate agents for future development and pediatric optimization [30]. Overall, reductions in childhood AMR burden highlight the importance of IPC, WASH, and immunization in AMR prevention, with estimates suggesting these strategies could prevent more than 760,000 AMR-associated deaths annually in LMICs [31]. Moving forward, consolidating these preventive strategies and improving age-disaggregated AMR surveillance will be essential for capturing variations in resistance patterns throughout the life course.

While AMR-related deaths among people <25 years have decreased over the past three decades, deaths among people ≥70 years have more than doubled, highlighting that aging populations in SEAR and WPR are likely to face a growing AMR burden in the future. This contrasting trend underscores the need for age-appropriate interventions, given that the drivers of AMR burden in children differ fundamentally from those in elderly individuals. First, advancing age constitutes a primary risk factor for mortality from AMR infections [32]. These two WHO regions are experiencing changes in population structure and population growth and contain more than 258 million (52.2% of the world's population over 70) people aged ≥70 years in 2021 [33]. Second, the comorbidities and immunosenescence that can accompany aging aggravate susceptibility to infections, drive repeated courses or long-term use of antibiotics, and increase an individual's frequency of interactions with healthcare settings, collectively contributing to the increasing burden of antimicrobial-resistant infections [34-37]. Third, beyond antibiotic overuse, long-term care facilities often have suboptimal antibiotic practices and a high prevalence of multidrug-resistant organisms, further amplifying transmission risks among older adults [38]. Fourth, certain IPC interventions, such as vaccinations, demonstrate efficacy in pediatric populations but may exhibit reduced effectiveness in adults. This can be attributed to two main factors. On the one hand, many LMICs in both regions tend to prioritize the infectious disease burden in children over adults, with a lack of well-established adult vaccination programs such as those for adult pneumococcal conjugate vaccine [39]. On the other hand, the occurrence of a nonoptimal age of vaccination in older adulthood may result in waning protection from vaccination [40]. Consequently, unlike preventive strategies in children, reducing the AMR burden among older adults requires strengthening infection prevention within healthcare and long-term care settings, and optimizing antimicrobial stewardship in chronic disease management.

Although disparities in age-stratified AMR burden and demographic transitions warrant considerable attention, a more critical focus lies in capturing the burden of antibiotic-resistant pathogens and their evolving trends responsible for infectious diseases, which holds potential implications for the development of new antibiotics and vaccines. A summary of the leading pathogen-drug interactions and corresponding interventions is provided in Additional file 2: Table S13. In the 2024 updated Bacterial Priority Pathogens list (BPPL) [41], Gram-negative bacteria retain a critical priority, including Carbapenem-resistant *Acinetobacter baumannii*, carbapenem-resistant *Enterobacterales*, third-generation cephalosporin-resistant *Enterobacterales*, and rifampicin-resistant *Mycobacterium tuberculosis*. The growing prevalence of multidrug resistance (MDR) in these invasive Gram-negative pathogens, combined with the absence of effective vaccines, is shifting the AMR burden from *Streptococcus pneumoniae*-dominated lower respiratory infections toward bloodstream infections [42]. Our analysis further demonstrated that carbapenem-resistant bacteria, particularly Gram-negative bacteria, constitute the predominant cause of death attributable to AMR across all countries. Among 8 carbapenem-resistant bacteria, the number of deaths attributable to all bacteria except *Streptococcus pneumoniae* and *Enterobacter* spp. increased, with the highest burden occurring in carbapenem-resistant *Acinetobacter baumannii*, which aligns with data reported by Antimicrobial Testing Leadership and Surveillance [43]. At the national level, India has the highest annual incidence of tuberculosis and mortality attributable to MDR *Mycobacterium tuberculosis* [44]. A large-scale genome-based study has indicated a drastic increase in fluoroquinolone resistance, as well as emerging bedaquiline resistance, driving the MDR tuberculosis epidemic in India, where rapid adaptation of treatment strategies is needed in the future [45]. MRSA maintains its position in the BPPL high-priority pathogen category, in line with its highest estimated burden of pathogen-drug combinations. However, analyses from low-prevalence areas in Nordic countries highlight effective strategies that may inform efforts to control the spread of MRSA. First, rigorous national surveillance systems, along with strict strategies for antibiotic stewardship and infection control are vital [46]. Second, preventive strategies such as *Staphylococcus aureus* vaccines, lytic agents, probiotics, microbiota transplants, and phage therapy are useful for interrupting recurrent infections [47]. Third, employing a combination of systemic and topical agents, manipulating the nasal microbiome, and minimizing antibiotic overuse are effective approaches for eradicating MRSA colonization [48,49].

Bacterial AMR poses a significant public health threat in the SEAR and WPR, with projections indicating a continued high burden in the coming decades. Across the studied countries, the estimated AMR burden shows substantial variation, which may reflect differences in healthcare infrastructure, diagnostic capacity, and resource availability. LMICs and small Pacific Island countries and territories (such as Kiribati, Nauru, and the Solomon Islands) face particularly high AMR burdens due to limited laboratory and diagnostic infrastructure, restricted antibiotic procurement, and fragmented referral systems, which collectively restrict timely detection and treatment of resistant infections [50,51]. In many LMICs, AMR surveillance networks primarily collect phenotypic and genotypic data from healthcare facilities with suboptimal laboratory quality, and paper-based ordering, reporting, and storage systems remain common, limiting the generalizability and completeness of national data [7,52]. These constraints further hamper routine microbiological surveillance and antimicrobial susceptibility testing, thereby constraining the monitoring of trends and emerging resistance patterns. Strengthening national-level and integrated surveillance systems is therefore essential to generate invaluable data for understanding local AMR epidemiology and guiding intervention strategies in these specific contexts. Additionally, there is an urgent need to investigate and evaluate the rapid point-of-care diagnostic tests and diagnostic algorithms in early distinguishing drug-resistance related infections in low-resource settings and across different subpopulations [53]. Integrating antimicrobial susceptibility tests, molecular, and genomic surveillance can further illuminate the emergence and spread of antibiotic resistance genes, supporting the identification of high-risk pathogens [54].

Our study presents a detailed analysis of bacterial AMR burden spanning three decades in the SEAR and WPR to date. By mapping age-stratified trends and identifying priority pathogens driving mortality, our work establishes an essential evidence base for precision interventions. However, several limitations must also be considered. First, as with other bacterial AMR studies discussed previously, a paucity of data from some LMICs prevented the linking of laboratory data from outcomes such as mortality, potentially leading to an underestimation of mortality associated with and attributable to AMR in the two regions. Second, the availability and quality of primary data vary widely across the studied countries, leading to biases and limitations in consolidating and standardizing AMR data. This includes the reliance on passive microbial surveillance, which may lead to an incomplete representation of AMR patterns, as well as the impact of evolving diagnostic methods on the accuracy and reliability of sepsis and AMR burden estimates [55]. Third, the COVID-19 pandemic posed a significant threat to the global healthcare system and led to the misuse and overuse of antibiotics, which may result in biased AMR data [56]. Fourth, the AMR burden projections to 2050 are constrained by limitations in historical data across SEAR and WPR. The ARIMA model is based on overall estimates of AMR deaths, rather than forecasts of individual pathogens or pathogen-drug combinations, which could reduce accuracy if there is substantial heterogeneity in pathogen trends over time. Finally, given the self-reported nature of the TrACSS responses and the absence of independent validation, the assessment of multi-sector collaboration reported by countries in this study may be subject to overestimation or underestimation. The accuracy and honesty of reporting may also vary across countries depending on institutional capacity and interpretation of survey indicators, which could introduce bias in cross-country comparisons. Nevertheless, the TrACSS remains the only available dataset for assessing country-level progress on AMR.

Conclusions

This study highlights the growing, age-specified burden of sepsis-related and AMR in SEAR and WPR from 1990 to 2021, with projections indicating a continued rise in AMR-related deaths through 2050. These findings emphasize the importance of ongoing efforts to reduce AMR among people <25 years while concurrently addressing the escalating concern of an increasing AMR burden among the elderly population in these two regions. Perhaps more importantly, increased attention should be given to the increasing prevalence of pathogens resistant to important antimicrobials, such as MRSA and carbapenem-resistant Gram-negative bacteria. These results provide not only essential evidence to bridge existing knowledge gaps in the AMR epidemiological landscape of LMICs but also provide scientific evidence to inform current AMR prevention and control policies in these regions.

Abbreviations

AMR: Antimicrobial resistance
ARIMA: Autoregressive integrated moving average
ASMR: Age-standardized mortality rates
BPPL: Bacterial Priority Pathogens List
CI: Confidence interval
DALYs: Disability-adjusted life-years
GRAM: Global Research on Antimicrobial Resistance
IPC: Infection prevention and control
LMICs: Low- and middle-income countries
MDR: Multidrug resistance
MRSA: Methicillin-resistant *Staphylococcus aureus*
NAP: National action plan
SEAR: Southeast Asia Region
TrACSS: Tripartite Antimicrobial Resistance Country Self-Assessment Survey
UI: Uncertainty interval
WASH: Universal access to high-quality water, sanitation, and hygiene
WHO: World Health Organization
WPR: Western Pacific Region
YLDs: Years lived with disability
YLLs: Years of life lost.

Supplementary information

The online version contains supplementary material available at https://doi.org/10.1016/j.mmr.2026.100002.

Additional file 1. Methods. Fig. S1 Heat map of input data density in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 1990–2021. **Fig. S2** A decomposition analysis that quantifies the effect of different contributory factors on the number of sepsis-related deaths between 2019 and 2021. **Fig. S3** Total deaths from 22 infectious syndromes per country in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 2021. **Fig. S4** Treemap of deaths associated with and attributable to antimicrobial resistance (AMR) by 11 infectious syndromes in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 2021. **Fig. S5** Deaths attributable to antimicrobial resistance (AMR) burden by infectious syndrome and specific pathogens in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 2021. **Fig. S6** Deaths by 63 pathogens in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 2021. **Fig. S7** Deaths by 63 pathogens per country in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 2021. **Fig. S8** Deaths attributable to antimicrobial resistance by 21 pathogens in the WHO Southeast Asia Region (SEAR) and Western Pacific Region (WPR), 2021. **Fig. S9** Heatmaps showing death counts associated with (a) and attributable to (b) antimicrobial resistance (AMR) across pathogen-drug combinations in the WHO Southeast Asia (SEAR) and Western Pacific (WPR) regions, 1990. **Fig. S10** Heatmaps showing number of death in 2021 (a) and percentage change from 1990 to 2021 (b) associated with antimicrobial resistance (AMR) across pathogen-drug combinations in the WHO Southeast Asia (SEAR) and Western Pacific (WPR) regions. **Fig. S11** Heatmap representing all-age number of disability-adjusted life years (DALYs) attributable to antimicrobial resistance by pathogen-drug combination in the Southeast Asia Region (SEAR) and Western Pacific Region (WPR) in 1990. **Fig. S12** Heatmap representing all-age number of disability-adjusted life years (DALYs) attributable to antimicrobial resistance by pathogen-drug combination in the regions of Southeast Asia and Western Pacific in 2021. **Fig. S13** Mortality attributable to antimicrobial resistance for people <5 years, ≥5 years, and age-standardized rates per 100,000 in the WHO Southeast Asia Region, 1990–2021. **Fig. S14** Residual analysis of the ARIMA model for the death of sepsis. **Fig. S15** Residual analysis of the ARIMA model for death associated with AMR. **Fig. S16** Residual analysis of the ARIMA model for death attributable to AMR.

Additional file 2. Table S1 Data input sources from the WHO SEAR and WPR. **Table S2** Sepsis-related deaths attributable to and associated with AMR by infectious syndrome, 1990, 2019, and 2021. **Table S3** Deaths attributable to and associated with AMR per country in the WHO SEAR and WPR, 2021 and infectious syndromes. **Table S4** DALYs attributable to and associated with AMR per country in the WHO SEAR and WPR, 2021, and infectious syndromes. **Table S5** Deaths attributable to and associated with AMR per country in the WHO SEAR and WPR, 2021, and pathogens. **Table S6** DALYs attributable to and associated with AMR per country in the WHO SEAR and WPR, 2021, and pathogens. **Table S7** Deaths attributable to AMR by pathogen for people <5 years, 5–24 years, and ≥25 years in the WHO SEAR and WPR between 1990 and 2021. **Table S8** 82 fatal pathogen-drug combination ranking by mortality burden attributable to AMR in 1990, WHO SEAR and WPR. **Table S9** 82 fatal pathogen-drug combination ranking by mortality burden attributable to AMR in 2021, WHO SEAR and WPR. **Table S10** 84 fatal pathogen-drug combination ranking by DALYs burden attributable to AMR in 1990, WHO SEAR and WPR. **Table S11** 84 fatal pathogen-drug combination ranking by DALYs burden attributable to AMR in 2021, WHO SEAR and WPR. **Table S12** Projections of the number of deaths and crude rate for AMR from 2022 to 2050, WHO SEAR and WPR. **Table S13** Prevention and control strategies for major AMR pathogens in the WHO SEAR and WPR.

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Authors' contributions

XRY and YHD developed the study concept. XRY drafted the manuscript, provided the analysis and visualization. QSH and IM contributed to interpretation of the data and extensive revision of the manuscript. HW, JW, XY, and XDZ helped interpret the results. All authors critically revised the manuscript for important intellectual content, including input into the panel, figures, and tables, and approved the final manuscript.

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Availability of data and materials

The AMR burden datasets generated and evaluated in this study are publicly available through the 2021 Global Antimicrobial Resistance Burden study (https://vizhub.healthdata.org/microbe/). The Global Database for Tracking Antimicrobial Resistance Country Self-Assessment Survey is publicly available through https://amrcountryprogress.org/. The analytical code used for data processing and visualization is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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