Burden of cardiovascular disease among the Western Pacific region and its association with human resources for health, 1990–2021: a systematic analysis of the Global Burden of Disease Study 2021

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Summary

Background A comprehensive profile of cardiovascular disease (CVD) burden and human resources for health (HRH) distribution in the WHO Western Pacific region has yet to be presented. Studies on the relationship between HRH and CVD in this region are limited. We aimed to describe CVD trends and HRH density in the Western Pacific region and explore the association of HRH with CVD burden.

Methods Estimates of CVD deaths and disability-adjusted life years (DALYs) were obtained from the Global Burden of Disease Study (GBD) 2021, and the annual density of HRH was retrieved from GBD 2019. We presented trends in CVD burden and HRH density across 31 Western Pacific countries. Spearman rank correlation analysis and generalized linear models were used to examine associations between CVD burden and HRH density.

Findings In 2021, CVD caused six million deaths and 125 million DALYs in the Western Pacific region, accounting for 39.4% and 22.5% of all-cause deaths and DALYs. From 1990 to 2021, the number of CVD deaths and DALYs increased by 94.9% and 57.3% in this region, whereas the age-standardized rate of CVD deaths and DALYs declined in all countries. In 2021, stroke and ischemic heart disease were the leading causes in the Western Pacific region, and a 32-year increase in CVD burden was primarily driven by aortic aneurysm, lower extremity peripheral arterial disease, endocarditis, and atrial fibrillation and flutter. In 2019, there was an approximately 20-fold difference in HRH density across 31 countries from the lowest in Papua New Guinea to the highest in Australia. HRH density was negatively related to the age-standardized rate of CVD deaths (r_s = –0.74) and DALYs (r_s = –0.73), especially strong associations between CVD burden and the density of dentistry personnel, aides & emergency medical workers, and medical laboratory technicians.

Interpretation CVD remains a pressing public health issue in the Western Pacific region where noticeable shortages in health workers exist. The negative associations between CVD burden and HRH density suggest that health workers, especially dentistry personnel, aides & emergency medical staff, and medical laboratory technicians merit more investment to reduce the CVD burden.

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Keywords: Cardiovascular disease; Human resources for health; Western Pacific region; Disease burden

Introduction

One-quarter of global deaths due to non-communicable diseases occur in the World Health Organization (WHO) Western Pacific region.[1] As one of the most common non-communicable diseases, cardiovascular disease (CVD) caused a 25% increase in deaths worldwide between 2000 and 2019, with the greatest rise of 1.8 million in the Western Pacific region.[2] The Global

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Research in context

Evidence before this study

Few systematic studies have presented the fatal and non-fatal burdens of cardiovascular disease (CVD) at the national level in the Western Pacific region using the most recent post-COVID-19 pandemic data. There is limited research on its association with Human Resources for Health (HRH), which encompasses various occupations responsible for promoting and improving human health. Understanding the CVD trend and its relationship with HRH is crucial for accelerating progress towards Universal Health Coverage and Sustainable Development Goal (SDG) targets 3.4 and 3.8, which aim to improve accessibility to quality essential health-care services and achieve a 30% reduction in premature mortality from non-communicable diseases by 2030. We searched PubMed using the following terms and their combinations: "cardiovascular diseases", "CVD", "burden", "death", "mortality", "disability", "human resources for health", "HRH", "Western Pacific region", and names of all 31 countries and areas in the Western Pacific region, without language restrictions, for publications from January 1, 2019 to December 31, 2023. Our search did not identify studies specifically presenting comprehensive CVD burden in the Western Pacific region at a national level or further assessing its relation with HRH. Previous studies indicated that HRH was associated with life-expectancy, maternal, neonatal, infant, and under-five mortality rates but findings varied; of those studies, doctors and nurses were primarily analyzed, while the role of other components of health-care labor in health outcomes was less explored. Additionally, only two studies have reported the relationship between CVD mortality and HRH. One study from the United States indicated that a greater primary care physician supply was related to lower mortality due to CVD; another global study including 172 countries also suggested a negative association between HRH and CVD mortality. Given the necessity of devising timely strategies to prevent and control CVD, further research on the health workforce in relation to CVD burden is critically needed in the Western Pacific region.

Added value of this study

This study used the best available and robust estimates from the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021 to explicitly report CVD mortality and DALYs in the Western Pacific region from 1990 to 2021. We also described the temporal trends and shortages in HRH from 1990 to 2019, and further analyzed the association between HRH and CVD burden in 2019. In 2021, CVD still caused an unacceptably substantial number of deaths and DALYs in the Western Pacific region, accounting for 39.4% of the total deaths and 22.5% of the total DALYs. The proportion of CVD deaths and DALYs relative to all-cause deaths and DALYs increased among more than half of the countries in this region, while the age-standardized rate of CVD deaths and DALYs has shown steady improvements over the past 32 years. For 12 specific CVDs, stroke and ischemic heart disease were the leading causes in the Western Pacific region in 2021, and another discouraging finding was that the age-standardized rates for several CVDs increased (e.g., aortic aneurysm, lower extremity peripheral arterial disease, endocarditis, and atrial fibrillation and flutter), with the most notable increase for lower extremity peripheral arterial disease in Mongolia. Despite a modest increase in the density of health workforce in 1990–2019, the number of health workers was still insufficient in 17 (54.8%) of 31 countries to meet the Universal Health Coverage needs with apparent between-country differences across the Western Pacific region. An overall negative association between HRH density and the rate of CVD deaths and DALYs—especially relatively strong associations of rheumatic heart disease, stroke, ischemic heart disease, and pulmonary arterial hypertension with dentistry personnel, aides & emergency medical staff, and medical laboratory technicians—suggested that improving the accessibility of health workers was related to a reduction in CVD burden.

Implications of all the available evidence

The Western Pacific countries have experienced accelerating population ageing in the past three decades. The increasing number of CVD deaths and DALYs underscores the significance of more extensive health resources and services to meet health-care demands within the Western Pacific region. However, there were substantial shortages in HRH with great between-country disparities, which are likely to be exacerbated by growing out-migration and an ageing population over the next several decades. Promoting the use of other non-physician health-care workers (e.g., dentistry personnel, aides & emergency medical staff, and medical laboratory technicians) would make health workforce more effective to prevent, treat, and manage CVD, thereby alleviating CVD-related disability and mortality. Furthermore, comprehensive measures considering the most important behavioral risk factors for CVD, such as unhealthy diet, physical inactivity, tobacco use, and harmful use of alcohol, are especially critical to prevent atherosclerotic CVD (e.g., ischemic heart disease, stroke, and lower extremity peripheral arterial disease). Interdisciplinary and integrated measures to address health workforce deficiencies, unhealthy lifestyles, psychosocial factors, and social determinants are increasingly crucial for reducing the burden of CVD in the Western Pacific region.

Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2019 estimated that disability-adjusted life years (DALYs) for CVD have grown by 52.4% since 1990 in the Western Pacific region, reaching 114.9 million in 2019.[3] Furthermore, this region is experiencing accelerating population ageing, with more than 265 million people aged 65 years and above (the share of the over-65 population of 13.8%) in 2021,[4] which is linked to an increased burden of non-communicable diseases and chronic conditions.[5] To make the Western Pacific region the

healthiest and safest region, non-communicable diseases have emerged as one of the strategic priorities in the coming five years to 2025.[6] Although research has reported trends and disparities in non-communicable diseases in this region, a country-specific CVD burden has not been comprehensively described.[7] Additionally, how the specific fatal and non-fatal burden of CVD changed in each Western Pacific country and area has yet to be comprehensively reported using the most recent post-COVID-19 pandemic data, which would provide important evidence on investing the prevention and control of CVD and achieving the United Nations Sustainable Development Goals (SDG) target 3.4.

Human resources for health (HRH) indicates a variety of occupations that are typically responsible for the promotion and improvement of human health, playing an essential role in accelerating progress towards Universal Health Coverage and SDG targets.[8,9] Previous cross-country[10–12] and within-country studies[13–15] have shown that HRH is associated with life-expectancy, maternal, neonatal, infant, and under-five mortality rates, whereas the associations between HRH and health outcomes were inconsistent across studies because of heterogeneity in the data sources, analysis methods, and study settings. In addition, these studies mainly focused on doctors, nurses, and midwives and the SDG target indicators 3.1 and 3.2 (maternal mortality ratio, mortality rates of neonatal and under-five), which is insufficient to strengthen the evidence on accelerating progress to other SDG targets. One study from the United States concluded that a greater primary care physician supply was related to lower mortality due to CVD, cancer, infectious diseases, respiratory tract diseases, and substance use or injury.[16] Another observational study in 172 countries also showed negative associations between the density of total HRH and specific categories of health workers and all-cause and CVD mortality rates.[17] However, the relationship between CVD burden and HRH density has been less explored in the Western Pacific region.

Given the economic growth, ageing population, and rising cardiovascular risk factors in the Western Pacific region, we expected to provide a comprehensive and up-to-date profile of the CVD burden and the coverage of health workers, and we hypothesized that there are negative associations between CVD burden and the health workforce. Importantly, GBD 2019 Human Resources for Health Collaborators first estimated HRH densities worldwide using comparable data sources and standardized methods, and calculated the health workforce shortages for four cadres of health workers identified in SDG indicator 3.c,[8] allowing us to investigate how specific types of HRH correlated with CVD in the Western Pacific region.

Therefore, we aimed to report CVD deaths and DALYs and how they changed from 1990 to 2021 using newly updated estimates of total and specific CVDs. We also presented the trend in the density of HRH from 1990 to 2019. Finally, we explored the associations between HRH density and CVD burden in 2019.

Methods

Overview

For this study, we conducted secondary analyses using newly and publicly available data from the GBD 2021. The GBD study provides iterative and continuous estimates of disease burdens with the best available data sources to evaluate global health loss. We reported the deaths and DALYs for CVD because these metrics can characterize the fatal and non-fatal disease burden of CVD, respectively. The most updated GBD 2021 utilized 5086 data sources to estimate age-sex-location-year specific mortality and years of life lost (YLLs) for 288 causes of death in 204 countries and territories between 1990 and 2021,[18] while 100,983 data sources were synthesized to produce estimates of DALYs for 371 diseases and injuries by age (25 age groups from birth to 95 years and older), sex (male, female, and both sexes combined), location (204 countries and territories), and year (annually from 1990 to 2021).[18,19] All GBD 2021 health estimates are available at https://vizhub.healthdata.org/gbd-results/.

We reported CVD-related deaths and DALYs in numbers and age-standardized rates per 100,000 population. The age-standardized rates were calculated by the direct method using the GBD standard population structure, which allows us to compare estimates generated from different age structures. Our study focused on 31 countries and areas (hereafter "countries" for simplicity) in the WHO Western Pacific region, including American Samoa, Australia, Brunei Darussalam, Cambodia, China, the Cook Islands, Fiji, Guam, Japan, Kiribati, Laos, Malaysia, the Marshall Islands, the Federated States of Micronesia, Mongolia, Nauru, New Zealand, Niue, the Northern Mariana Islands, Palau, Papua New Guinea, the Philippines, the Republic of Korea, Samoa, Singapore, the Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Viet Nam. According to the share of the over-65 population, the Western Pacific countries are grouped into three categories: young (less than 7% aged 65 or over), ageing (7–13%), and aged (more than 13%) countries.[5,20] The GBD study aggregated deidentified data and the waiver of informed consent was reviewed and approved by the University of Washington Institutional Review Board.[21]

Data sources and definition of CVD

For GBD 2021, the fatal and non-fatal database encompassed substantial epidemiological data from 79,865 data sources identified in 198 previous rounds of the GBD study and an additional 19,055 new data sources identified from 199 literature reviews of the published and grey literature.[19] Multiple data sources included vital registration, verbal autopsy, surveillance,

and other health-related data sources from all countries and territories (Appendix pp 6 and 7, Table S1). Comprehensive source details for these input data are available online via the GBD 2021 Sources Tool from the Institute for Health Metrics and Evaluation website (https://ghdx.healthdata.org/gbd-2021/sources).

This study aimed to describe a comprehensive trend in total CVD and 12 specific types of CVD (rheumatic heart disease, ischemic heart disease, stroke, hypertensive heart disease, non-rheumatic valvular heart disease, cardiomyopathy and myocarditis, pulmonary arterial hypertension, atrial fibrillation and flutter, aortic aneurysm, lower extremity peripheral arterial disease, endocarditis, and other cardiovascular and circulatory diseases). The detailed International Classification of Diseases (ICD) codes mapped to CVD death causes are shown in the Appendix material (Appendix pp 6 and 7, Table S1) and standardized case definitions of CVD can be found in a recent summary publication.[21] Additionally, we combined ischemic heart disease, stroke, and lower extremity peripheral arterial disease to investigate the burden of atherosclerotic cardiovascular disease (ASCVD), which is an essential component of CVD and has major ASCVD risk factors identified as well as prevention guidelines in clinical practice.[22]

Mortality

Vital registration data, verbal autopsy data, and surveillance data for total and specific CVDs were used to model mortality estimates of CVD. All CVD-related mortality and YLLs in the GBD 2021 were estimated using the Cause of Death Ensemble model (CODEm), which is a Bayesian geospatial ensemble regression model used to produce cause-specific fatal burden estimates by evaluating the out-of-sample predictive validity of various statistical models and covariate permutations and then integrating the results of those evaluations. Individual models included in the ensemble are weighted according to performance on out-of-sample predictive validity testing. The YLLs were computed as the number of deaths for each cause-age-sex-location-year multiplied by the standard life expectancy at each age.[18,19,21] The modeling strategy for CVD estimation includes input data standardization, ICD causes mapping, age-sex splitting, garbage code redistribution, noise reduction, and covariates adjustment. Detailed methods for GBD can be found in the Appendix material (Appendix pp 3–8).

Disability-adjusted life-years

DALYs are the sum of YLLs and years lived with disability (YLDs). YLDs were computed as the product of estimated age-sex-location-year-specific prevalence and their corresponding disability weights. The prevalence of most diseases was modeled using the Disease Model-Bayesian meta-regression version 2.1 (DisMod-MR 2.1) which is an epidemiologic state-transition disease modeling tool and generates internally consistent estimates of prevalence, incidence, remission, and mortality by age, sex, location, and year, while enforcing consistency among these various parameters.[21] The detailed methodologies used to estimate YLLs, YLDs, and DALYs have been described in previous GBD studies.[19,23]

Human resources for health

HRH 2019 is the most updated data provided by the GBD 2019 Human Resources for Health Collaborators. We retrieved the annual density (per 10,000 population) of total and 16 categories of HRH between 1990 and 2019 from the GBD 2019 study, for which the input data were derived from the WHO's Global Health Observatory, representative surveys and censuses, and the WHO National Health Workforce Accounts. All available individual-level survey microdata were extracted, including total employment levels and the proportion of employed populations actively working in various occupations. Data from all occupational coding systems were closely mapped to the International Standard Classification of Occupations 1988 (ISCO-88).[8] Spatio-temporal Gaussian process regression was utilized to estimate the density of the HRH from 1990 to 2019.

Sixteen health workers cadres were included in our study: physicians; nurses and midwifery personnel; dentistry personnel; pharmaceutical personnel; clinical officers, medical assistants, and community health workers (CHWs); health-care aides and ambulance workers; medical laboratory technicians; dietitians and nutritionists; optometrists and opticians; audiologists, speech therapists, and counsellors; psychologists; environmental health workers; home-based personal care workers; traditional and complementary practitioners; physiotherapists and prosthetic technicians; and medical imaging and therapeutic equipment technicians. Among the 16 categories of HRH, physicians, nurses and midwifery personnel, dentistry personnel, and pharmaceutical personnel were the four cadres of health workers identified in SDG indicator 3.c,[24] and the GBD 2019 Human Resources for Health Collaborators quantified the national shortages in 2019 concerning the minimum workforce density thresholds required to meet a specified target of 80 out of 100 on the Universal Health Coverage effective coverage index.[8]

Uncertainty of results

In the GBD modeling process, 95% uncertainty intervals (UIs) of estimates were propagated by generating 1000 random draws from the distribution of each metric and taking the 2.5th and 97.5th percentiles of the posterior distribution of the random draws.[18]

Data analysis

Thirty-one countries in the Western Pacific region were ranked by their age-standardized rates of CVD deaths and DALYs in 1990, 2019, and 2021. We reported the

proportion of CVD burden relative to all-cause burden and percentage changes in the number and age-standardized rate of CVD deaths and DALYs for the periods 2019–2021 and 1990–2021 to examine the CVD burden. The trend in CVD burden was assessed using percentage changes: (estimates for CVD deaths and DALYs in the end year—estimates for CVD deaths and DALYs in the start year)/(estimates for CVD deaths and DALYs in the start year) × 100%.

The temporal trend in the HRH density was evaluated using the estimated annual percentage change, which was calculated by fitting the linear regression models as $\ln(\text{HRH density}) = \alpha + \beta \times \text{calendar years} + \varepsilon$, where β denotes the annual change in the natural logarithm of HRH density, and the estimated annual percentage changes (%) and corresponding 95% confidence intervals (CI) were computed as $100\% \times (\exp[\beta] - 1)$. An increasing trend in the workforce density is presented if both the estimated annual percentage change and its 95% CI are greater than zero, while the workforce density shows a decreasing trend if both the estimated annual percentage change and its 95% CI are lower than zero; otherwise, there is no significant trend in the workforce density if the 95% CI includes zero. We also presented the national health worker shortages for the four cadres (physicians, nurses and midwifery personnel, dentistry personnel, and pharmaceutical personnel) at a Universal Health Coverage effective coverage index of 80 in the Western Pacific region in 2019.

The overall relationships between CVD burden and HRH density in 2019 were visualized using scatter plots and data points were fitted through local regression smoothing (LOESS) curves using the "geom_smooth" function of "ggplot2" package. Additionally, the associations between the age-standardized rate of CVD deaths and DALYs and the density of HRH in 2019 were examined using Spearman rank correlation analysis and generalized linear models (GLM). The age-standardized rate of CVD deaths and DALYs was log-transformed to approximate normality and modeled using the "identity" link function in the GLM models. In the univariable model, each health-care workforce variable was individually regressed against the outcomes, while in the multivariable model, all health-care workforce variables were included in a single model.

If two-tailed p values were less than 0.05 or the 95% UIs did not include zero, the results were interpreted as statistically significant. All data analyses and visualizations were carried out using software R version 4.2.2.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Changes in population ageing

In 2021, there were more than 265 million of people aged 65 years and older in the Western Pacific region, accounting for 13.8% of the total population in the region; within 31 countries, Japan (28.9%), Australia (17.0%), the Republic of Korea (16.5%), New Zealand (15.7%), China (13.8%), Singapore (13.4%), and the Cook Islands (13.1%) were aged countries; Guam (12.0%), Niue (11.1%), Tokelau (10.0%), Palau (9.1%), Viet Nam (7.6%), the Northern Mariana Islands (7.4%), Malaysia (7.4%), American Samoa (7.4%), and Tuvalu (7.0%) were ageing countries. From 1990 to 2021, the pace of population ageing accelerated, for example, the proportion of people aged 65 years and above doubled in the Cook Islands, China, Singapore, Japan, and American Samoa, and tripled in the Northern Mariana Islands, the Republic of Korea, and Guam during this period (Fig. 1).

Trends in total CVD

In 2021, CVD caused approximately 6.23 million (95% UI 5.39–7.08) deaths in the Western Pacific region, and the age-standardized rate of CVD deaths was 230.49 per 100,000 (198.34–261.59), accounting for 39.4% (36.1–41.4) of all-cause deaths. The percentage of CVD deaths relative to all-cause deaths was more than 30% in 19 countries in this region (Table 1; Appendix pp 21–30, Tables S3–S5). There were 124.78 million (108.71–141.03) CVD-related DALYs in this region, and the age-standardized DALY rate was 4566.96 per 100,000 (3987.45–5156.95), making up 22.5% (20.1–25.0) of all-cause DALYs. The share of CVD DALYs among all DALYs was more than 20% in 17 Western Pacific region countries (Appendix pp 21–35, Tables S3 and S4, S6). By countries, the largest death number of CVD was 5.09 million (4.31–5.90) in China, while Tokelau had the smallest number of CVD deaths (6 [5–7]; Appendix pp 9, 36–41, Figure S2, Table S7). The highest age-standardized rate of CVD deaths was in Nauru (748.30 per 100,000 [624.69–892.44]) and the lowest was in Japan (72.47 per 100,000 [60.81–78.84]), where the rate was approximately 10-fold lower (Table 1; Appendix p10, Figure S3). Similarly, the number of CVD DALYs varied from the highest of 100.21 million (84.65–116.56) in China to the lowest of 132 (107–159) in Tokelau (Appendix pp 11, 46–54, Figure S4, Table S9), while Nauru had the highest age-standardized DALY rate, at 18,815.35 per 100,000 (15,360.05–23,025.24), and the lowest age-standardized DALY rate was 1650.99 per 100,000 (1498.36–1780.39) in Japan (Appendix pp 12, 55–64, Figure S5, Table S10).

From 1990 to 2021, the Western Pacific region had a significantly increased number of all-cause deaths (46.4% [95% UI 28.0–69.7]) and CVD deaths (94.9% [66.8–129.6]; Appendix p13, Figure S6). Seventeen countries (54.8%) had more than 50% increases in the CVD death number, with the largest increase of 169.4%

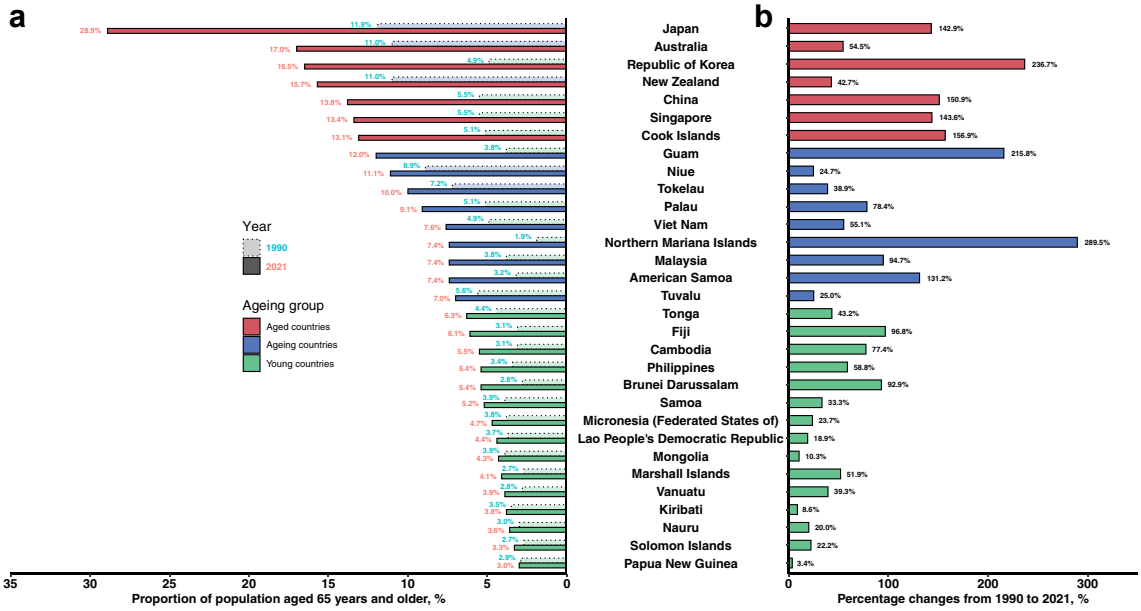

Fig. 1: **Population aged 65 years and older in the Western Pacific countries in 1990–2021**. According to the share of the over-65 population, the Western Pacific countries are grouped into three categories: young (less than 7% aged 65 or over), ageing (7–13%), and aged (more than 13%) countries. The proportion of the over-65 population in 1990 and 2021 (a), and percentage changes in the proportion of the over-65 population from 1990 to 2021 (b).

(131.0–216.0) in the Philippines, while the number of CVD deaths significantly decreased by 23.1% (7.7–36.4) in Niue and 8.5% (4.0–16.8) in Australia. In addition, the proportion of CVD deaths relative to all-cause deaths significantly increased in 17 (54.8%) of 31 countries (Appendix pp 26–30, 36–41, Tables S5, S7). The age-standardized rate of CVD deaths declined in all the member states, with the greatest reduction in the Republic of Korea (–74.0% [–76.9 to –71.6]; Table 1; Appendix p 16, Figure S9). For country rank in the age-standardized rate of CVD deaths, five countries had unchanged ranks, 15 showed upward ranks, while 11 presented downward ranks, while Nauru and Japan steadily ranked first and last, respectively (Appendix p 10, Figure S3). Similarly, this region had an increased number of CVD DALYs (57.3% [34.9–84.5]), and the percentage increases in the number of CVD DALYs were greater than 30% in 19 (61.3%) countries (Appendix pp 21–23, 46–54, Tables S3, S9). Furthermore, the proportion of CVD DALYs relative to all-cause DALYs significantly increased in 20 (64.5%) countries, and the largest rise was in Cambodia (140.0% [102.7–179.5]; Appendix pp 31–35, Table S6). The age-standardized rate of CVD DALYs showed a downward trend in all countries where the Republic of Korea showed the greatest decline (–73.7% [–75.9 to –71.3]; Appendix pp 12, 17, 55–64, Figures S5, S10, Table S10). Between 2019 and 2021, the number of CVD deaths (–12.8% [–17.5 to –7.6]) and DALYs (–9.6% [–14.4 to –4.5]) significantly dropped in Guam, while the age-standardized rate of CVD DALYs increased by 5.8% (0.3–11.9) in Tokelau and 4.8% (0.6–9.5) in Niue (Appendix pp 36–64, Tables S7–S10).

Trends in ASCVD and 12 specific CVDs

In 2021, the number of ASCVD in the Western Pacific region was 5.49 million, with an age-standardized mortality rate of 110.89 per 100,000, and the number of ASCVD DALYs was 109.18 million, with an age-standardized DALY rate of 2945.40 per 100,000. Among the 31 Western Pacific countries, the highest age-standardized rate of ASCVD deaths and DALYs was found in Nauru, while the lowest age-standardized rate of ASCVD deaths and DALYs was recorded in Japan and Australia, respectively. From 1990 to 2021, the number of ASCVD deaths (105.0%) and DALYs (67.6%) increased in the Western Pacific region, with the greatest increase in the Philippines (deaths: 170.5%; DALYs: 160.7%). The age-standardized rate of ASCVD deaths (–37.0%) and DALYs (–36.2%) decreased in this region, where the Republic of Korea showed the greatest decline across countries (deaths: –81.1%; DALYs: –79.1%; Appendix pp 65–70, Tables S11–S13).

For 12 specific types of CVD in 2021, stroke was the first leading cause of CVD in the Western Pacific region, contributing to around 3.10 million (95% UI 2.66–3.54) deaths and 64.53 million (55.68–73.44) DALYs (Fig. 2; Appendix pp 18, 21–23, Figure S11, Table S3). Nationally, stroke was the first leading cause of deaths in

Location	Age-standardized death rate, per 100, 000 (95% UI)						Percentage change, % (95% UI)	
	1990	Rank	2019	Rank	2021	Rank	1990–2021	2019–2021
Western Pacific region	352.24 (315.43–382.84)	–	234.42 (202.71–264.40)	–	230.49 (198.34–261.59)	–	−34.56 (−43.60 to −23.85)	−1.67 (−15.61 to 14.17)
Aged countries								
China	407.72 (361.40–452.12)	18	286.62 (245.77–328.57)	20	280.11 (237.90–323.90)	21	−31.30 (−42.40 to −17.37)	−2.27 (−18.52 to 16.63)
Cook Islands	419.76 (382.85–459.49)	15	247.93 (213.61–285.30)	23	240.40 (202.40–278.63)	24	−42.73 (−51.88 to −31.76)	−3.04 (−7.20 to 0.91)
New Zealand	294.62 (270.21–307.63)	27	124.99 (109.01–133.55)	27	119.10 (102.58–127.78)	27	−59.58 (−62.43 to −57.77)	−4.71 (−6.66 to −2.66)
Australia	277.12 (254.32–288.83)	28	93.67 (80.94–100.34)	28	89.70 (76.75–96.39)	28	−67.63 (−69.85 to −66.25)	−4.24 (−5.66 to −2.93)
Republic of Korea	330.21 (297.63–353.10)	25	85.97 (70.58–95.76)	29	85.94 (70.72–95.93)	29	−73.98 (−76.92 to −71.59)	−0.04 (−2.07 to 2.19)
Singapore	274.96 (259.54–283.54)	29	81.65 (73.46–86.54)	30	75.84 (67.37–80.94)	30	−72.42 (−74.37 to −70.96)	−7.11 (−9.33 to −5.08)
Japan	186.37 (164.86–196.78)	31	74.49 (62.58–80.99)	31	72.47 (60.81–78.84)	31	−61.12 (−63.17 to −59.76)	−2.71 (−3.57 to −1.92)
Ageing countries								
Tuvalu	637.75 (553.78–716.72)	2	513.55 (449.79–589.21)	6	502.80 (440.06–581.61)	6	−21.16 (−31.37 to −9.62)	−2.09 (−6.11 to 1.96)
Niue	483.90 (412.30–565.62)	11	423.97 (358.37–487.54)	10	430.03 (367.51–489.87)	10	−11.13 (−26.61 to 6.81)	1.43 (−1.75 to 4.58)
Palau	475.97 (401.73–561.66)	12	410.74 (350.82–479.98)	12	407.19 (341.67–476.14)	12	−14.45 (−31.39 to 6.42)	−0.86 (−5.51 to 4.15)
Tokelau	509.36 (433.89–591.05)	10	382.97 (313.87–462.47)	14	384.75 (312.77–461.23)	14	−24.46 (−38.19 to −7.13)	0.46 (−3.77 to 4.94)
American Samoa	369.60 (340.11–395.88)	20	338.54 (301.40–380.11)	17	335.69 (295.93–383.59)	17	−9.17 (−21.05 to 4.15)	−0.84 (−4.91 to 3.33)
Viet Nam	342.21 (283.04–418.53)	24	317.96 (271.93–354.94)	19	310.48 (262.18–351.11)	19	−9.27 (−28.39 to 12.96)	−2.35 (−6.79 to 1.64)
Northern Mariana Islands	324.74 (278.25–389.20)	26	285.15 (243.41–328.60)	21	286.93 (255.49–306.36)	20	−11.64 (−27.18 to 3.69)	0.62 (−13.04 to 16.69)
Malaysia	347.08 (325.90–363.47)	23	268.75 (249.92–283.29)	22	267.86 (250.11–282.57)	22	−22.82 (−27.11 to −17.71)	−0.33 (−2.51 to 1.65)
Guam	375.69 (347.63–395.17)	19	225.82 (204.93–245.00)	25	186.15 (166.15–204.39)	26	−50.45 (−54.89 to −45.54)	−17.57 (−22.01 to −12.71)
Young countries								
Nauru	780.02 (651.53–901.41)	1	763.85 (645.15–897.97)	1	748.30 (624.69–892.44)	1	−4.07 (−20.81 to 19.78)	−2.04 (−6.38 to 2.20)
Solomon Islands	610.16 (490.39–726.96)	5	559.03 (470.55–685.45)	2	550.31 (464.37–674.50)	2	−9.81 (−28.11 to 13.75)	−1.56 (−5.95 to 2.83)
Marshall Islands	601.79 (540.59–667.23)	7	556.50 (457.66–667.98)	3	546.75 (446.73–659.37)	3	−9.14 (−25.51 to 9.66)	−1.75 (−5.45 to 1.62)
Vanuatu	606.46 (517.76–718.41)	6	549.41 (471.95–624.18)	4	544.99 (465.73–625.02)	4	−10.14 (−25.87 to 8.57)	−0.81 (−4.60 to 3.32)
Micronesia (Federated States of)	624.63 (521.81–728.29)	3	535.24 (446.01–643.81)	5	531.96 (440.35–646.21)	5	−14.84 (−32.06 to 8.03)	−0.61 (−4.77 to 4.29)
Fiji	521.27 (464.35–590.00)	9	461.48 (384.79–540.40)	7	450.51 (364.44–544.59)	7	−13.57 (−30.61 to 8.15)	−2.38 (−10.20 to 5.94)
Kiribati	447.60 (366.64–519.62)	14	438.38 (373.02–523.24)	8	434.41 (370.13–514.95)	8	−2.95 (−20.22 to 23.47)	−0.90 (−5.18 to 3.26)
Samoa	467.76 (394.20–529.12)	13	436.57 (382.39–505.69)	9	430.44 (371.49–505.28)	9	−7.98 (−21.31 to 11.39)	−1.40 (−5.43 to 2.63)
Lao People's Democratic Republic	610.94 (502.41–717.86)	4	415.82 (341.15–491.60)	11	410.94 (337.22–485.94)	11	−32.74 (−47.46 to −13.09)	−1.17 (−7.30 to 4.39)
Mongolia	585.73 (536.43–634.20)	8	407.13 (364.89–451.40)	13	390.28 (346.56–430.31)	13	−33.37 (−40.75 to −24.82)	−4.14 (−14.52 to 5.57)
Papua New Guinea	413.40 (328.68–515.99)	16	370.41 (299.70–450.04)	15	364.85 (289.02–449.06)	15	−11.74 (−33.89 to 19.06)	−1.50 (−10.81 to 5.94)
Cambodia	411.46 (357.52–479.08)	17	341.70 (281.12–398.23)	16	341.75 (280.99–398.56)	16	−16.94 (−34.23 to 1.77)	0.02 (−5.06 to 4.99)
Philippines	363.23 (337.48–388.74)	21	320.70 (296.34–343.79)	18	315.11 (272.03–359.76)	18	−13.25 (−24.89 to 0.21)	−1.74 (−15.37 to 11.97)
Tonga	260.50 (219.86–298.50)	30	246.23 (205.05–294.38)	24	243.34 (200.03–291.85)	23	−6.59 (−27.49 to 19.63)	−1.17 (−5.29 to 3.23)
Brunei Darussalam	355.05 (322.84–391.63)	22	224.96 (203.01–246.26)	26	198.52 (176.86–222.73)	25	−44.09 (−50.83 to −35.59)	−11.75 (−18.19 to −6.59)

CVD, cardiovascular disease; UI, uncertainty interval. According to the share of the over-65 population, the Western Pacific countries are grouped into three categories: young (less than 7% aged 65 or over), ageing (7–13%), and aged (more than 13%) countries. https://www.weforum.org/agenda/2015/08/what-are-the-economic-consequences-of-rapidly-ageing-populations/.

Table 1: **Age-standardized CVD death rate in the Western Pacific region by member state, in 1990–2021.**

Cambodia, China, Japan, Laos, Papua New Guinea, the Republic of Korea, and Viet Nam, while ischemic heart disease was the major contributor to CVD deaths in the remaining 24 countries in the Western Pacific region. China had the largest death number due to stroke (2.59 million [2.18–3.03]) and Nauru presented the highest age-standardized death rate of ischemic heart disease (432.64 per 100,000 [361.02–517.42]; Fig. 2; Appendix pp 71–154, Tables S14 and S15). Consistently, stroke (in 7 countries) and ischemic heart disease (in 24 countries) also caused the most CVD-related DALYs in this region. China had the largest number of stroke DALYs (53.19 million [45.11–61.96]), and Nauru had the highest age-standardized DALY rate for ischemic heart disease (10,681.95 per 100,000 [8619.33–13,238.75]; Appendix pp 155–244, Tables S16 and S17).

In 1990–2021, the Western Pacific region had growing death numbers for 11 CVDs, except for a decreased number for rheumatic heart disease, while the age-standardized mortality rate of 11 CVD causes

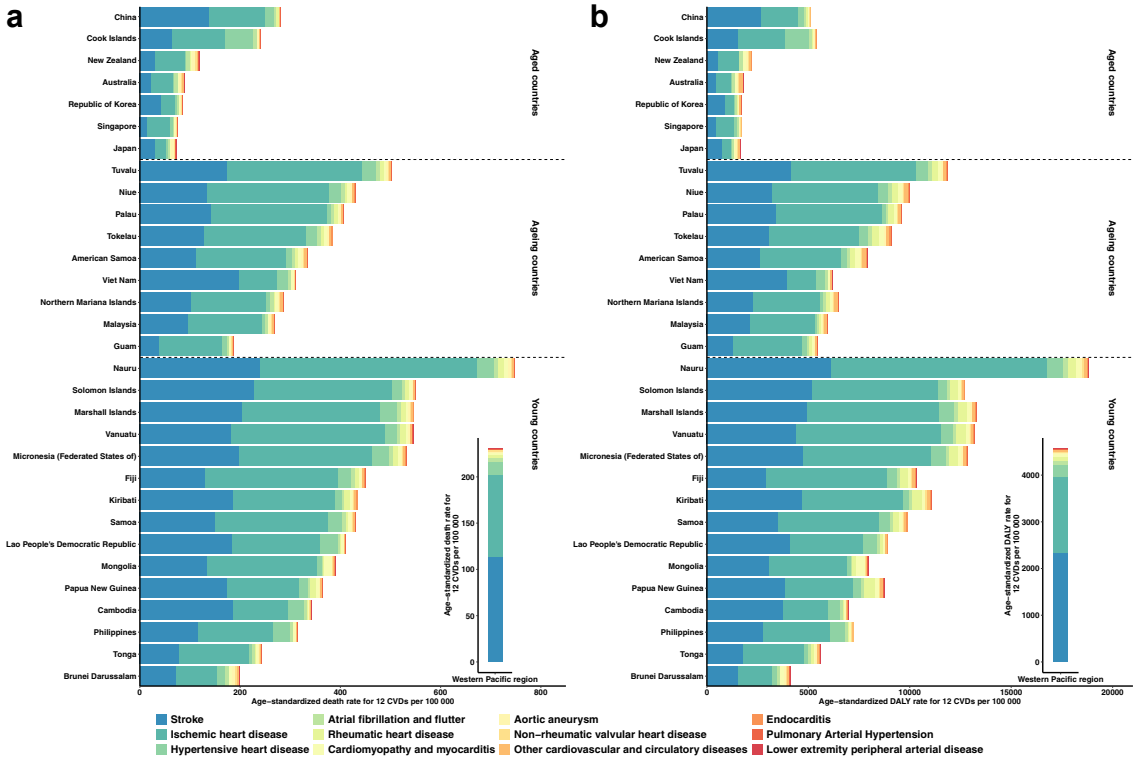

Fig. 2: **Age standardized rate of deaths (a) and DALYs (b) for 12 types of CVD in the Western Pacific region by member state, in 2021.** CVD, cardiovascular disease; DALYs, disability-adjusted life years.

significantly declined with exception of an increase in aortic aneurysm (Appendix pp 21–25, Tables S3 and S4). Across countries, the largest significant increases in death numbers were driven by lower extremity peripheral arterial disease (in 24 countries), endocarditis (in New Zealand, American Samoa, Japan, Australia), atrial fibrillation and flutter (in Cambodia and the Republic of Korea), and aortic aneurysm (in Brunei Darussalam; Appendix pp 71–106, Table S14). Additionally, lower extremity peripheral arterial disease, endocarditis, aortic aneurysm, atrial fibrillation and flutter, and other cardiovascular and circulatory diseases presented significantly increasing trends in the age-standardized mortality rates, with the percentage increases ranging from 14.8% (95% UI 4.4–24.6) for other cardiovascular and circulatory diseases in Australia to 293.6% (116.5–640.8) for lower extremity peripheral arterial disease in Mongolia (Appendix pp 107–154, Table S15). For DALYs, the country-specific increases in the number and age-standardized rate were primarily due to lower extremity peripheral arterial disease, aortic aneurysm, endocarditis, atrial fibrillation and flutter, and non-rheumatic valvular heart disease, where the Northern Mariana Islands had the largest growth in the number of DALYs for lower extremity peripheral arterial disease, increasing by 584.7% (428.7–908.8); the greatest increase in the age-standardized rate of DALYs was due to lower extremity peripheral arterial disease in Mongolia (136.9% [59.9–261.9]; Appendix pp 155–244, Tables S16 and S17). For 12 specific types of CVD in 2019–2021, few significant changes in the number and age-standardized rate of deaths and DALYs were found in the Western Pacific region.

Distribution of HRH

In 2019, the Western Pacific region had 29.8 million employed health workers, including 4.6 million physicians, 7.4 million nurses and midwifery personnel, 1.3 million dentistry personnel, and 1.6 million pharmaceutical personnel. There was an approximately 20-fold difference in the total HRH density across 31 Western Pacific countries, which the total HRH density ranged from 24.24 per 10,000 (95% UI 17.54–33.38) in Papua New Guinea to 483.13 per 10,000 (383.87–610.84) in Australia (Table 2). Generally, for the 16 categories of HRH, Australia and New Zealand were at the highest level of the health workforce, while Papua New Guinea and the Marshall Islands were the least. For example, the density of physician, nurses and midwifery personnel, and the dentistry personnel was lowest in Papua New Guinea, whereas the highest density was in Australia and New Zealand. Sizeable location

Location	Density per 10,000 in 1990 (95% UI)	Density per 10,000 in 2019 (95% UI)	EAPC, % (95% CI)	p value
Aged countries				
China	29.40 (21.14–40.03)	140.23 (103.12–182.50)	5.65 (5.49–5.80)	<0.001
Cook Islands	94.03 (67.60–129.45)	165.19 (123.07–220.05)	2.18 (2.06–2.29)	<0.001
New Zealand	312.68 (249.56–385.97)	471.55 (363.81–594.96)	1.60 (1.52–1.69)	<0.001
Australia	346.87 (285.72–408.32)	483.13 (383.87–610.84)	0.95 (0.84–1.05)	<0.001
Republic of Korea	50.15 (37.80–66.19)	200.52 (157.26–250.76)	5.33 (5.16–5.49)	<0.001
Singapore	106.50 (76.90–140.42)	366.23 (269.30–490.45)	4.97 (4.78–5.16)	<0.001
Japan	198.46 (148.15–264.79)	386.81 (314.84–471.29)	2.47 (2.39–2.55)	<0.001
Ageing countries				
Tuvalu	38.12 (27.77–51.25)	64.15 (46.20–85.53)	1.77 (1.67–1.87)	<0.001
Niue	65.52 (46.04–88.12)	118.76 (86.36–159.94)	2.21 (2.10–2.33)	<0.001
Palau	100.85 (71.64–135.41)	167.35 (120.28–221.58)	1.69 (1.53–1.85)	<0.001
Tokelau	35.48 (25.23–47.31)	87.55 (62.77–116.74)	3.43 (3.27–3.59)	<0.001
American Samoa	83.09 (59.67–110.33)	114.69 (83.12–153.18)	1.08 (0.99–1.18)	<0.001
Viet Nam	21.52 (15.73–28.98)	79.36 (57.50–108.79)	5.20 (4.99–5.41)	<0.001
Northern Mariana Islands	155.43 (114.82–205.13)	198.27 (146.31–260.32)	0.34 (0.05–0.62)	0.027
Malaysia	54.91 (41.71–70.56)	147.26 (108.73–192.97)	3.53 (3.37–3.69)	<0.001
Guam	189.36 (139.40–250.16)	215.37 (160.34–287.12)	0.64 (0.55–0.74)	<0.001
Young countries				
Nauru	51.13 (35.82–68.35)	81.22 (59.26–106.86)	1.56 (1.31–1.82)	<0.001
Solomon Islands	11.46 (8.19–15.70)	42.03 (30.31–55.67)	5.86 (5.33–6.40)	<0.001
Marshall Islands	26.27 (19.06–35.25)	59.09 (42.92–80.77)	3.11 (2.83–3.38)	<0.001
Vanuatu	17.71 (12.88–23.55)	36.32 (26.22–49.33)	2.79 (2.55–3.02)	<0.001
Micronesia (Federated States of)	25.12 (18.24–33.54)	51.69 (36.92–70.87)	3.27 (2.54–4.00)	<0.001
Fiji	44.36 (31.79–60.21)	80.64 (57.55–107.00)	2.35 (2.06–2.63)	<0.001
Kiribati	19.49 (13.82–26.45)	52.45 (38.29–71.27)	3.88 (3.53–4.22)	<0.001
Samoa	23.81 (17.14–32.44)	36.30 (26.52–49.66)	1.23 (1.04–1.42)	<0.001
Lao People's Democratic Republic	18.81 (13.84–25.00)	51.65 (36.62–70.12)	3.86 (3.71–4.02)	<0.001
Mongolia	53.56 (39.97–69.81)	127.94 (107.70–150.99)	3.10 (2.83–3.38)	<0.001
Papua New Guinea	15.86 (11.24–21.99)	24.24 (17.54–33.38)	1.48 (1.32–1.65)	<0.001
Cambodia	21.42 (17.19–26.16)	64.23 (52.72–76.85)	4.67 (4.29–5.06)	<0.001
Philippines	44.12 (35.21–54.64)	65.52 (53.93–77.89)	0.98 (0.75–1.20)	<0.001
Tonga	29.12 (21.23–39.00)	47.06 (33.90–62.34)	1.28 (1.02–1.53)	<0.001
Brunei Darussalam	129.01 (94.06–175.18)	236.72 (172.62–317.24)	2.09 (2.01–2.17)	<0.001

CI, confidence interval; EAPC, estimated annual percentage change; UI, uncertainty interval.

Table 2: **Trends in density of human resources for health in the Western Pacific region by member state, 1990–2019.**

differences also existed in the density of pharmaceutical personnel, ranging from 1.50 per 10,000 (1.02–2.11) in the Marshall Islands to 31.24 per 10,000 (23.30–40.35) in New Zealand (Appendix pp 245–268, Table S18).

From 1990 to 2019, the total HRH density increased across all Western Pacific countries, with the largest estimated annual percentage change of 5.86% (95% CI 5.33–6.40) in the Solomon Islands, while the Northern Mariana Islands had the smallest estimated annual percentage change (0.34% [0.05–0.62]; Table 2). The density of 16 categories of HRH also modestly increased in the Western Pacific region between 1990 and 2019 (Fig. 3).

To meet the Universal Health Coverage effective coverage index of 80 out of 100, the minimum density of four cadres of health workers per 10,000 population was 20.7 for physicians, 70.6 for nurses and midwifery personnel, 8.2 for dentistry personnel, and 9.4 for pharmaceutical personnel.[8] In 2019, 26 (83.9%) countries had a workforce shortage for physicians, as did 22 (71.0%) for nurses and midwifery personnel, 19 (61.3%) for dentistry personnel, and 25 (80.6%) for pharmaceutical personnel, leaving 17 (54.8%) countries with shortages for all four health workers at the same time. Generally, young countries such as, Papua New Guinea, Vanuatu, the Marshall Islands, and Kiribati had the greatest shortages in the four cadre groups (Fig. 4; Appendix pp 269–271, Table S19).

Associations between HRH and CVD

There were negative associations between the density of total HRH and the age-standardized rate of CVD

***Fig. 3:* Density of human resource for health in the Western Pacific region by member state, in 1990–2019**. CHWs, community health workers.

deaths and DALYs in 2019, and the Spearman rank correlation coefficients were –0.74 (95% CI –0.96 to –0.51) for CVD deaths, –0.73 (–0.94 to –0.51) for CVD DALYs, –0.74 (–0.95 to –0.52) for ASCVD deaths, and –0.71 (–0.93 to –0.48) for ASCVD DALYs (Fig. 5). The density of 16 cadres of health workforce was also negatively related to the age-standardized rate of CVD deaths and DALYs, with Spearman rank correlation coefficients ranging from –0.79 to –0.34 for the age-standardized rate of CVD deaths (Appendix p 19, Figure S12) and a range of –0.79 to –0.30 for the relationship between the density of health workers and the age-standardized rate of CVD DALYs (Appendix p 20, Figure S13).

Similarly, there were general negative correlations between specific types of CVD deaths and DALYs and 16 cadres of HRH density, with especially relatively strong associations of rheumatic heart disease, stroke, ischemic heart disease, and pulmonary arterial hypertension with medical laboratory technicians, physical therapists, and personal care workers. However, weakly or moderately positive correlations were also found between 12 CVDs and total and 16 cadres HRH; for example, the age-standardized rates of DALYs due to

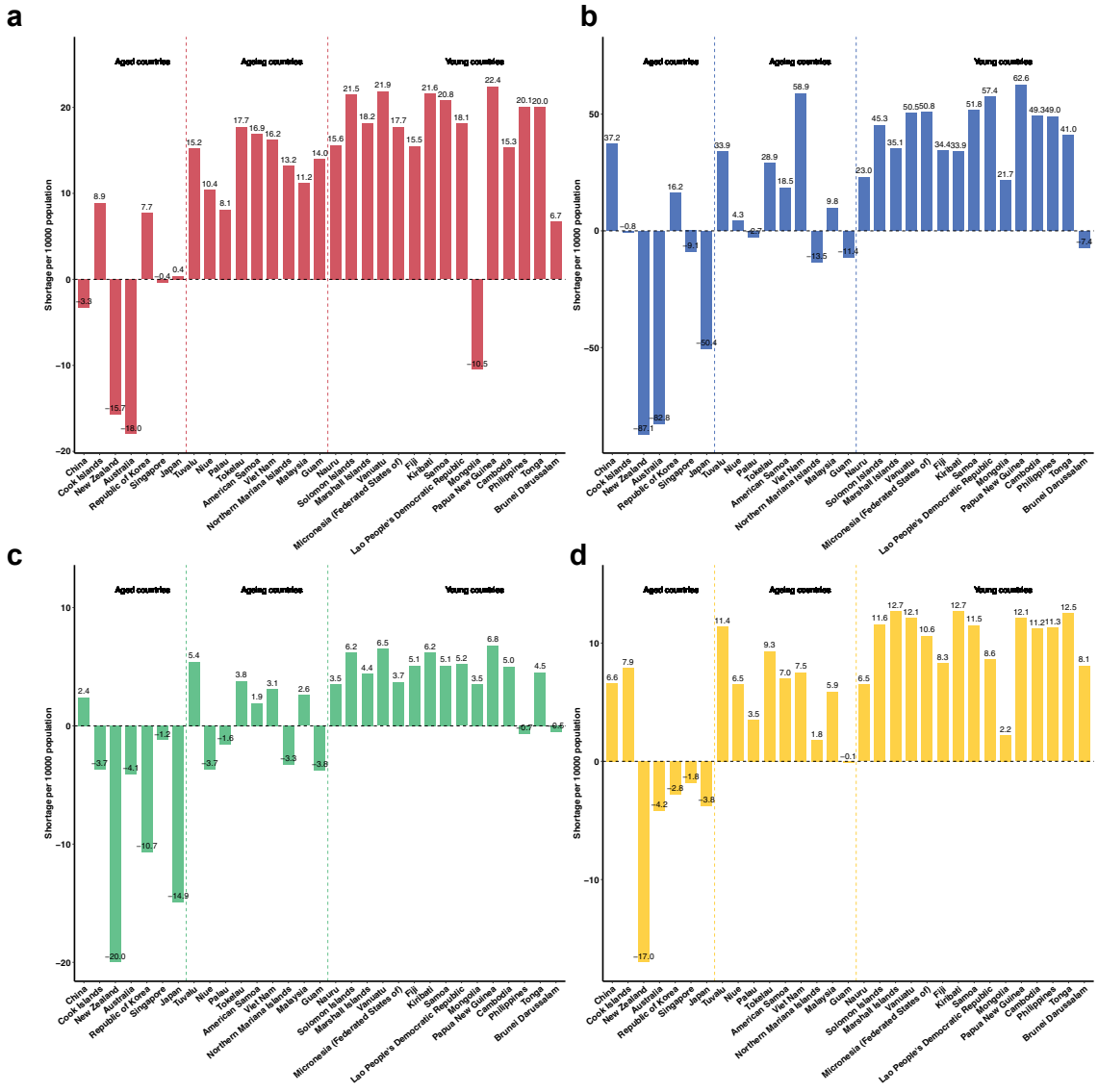

Fig. 4: **Health worker shortages for physicians (a), nursing and midwifery personnel (b), dentistry personnel (c), and pharmaceutical personnel (d) at universal health coverage service coverage of 80 in the Western Pacific region by member state, in 2019.**

lower extremity peripheral arterial disease, aortic aneurysm, and non-rheumatic valvular heart disease were positively related to the density of medical assistants & CHWs, nursing and midwifery personnel, and radiographers (Spearman rank correlation coefficients ranging from 0.36 to 0.57; Appendix pp 272–278, Table S20). In the univariate GLM analysis, the age-standardized rate of CVD deaths and DALYs were generally negatively associated with the density of the 14 selected cadres of HRH, although these associations were mitigated in the multivariable GLM analysis when all 14 health workforce variables were included in a single model (Appendix pp 279–294, Tables S21 and S22).

Discussion

In the past three decades, the pace of population ageing has continued to accelerate in the Western Pacific region, and CVD still caused an unacceptably substantial number of deaths and DALYs in this region in 2021, with stroke and ischemic heart disease as the leading causes. Although this region had an overall improvement in the age-standardized rate of CVD deaths and DALYs since 1990, there have been increasing age-standardized rates for several CVDs, such as aortic aneurysm, lower extremity peripheral arterial disease, endocarditis, and atrial fibrillation and flutter. Despite modest improvements in the health workforce in

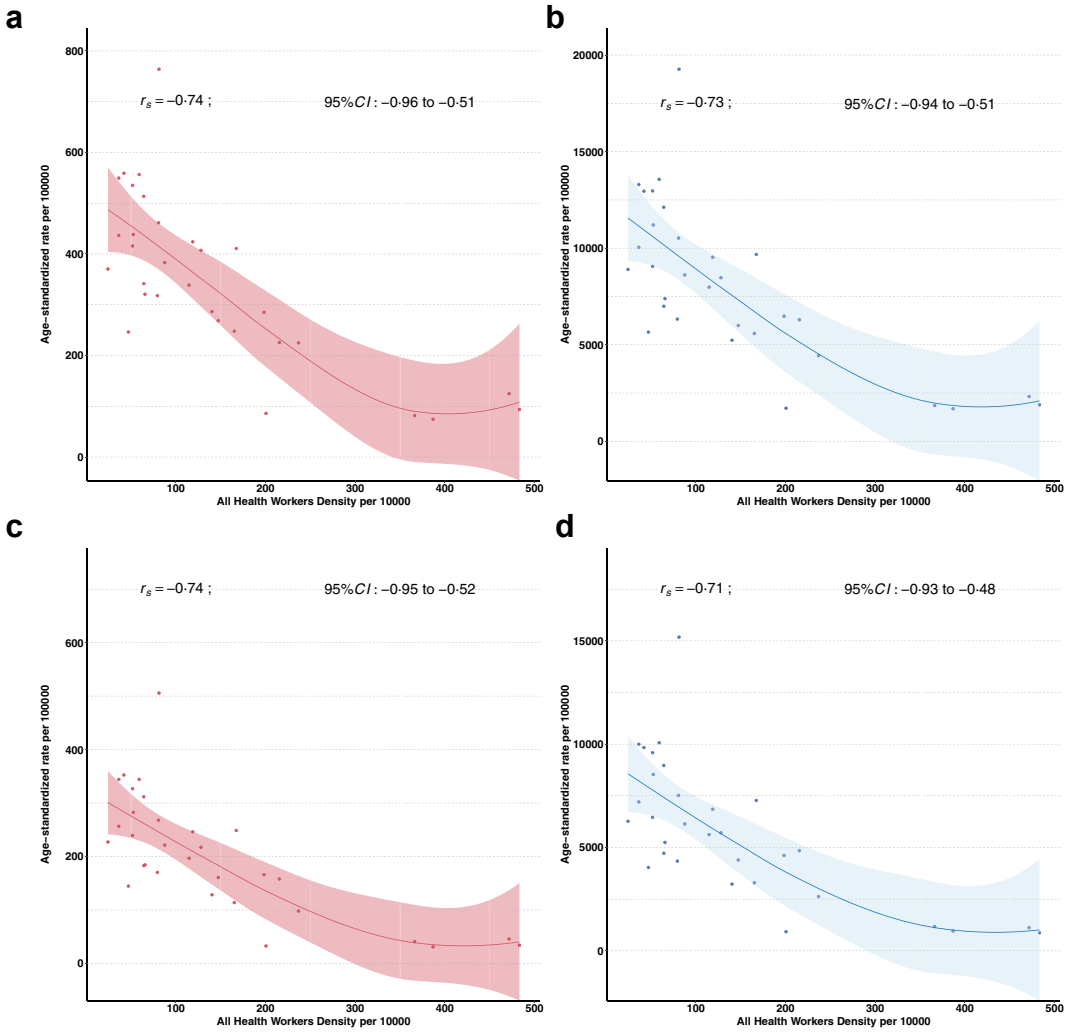

Fig. 5: **Associations of age-standardized rate of deaths and DALYs for CVD (a, b) and ASCVD (c, d) with human resource for health density in the Western Pacific region, in 2019**. ASCVD, atherosclerotic cardiovascular disease; CI, confidence intervals; CVD, cardiovascular disease; DALY, disability-adjusted life years.

1990–2019, approximately 54.8% of the Western Pacific countries failed to meet the Universal Health Coverage needs for the health workforce in 2019. A general negative association between HRH density and the rate of CVD deaths and DALYs suggested that improving the accessibility of health workers was related to a reduction in CVD burden, especially for augmenting dentistry personnel, aides & emergency medical staff, and medical laboratory technicians.

The significantly increasing number of CVD deaths and DALYs indicated that more extensive health resources and services are needed to meet the health-care demands within the Western Pacific region, where China has consistently had the largest number of CVD deaths and DALYs, mainly due to its populous and ageing population. China has been experiencing accelerating population ageing, which highlights the imperative of taking actions to address the unique needs of this vulnerable population. Only Niue, Australia, and New Zealand presented a significantly decreased number of CVD deaths and DALYs. A well-established universal health-care system and strong regulatory capacity in Australia are reasonable explanations, with achievements in the declining rate of tobacco smoking and harmful alcohol consumption over the last 30 years.[25] The population of Niue has emigrated to New Zealand and Australia in recent decades, resulting in a reduced Niuean population,[26] which might contribute to its reduced number of individuals with CVD. However, prevalent non-communicable disease risk factors (e.g., tobacco use, alcohol consumption, poor diet, physical inactivity, obesity, high blood pressure, raised blood

glucose and cholesterol levels) and a relatively high proportion of older people due to outward migration have caused serious threats to the national population and productivity in Niue.[26,27] Health promotion programs and control measures for behavioral risk factors remain crucially important to prevent CVD deaths and DALYs from increasing. Furthermore, the equitable allocation of health-care resources and the cooperation of multi-sectors across all Western Pacific countries further contribute to achieving the vision of making the Western Pacific region the safest and healthiest region.

Although the Western Pacific region has witnessed an overall improvement in the age-standardized rate of CVD deaths and DALYs since 1990, there were approximately tenfold differences between countries in 2021, where Japan had the persistently lowest rates and the highest was in Nauru. Health and clinical interventions for common and critical noncommunicable disease risk factors and public health awareness about healthy lifestyles should be truly implemented to prevent and control CVD in Nauru.[28] Additionally, Nauru, as a single coral island, promoting the availability of fresh food at a reasonable price plays a crucial role in increasing fruit and vegetable consumption. Japan's food and nutrition culture ranks highly alongside its excellent medical care, services, and systems, which account for its reduction in CVD mortality and disability, such as salt-intake reduction, decreased mean systolic blood pressure and smoking prevalence and improvement in medical and surgical treatments for CVD.[29,30] However, a challenge in Japan is that the ageing population and unfavorable levels of body mass index, diabetes, and cholesterol need to be addressed,[29] suggesting that building an optimal population structure and creating conducive environments for adopting healthy behaviors should be national priorities. It is crucial to identify key drivers of CVD mortality and disability and continue to alleviate the CVD burden and narrow the existing health gaps through multilateral collaboration and coordination.

There is a transition from communicable diseases to non-communicable diseases in the Western Pacific region, and ASCVD is still a major contributor of CVD-related disability and mortality. More than 50% of Western Pacific countries had an increased proportion of CVD burden relative to all-cause disease burden over time. Our findings that stroke and ischemic heart disease were the leading causes in the Western Pacific region in 2021, and the age-standardized rate of lower extremity peripheral arterial disease increased in 24 Western Pacific countries especially in Mongolia. During the past three decades, the Western Pacific region has experienced diverse shifts in modifiable risk factors, such as unhealthy diet, physical inactivity, smoking and alcohol consumption, which have shaped the health patterns in this region.[31] Additionally, the increase in lower extremity peripheral arterial disease could also be explained by the underappreciation of lower extremity peripheral artery disease among health care professionals and patients.[32] The prevention of CVD, especially for ASCVD requires interdisciplinary and integrated measures to address cardiovascular health determinants, including behavioral, metabolic, environmental, and social risk factors.[22,33,34] Without reductions in these CVD risk factors, countries in the Western Pacific region still have some way to go before reducing the CVD burden and reaching SDG target 3.4.[35,36] Furthermore, many countries are unlikely to achieve this target due to the impact of the COVID-19 pandemic on health-care services and care-seeking behaviors, especially in low-income and middle-income countries.[37,38]

Despite modest improvements in the health workforce, the number of health workers was still insufficient to meet Universal Health Coverage needs in approximately 54.8% of the countries and noticeable between-country differences existed across the Western Pacific region. Unfortunately, the world is off track to make significant progress towards SDG target 3.8—achieving universal health coverage by 2030, which the global pattern of faltering progress in health service coverage and increasing catastrophic health expenditure is consistent across all regions and most countries at all income levels.[39] While the pace of progress on health service coverage varied across countries, depending on variations in overall health system resilience and reach, consistency and absolute levels of health financing, abrupt or ongoing conflict, and how quickly countries could introduce and scale up newer services or interventions.[40] Our finding showed that Australia and New Zealand were at the highest level of the health workforce, while Papua New Guinea, Vanuatu, the Marshall Islands, and Kiribati had the greatest shortage. The geopolitical conflicts, growing migration of health workers to high-income countries and insufficient investment in health workers' education, lifelong learning, and employment could further threaten the scaling up of the sound primary health-care system. According to the 2023 WHO Health Workforce Support and Safeguards List, the density of doctors, nurses and midwives was below 49 per 10,000 population and the Universal Health Coverage Service Coverage Index was less than 55 in Kiribati, the Laos, the Federated States of Micronesia, Papua New Guinea, Samoa, the Solomon Islands, Tuvalu, and Vanuatu.[41] These countries face the most pressing health workforce challenges and require concerted investment and support to strengthen their primary health care systems and workforce. In our study, there were dramatic shortages in dentistry personnel and pharmaceutical personnel among most Western Pacific countries, even in countries beyond the WHO Health Workforce Support and Safeguards List. Both economic and non-economic measures should be

proposed to address health workforce shortages. Furthermore, a high quality and equal health workforce has long been a priority for addressing critical health personnel shortages.

An overall negative association between HRH density and the rate of CVD mortality and DALYs suggested that augmenting human resources for cardiovascular health could be a critical priority, especially for several non-physical health workers. This finding was consistent with the previous studies.[10,17] The Western Pacific countries generally had the heaviest CVD burden, but they had the least health workforce. Furthermore, a mere focus on doctors, nurses, and midwives is insufficient to address the evolving epidemiological profiles and changing population structure. We found that the density of HRH was negatively related to the rate of CVD deaths and DALYs, which was more evident for specific types of health workers (e.g., dentistry personnel, aides & emergency medical staff, and medical laboratory technicians). For example, a lower CVD burden was more likely associated with an adequate density of aides & emergency medical workers, which might be due to their cooperation with doctors and nurses for the prevention and treatment of CVD. Previous studies indicated that a better level of health outcomes was associated with a higher density of medical doctors or nursing & midwifery personnel,[10,11,13,14,16] but these studies might underappreciate other HRH categories. Apart from the largest number of doctors and nurses in most countries, our study suggested that investment in the omitted categories of health workers can be expected to contribute even more to the alleviation of CVD burden. While rheumatic heart disease may need more support from primary care providers and field nurses, ASCVD such as stroke and ischemic heart disease need more secondary and tertiary care. Overall, the global strategy on HRH should also highlight the importance of diverse health personnel and interdisciplinary measures to improve long-term cardiovascular health for the whole population.[9,22]

Our study used the best available and robust estimates from the GBD 2021 to explicitly report CVD mortality and DALYs in the Western Pacific region. Moreover, we also highlighted that improving the accessibility and equality of health workers was related to decreasing the fatal and non-fatal burden of CVD. However, this study had several limitations. First, the original data sources and the validity and reliability of the predictive models account for the quality and quantity of the GBD estimates. Given that the availability and completeness of vital registration and verbal autopsy data from specific countries and periods might influence the accuracy of the GBD estimates, countries and territories with scarce input data should establish high quality databases to help conduct more comprehensive and rigorous research. Second, the estimate of HRH densities might be inaccurate based on self-reported data sources because of response bias or miscoding by interviewers; additionally, the roles and responsibilities among different health workers can overlap and the requirement of one category of health work might compensate for another category at a relatively higher density; therefore, the true workforce demands are likely to be underestimated when interactions between diverse health staff are omitted. Third, the density of total and 16 categories of HRH was retrieved from the GBD 2019, which precludes a direct comparison of HRH before and after the pandemic and might overlook the negative impact of the COVID-19 pandemic on the health workforce. COVID-19 has caused long-standing shortages of health workers due to increasing demand for health workers and the loss of health workers related to COVID-19.[42] Therefore, current shortages in health care are likely even greater than our estimation. Fourth, our analysis did not adjust for other important cardiovascular health determinants, such as behavioral, metabolic, and socioeconomic risk factors, so our study neither fully accounted for other environmental risk factors for CVD nor drew causal inferences from these findings due to the nature of the ecological study. Finally, the substitutability or complementarity between various types of health staff was not adequately investigated in our study. It is important to explore the interactions between different health workers because diversity in the health workforce provides an opportunity to strengthen the effect of HRH on human health.

From 1990 to 2021, despite decreases in the age-standardized rate of CVD deaths and DALYs, the Western Pacific region was at an accelerating pace of ageing, with an increasing number of CVD deaths and DALYs. The health workforce is still inadequate to meet universal health coverage needs, although there are steady improvements. The negative association between the density of HRH and the burden of CVD suggests that augmenting human resources for health should be a critical priority to address the inadequate accessibility and maldistribution of the health workforce and reduce the CVD burden in the Western Pacific region.

Contributors

ZZ and YS conceptualized the study. HW drafted the manuscript. ZZ and YS had access to and verified the data. HW provided the analysis, YH, YS, and ZZ helped in the interpretation of results. ZZ and YS obtained the funding. XY, JG, SM, YL, YH, JL, YS and ZZ contributed to reviewing and finalizing the manuscript. ZZ and YS had final responsibility for the decision to submit for publication. All other authors reviewed results, provided guidance on methods, or reviewed and contributed to the manuscript. All authors approved the final version of the manuscript.

Data sharing statement

All data in this study are publicly available through the GBD 2021 portal, please visit the website at https://vizhub.healthdata.org/gbd-results/

Declaration of interests
We declare no competing interests.

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Appendix A. Supplementary data
Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2024.101195.

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