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REVIEW

Prevalence of osteoporosis and incidence of related fractures in developed economies in the Asia Pacific region: a systematic review

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Abstract

Summary Robust data on osteoporosis in the Asia Pacific region could improve healthcare decision-making. Osteoporosis affects 10–30% of women aged 40 + , and up to 10% of men in 7 developed economies in Asia Pacific. Fractures affect 500–1000 adults aged 50 + per 100,000 person-years. Policymakers and clinicians must address this problem.

Purpose Osteoporosis and associated fractures result in considerable morbidity, loss of productivity, early mortality, and increased healthcare expenses. Many countries in the Asia Pacific (AP) region, especially middle- and higher-income economies, are faced with aging and increasingly sedentary populations. It is critical to consolidate and analyze the available information on the prevalence and incidence of the disease in these countries.

Methods We systematically reviewed articles and gray literature for Australia, China, Hong Kong, Japan, Singapore, South Korea, and Taiwan. We searched PubMed, ScienceDirect, JSTOR, Cochrane, Google Scholar, and other databases for data published 2009–2018. We included articles with prevalence or incidence estimates for adults with osteoporosis or related fractures.

Results All locations had data available, but of widely varying quantity and quality. Most estimates for osteoporosis prevalence ranged from 10 to 30% for women ages 40 and older, and up to 10% for men. Osteoporotic fracture incidence typically ranged between 500 and 1000 per 100,000 person-years among adults aged 50 and older. Both outcomes typically increased with age and were more common among women.

Conclusion Osteoporosis and associated fractures affect significant portions of the adult population in developed economies in the AP region. Governments and healthcare systems must consider how best to prevent and diagnose osteoporosis, and manage affected individuals, to reduce healthcare costs and mortality associated with fractures.

Keywords Ethnicity · Fracture · Osteoporosis · Asia Pacific · Fragility fracture

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Introduction

Osteoporosis and associated fractures cause significant morbidity and mortality and represent a major source of non-communicable disease burden and healthcare resource utilization around the world.

The Asia Pacific (AP) region is comprised of South Asia, South-East Asia, East Asia, and Oceania. An audit conducted in 2013 by the International Osteoporosis Foundation (IOF) encompassing 16 countries revealed a dearth of epidemiological information on osteoporosis and related fractures in the AP region [1]. In addition, only about one-fourth of the countries in the audit considered osteoporosis a national health priority, despite the burden of the disease and related fractures placed on healthcare institutions, reimbursement services, and patients. The number of people affected by osteoporosis and related fractures in this region is expected to rise significantly in the coming decades, largely due to the region's aging population, increasing urbanization, and its associated sedentary lifestyles. By 2050, more than 50% of the world's osteoporotic fractures are expected to occur in Asia, which will strain healthcare and government resources, especially considering the significant shortcomings in the quality and availability of health services for osteoporosis and related fractures currently present in many AP nations [1].

Since many individuals with poor bone health are still of working age and actively contributing to these countries' economies, lost productivity and increased healthcare expenditures caused by preventable disease, fractures, and even deaths may become a heavy economic and societal burden. About one in four individuals suffering a hip fracture dies within a year, and other fragility fractures are also associated with premature mortality. Osteoporosis is more common in women, but its impact on health and survival is more marked in men than in women [2, 3].

Professional and health service organizations in the region are increasingly taking note of the importance of addressing osteoporosis and related fractures on a large scale. Organizations such as the Asia Pacific Consortium on Osteoporosis (APCO) and the IOF are working to highlight the economic, social, and health impact of osteoporosis and related fractures in the AP region. The knowledge and support of these organizations are available to provide governments the information and guidance they may need to craft action plans, data acquisition efforts, healthcare reimbursement policies, and more.

Though the governments of some of the more developed economies in the region have begun to recognize osteoporosis as a healthcare priority, a lack of in-depth understanding of the impact that osteoporosis and related fractures have on populations, healthcare systems, and the economy still exists. It is therefore crucial to gather data on the epidemiology of the disease in these locations to mitigate this gap in knowledge.

The objective of this systematic literature review was to obtain location-specific, epidemiological estimates of the prevalence and incidence of osteoporosis and related fractures in seven upper-middle- and high-income economies in the AP region: Australia, China, Hong Kong, Japan, Singapore, South Korea, and Taiwan. Estimates from any age, sex, or ethnicity group were of interest, provided the studies included at least one study arm considered reasonably representative of the broader population from which they were selected. The findings can be used by the governments of these countries and regions to inform policies or strategies for addressing poor bone health and its related societal burden.

Methods

This study was conducted according to the Cochrane review methodology for systematic literature reviews (version 5.1.0) [4] with some adaptations to allow for the emphasis on observational/epidemiological studies and the inclusion of non-academic gray literature, foreign-language database searches, secondary data, and general Internet searches. The PRISMA Checklist for systematic reviews guided protocol creation [5].

Study eligibility

Studies were included based on predetermined criteria using the PICOS design (see Table 1), in order to obtain estimates that may reasonably reflect the prevalence or incidence of osteoporosis and related fractures from the broader populations from which the study participants were drawn.

Search terms and database selection

Data sources selected included PubMed, ScienceDirect, the Cochrane Database of Systematic Reviews, JSTOR, and Google Scholar. To capture data and reports of osteoporosis and fractures from public health agencies or organizations that may have published on prevalence and incidence outside of formal academic literature, such as in government reports, we also conducted a review of gray literature via country-specific Google search pages and special-interest websites from a preselected list of regional health organizations, journals, and advocacy groups.

The guiding Boolean search string for each database, customized according to the country/location and as needed for database search limitations, was as follows:

Table 1 PICOS summary criteria for article inclusion

PICOS criterion	*Key inclusion criteria*
Population	• Adults with osteoporosis or related fractures. The locations included in this report represent a subset of the 27 locations searched as part of a broader research effort for the AP region. Due to the volume of results obtained, only seven locations are reported here (Australia, China, Hong Kong, Japan, Singapore, South Korea, and Taiwan) to represent many of the region's most developed economies. Data for the remaining locations were more limited but may be published elsewhere and are available from the study sponsor by request
Intervention/comparators	• All intervention and comparator studies unless the comparator arms had no group that was potentially representative of the general population (e.g., a control arm)
Outcomes	• Incidence and prevalence of osteoporosis and related fractures; the conditions could be self-reported or medically diagnosed • Related fractures were any broken or fractured bones associated with osteopenia or osteoporosis, including stress, compression, hairline and other fractures formally diagnosed or empirically treated; self-reported fractures were also included. Fractures or bone loss specifically attributed to another medical condition were excluded
Study types	• Observational or epidemiological study published 2000–2018 • Intervention study with a minimally restricted or general population control arm published 2000–2018 • Conference abstracts or posters from professional societies published 2016–2018 • Gray literature, such as professional society or government health organization reports, policies or guidelines, fact sheets, database statistics reports, or web content, published 2000–2018

Abbreviations: *AP*, Asia Pacific

*(osteoporo** OR *bone density* OR *bone loss* OR *fragility* OR *low-trauma)* AND *(inciden** OR *prevalen** OR *fracture** OR *annual* OR *rate* OR *epidemiol*)* AND COUNTRY

Study selection and data abstraction

Studies were reviewed and selected in two phases (see Fig. 1).

In phase one, two reviewers separately reviewed titles/abstracts divided by locations and applied inclusion/exclusion criteria. If a reviewer was uncertain, the two reviewers consulted each other and, if needed, discussed the article with the lead data reviewer (author KB) for a final decision on inclusion. In phase two, two reviewers independently reviewed all full-text articles, compared their decisions to align on any articles with mismatched selection status, and consulted the lead reviewer as needed for questions or final decisions. Translations were not obtained for the small number of non-English resources.

One reviewer extracted all data from the papers selected for inclusion and subsequently scored each included article for quality according to the criteria in the National Heart Lung and Blood Institute's (NHLBI) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [6]. NHLBI quality scores were recorded for each article and considered in interpretation of the findings. Quality assessment checks of the data and study quality categorizations were made by the lead data reviewer (author KB) at least once at each step.

Data sought included location/country, sex, age, and other pertinent population details; year(s) in which the research was conducted; densitometry technology used for diagnosis of osteoporosis, criteria, and anatomical location of screening (heel, spine, hip, etc.); study type (longitudinal, review, cross-sectional, etc.); and estimates provided for prevalence of osteoporosis or incidence of related fracture, by body site. Summary tables were developed to provide location-specific ranges of osteoporosis prevalence and hip and vertebral fracture incidence by age group and sex.

Results

Full-paper distribution by country

All seven locations had results for both osteoporosis and related fractures. The final full-text article count was 316; some papers covered more than one place or provided data for both disease prevalence and fracture incidence. Table 2 shows the final distribution of articles covering each type of data for each location.

Figures 2,3, 4, 5, 6, 7, and 8 display graphical summaries of osteoporosis prevalence and fracture incidence in each location. Study characteristics, quality assessments, and summary results for studies reporting osteoporosis prevalence can be found together in location-specific tables (Tables 3, 4,5, 6,7,8, and 9, Appendix). Tables 10, 11, 12, 13, 14, 15, and 16 in the Appendix provide location-specific study characteristics, quality assessments, and reported results for studies reporting osteoporotic fracture incidence. The complete citation list for the 316 articles that underwent data extraction can be found in the Appendix.

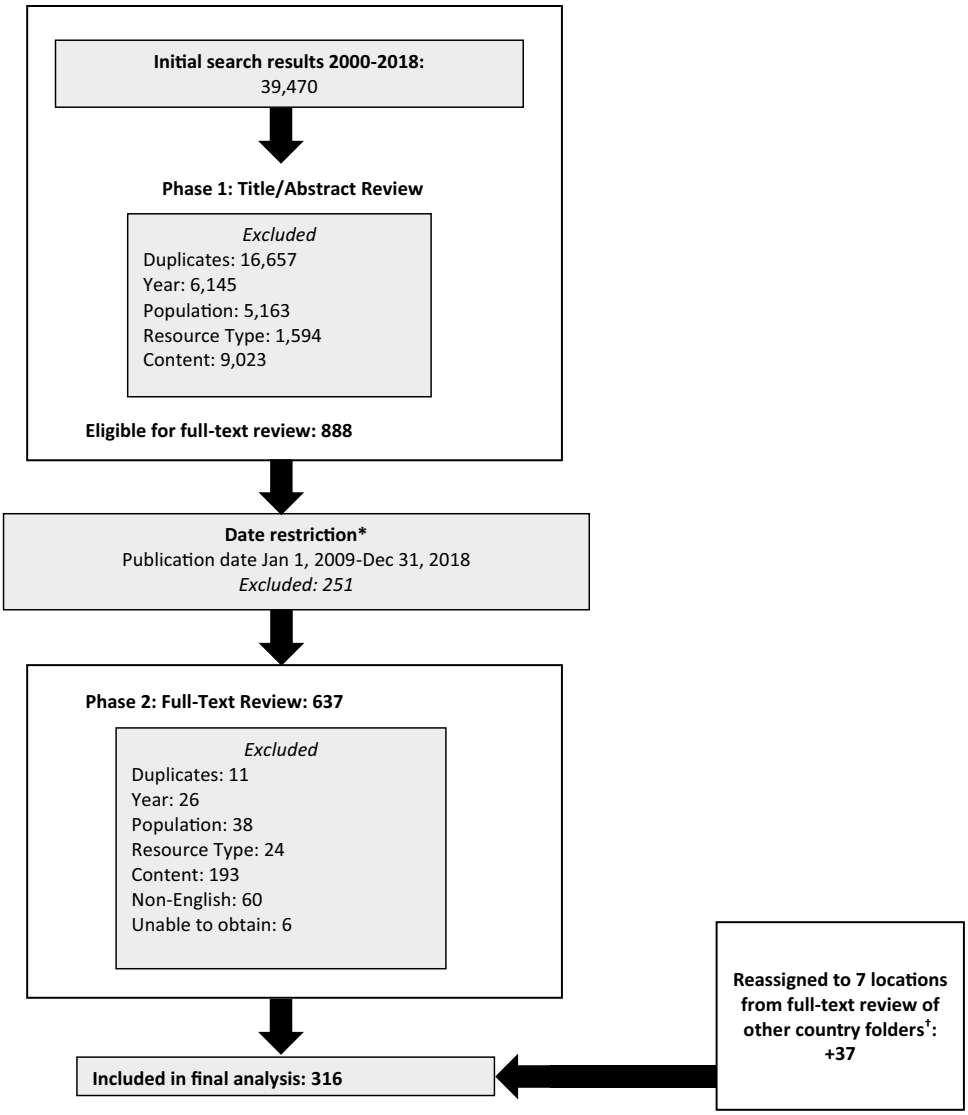

Fig. 1 Study selection flowchart. *Due to volume of results and budget limitations, the results were restricted to 2009 onward (2016 onward for posters) for full-text review. †Because this review was part of a broader study of 27 locations in the AP region, some articles were initially obtained and filed in folders for other locations; full-text review revealed 37 articles originally connected with other locations that included data relevant to the seven locations of interest for this manuscript

Table 2 Articles included by location for each outcome

Country	Final osteoporosis prevalence article count	Final fracture incidence article count
Australia	20	24
China	61	46
Hong Kong	15	31
Japan	19	46
Korea	59	45
Singapore	7	19
Taiwan	53	22
Total	**234**	**233**

Australia

Total population estimates suggested that 3.5% of all Australians have osteoporosis [7], with the number rising to 8.8–10% among those aged 50 + [8, 9]. In women aged 50 +, prevalence of osteoporosis ranged from about 15–23% [9, 10], with estimates of more than 40% among the female population aged 60 + [11, 12]. There were few estimates for men and younger adults. Fracture incidence also appeared to rise with age; hip fracture incidence was frequently in the 100 s-500 s per 100,000 person-years for most adults aged 50 + [13–16], with estimates topping 1,000 and 2,400 among adults in their 70 s and 80 s, respectively [16, 17]. Estimates for general osteoporotic fractures suggested an annual incidence of 1000–6500 per 100,000 person-years [11, 18, 19].

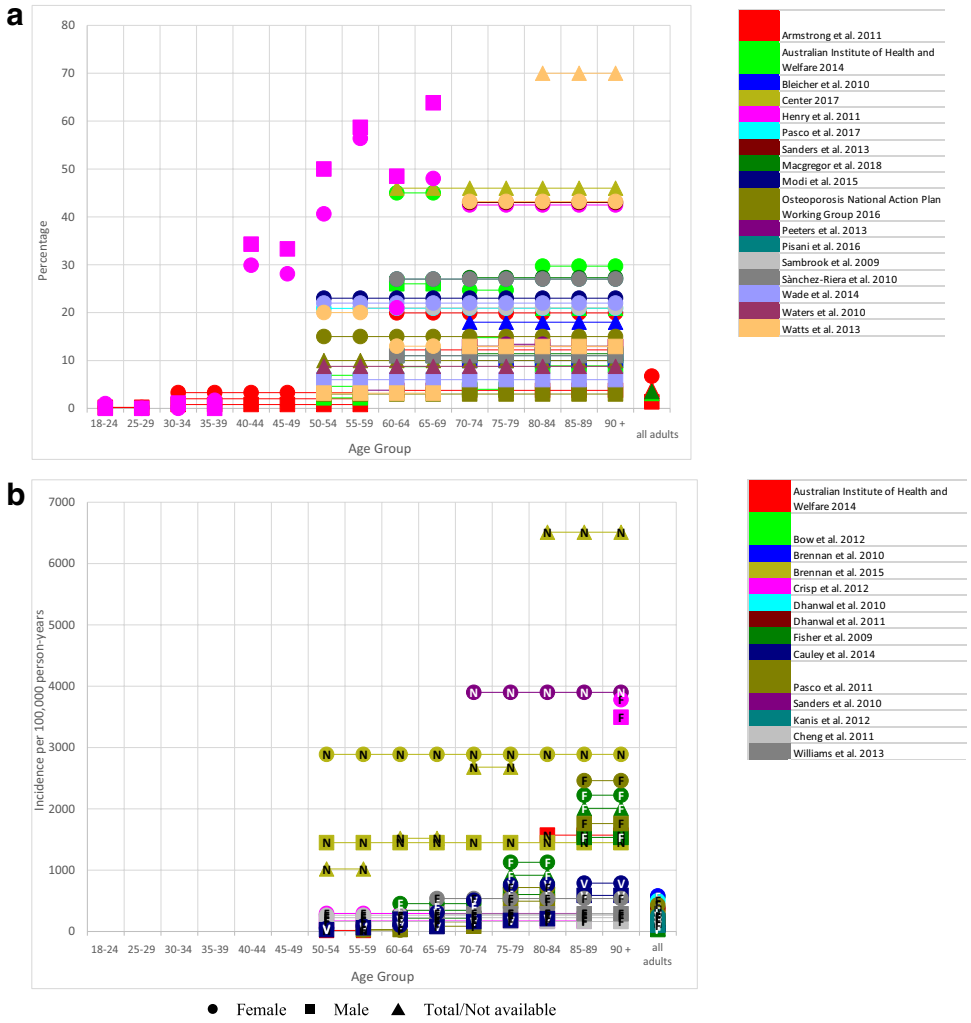

Fig. 2 **a** Australia osteoporosis prevalence. **b** Australia fracture incidence per 100,000 person-years. Connected lines represent "estimated" data reflecting findings for broad age ranges (e.g. 60–75, 50 +); these data were noted as linked data points for all age categories included in the reported range. Each color represents a single study. "All adults" represents generalized data describing broad populations without specified age groups (e.g. "Five percent of Australian men have osteoporosis"). Full citations for articles not cited in-text can be found in the Appendix. Circle = female; square = male; triangle = total/not available. *F*, femoral neck/hip; *V*, vertebrae/spine; *W*, wrist/forearm; *H*, humerus; *M*, multiple; *O*, other; *N*, not specified/general fragility fractures

China

True prevalence of osteoporosis was difficult to discern due to a wide range of estimates, many of which covered large age ranges. Among young women (< 40 years), the rate appeared to be less than 10% [20–22]. Estimates rose with age [20, 23, 24]; among women aged 70 +, no estimate was lower than 10%, and the majority were 20% or higher (with some approaching 80%) [25–29]. Most prevalence estimates among men were below 15% [20, 23, 26, 30, 31], although numerous estimates placed prevalence above 20% among men aged 40 + [25, 32–34]. Studies with narrow age ranges for fracture incidence demonstrated a clear rising trend for fragility fractures with advancing age [23, 35–37]. Most estimates placed incidence of fragility fractures of the hip at less than 500 per 100,000 person-years [35–39], although one study suggested the rate surpasses 1500 and 2400 per 100,000 for men and women aged 50 +, respectively [40].

Hong Kong

Hong Kong literature offered very few data on adults younger than 50 years [41, 42], and data on older individuals showed a wide range of osteoporosis prevalence, even among the oldest adults [43, 44]. However, point estimates for narrow age ranges suggested rising prevalence with age [45]. Otherwise, most prevalence estimates were below 15% for men and below 35% for women [43, 46, 47]. Fracture incidence data showed a more obvious trend for increases with age, with numerous estimates between 1000 and 3000 per 100,000 for hip fractures among adults aged 65 + [37, 49–51]. However, most estimates for vertebral, hip, or other fragility fractures in Hong Kong adults aged 50 + were less than 1000 per 100,000 person-years per fracture type [14, 38, 51–53].

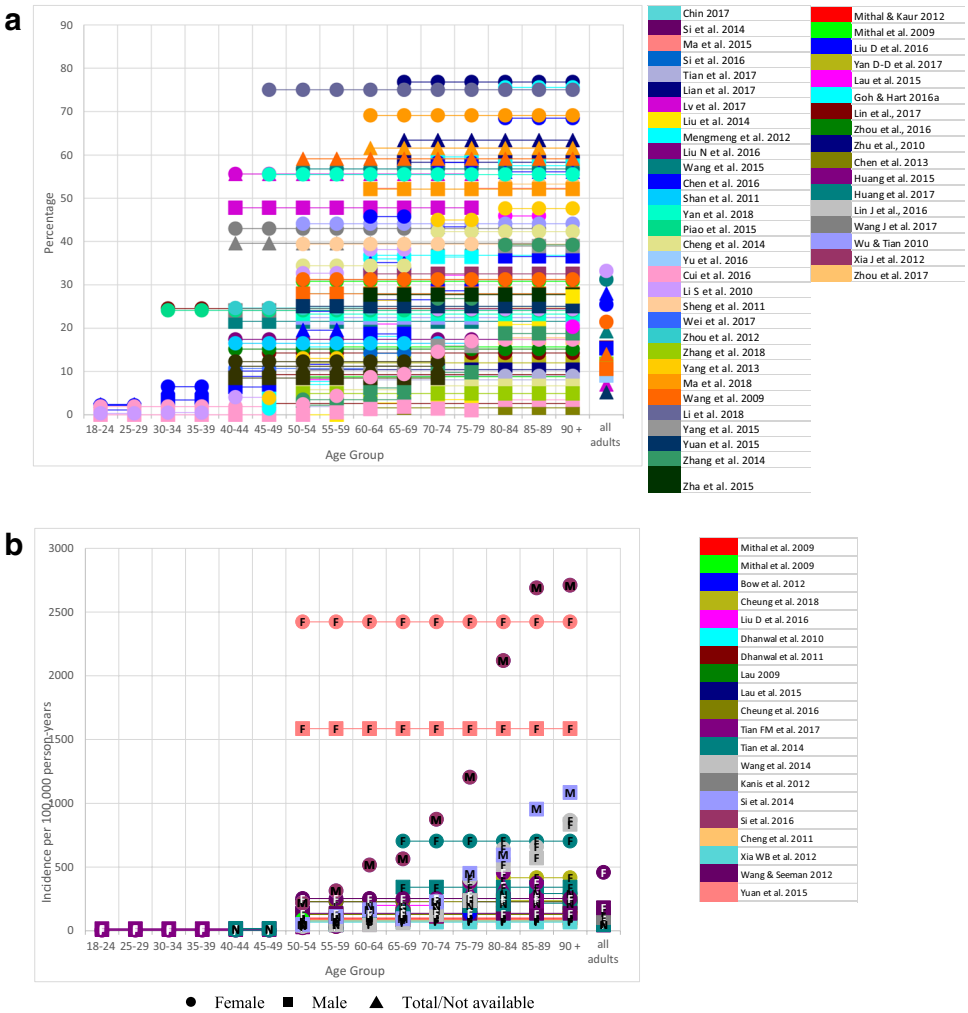

Fig. 3 **a** China osteoporosis prevalence. **b** China fracture incidence. Connected lines represent "estimated" data reflecting findings for broad age ranges (e.g. 60–75, 50 +); these data were noted as linked data points for all age categories included in the reported range. Each color represents a single study. "All adults" represents generalized data describing broad populations without specified age groups (e.g. "Five percent of Australian men have osteoporosis"). Full citations for studies not cited in-text can be found in the Appendix. Circle = female; square = male; triangle = total/not available. *F*, femoral neck/hip; *V*, vertebrae/spine; *W*, wrist/forearm; *H*, humerus; *M*, multiple; *O*, other; *N*, not specified/general fragility fractures

Japan

Osteoporosis prevalence appeared to be low among men across most age groups, with most estimates at or lower than 5% until ages 70 + [54–57], at which point most estimates still suggested prevalence lower than 15% [54, 55, 58]. Prevalence among women trended higher than among men in every age group and also appeared to increase with age [54, 55, 58, 59], although few estimates were found for women under 50. Broad age group estimates of 40 + or 50 + had a wide prevalence range as well, from 5.8% to more than 40% [60, 61]. Narrower age group prevalence estimates suggested that after the age of 50, prevalence (starting below 10% in ages 50–59) grew 10–20% with each decade of life [54, 55]. Femoral neck fracture incidence also varied considerably (with several estimates below 500 per 100,000 person-years for both men and women aged 50 +) [62–64] but appeared to increase with age, surpassing 1300 per 100,000 person-years in women by age 80 + [37, 49]. Vertebral fractures may be similarly frequent among women and lower than 500 per 100,000 person-years for men [65, 66].

Singapore

Data on osteoporosis prevalence were limited and differed in their estimates, with one suggesting 8.5% prevalence among all adult men [67], one reporting 6.8% prevalence among women aged 45–69 [68], and two others of 35.7% and 59% among all adults aged 60 + [69, 70]. Nearly all femoral neck fracture incidence articles reported rates of 611 or fewer per 100,000 person-years for men and women aged 45 + [38, 63, 71–73], although a few estimates for women aged 75 + were much higher (up to 1369 per 100,000 person-years) [14, 37].

South Korea

Prevalence of osteoporosis appeared to rise with age among Korean women [74–77], with numerous estimates higher than 50% in age groups 60 + [77–79]. Wider age group estimates largely ranged between 20 and 45% for women aged 40 + and 50 + [80–84]. Most estimates for men suggested a prevalence of 15% or lower [80, 85–87], although some ranged from 20% to more than 40% for men aged 70 + [75,

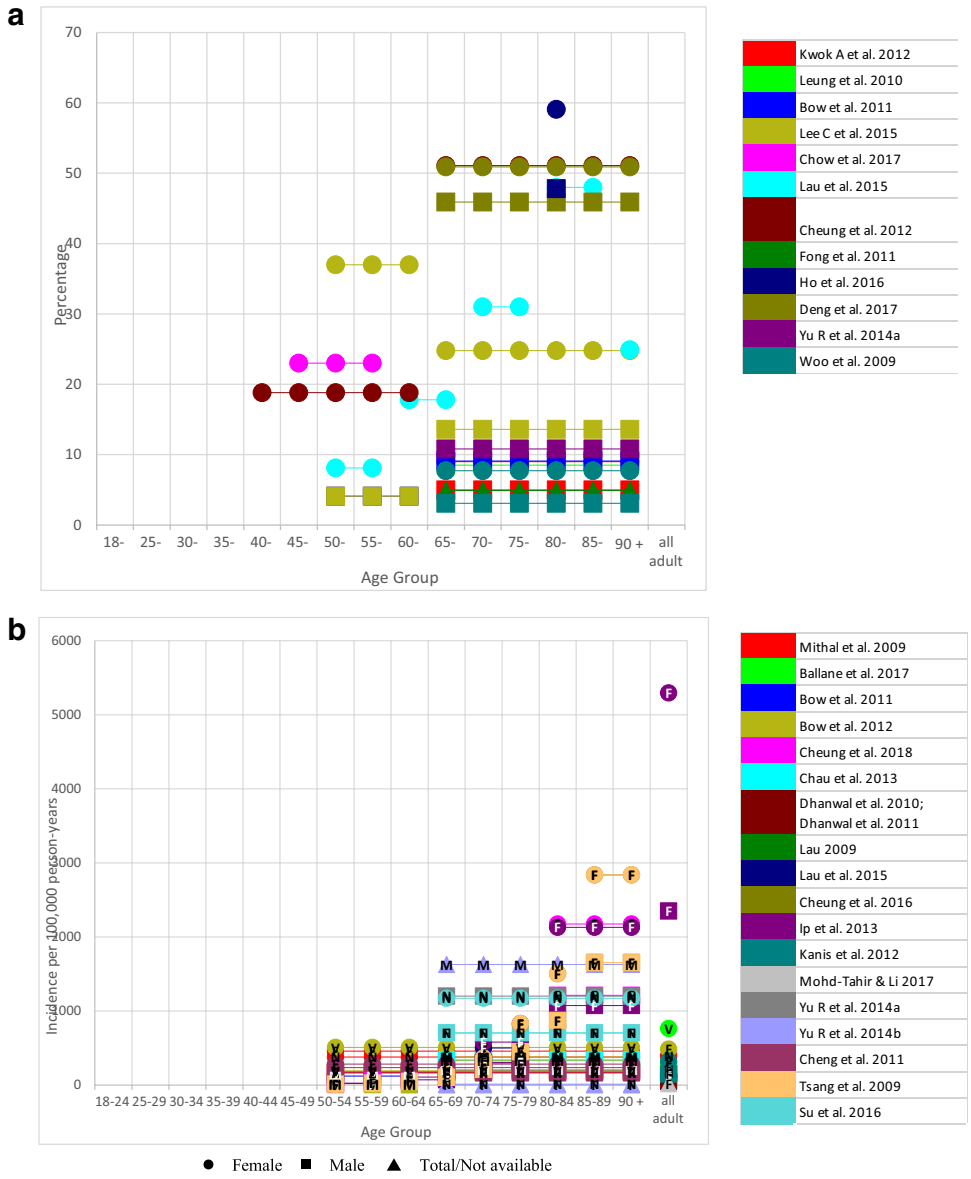

Fig. 4 **a** Hong Kong osteoporosis prevalence. **b** Hong Kong fracture incidence. Connected lines represent "estimated" data reflecting findings for broad age ranges (e.g. 60–75, 50 +); these data were noted as linked data points for all age categories included in the reported range. Each color represents a single study. "All adults" represents generalized data describing broad populations without specified age groups (e.g. "Five percent of Australian men have osteoporosis"). Full citations for studies not cited in-text can be found in the Appendix. Circle = female; square = male; triangle = total/not available. *F*, femoral neck/hip; *V*, vertebrae/spine; *W*, wrist/forearm; *H*, humerus; *M*, multiple; *O*, other; *N*, not specified/general fragility fractures

77, 88]. The vast majority of fragility fracture incidence data suggested site-specific and combined rates below 500 per 100,000 person-years [37, 38, 89–91], although numerous estimates between 500 and 1000 per 100,000 and even higher were also found, especially for individuals aged 80 + [92–97].

Taiwan

The osteoporosis data for Taiwan were many and varied, but the majority of "all adult" estimates suggested a general population prevalence of 16% or lower [98–101]. Prevalence rose with age, especially among women [102–105], with numerous estimates suggesting 45% or more of all women aged 60 + or 65 + had osteoporosis [105–108]. The majority of the femoral neck fracture incidence estimates encompassed a wide age range (50 +) and suggested a rate of about 500 or fewer per 100,000 person-years [63, 109–111]. However, several estimates, particularly for those aged 70 + or 80 +, suggested an incidence closer to 1,500 or more per 100,000 person-years, even for men [37, 49, 112]. The data also suggested a general fragility fracture incidence of 1500 or more per 100,000 person-years among Taiwanese adults aged 50 + [99, 113].

Discussion

In total, 316 papers were obtained discussing at least one of the two primary outcomes of interest, providing a detailed overview of the prevalence and incidence of

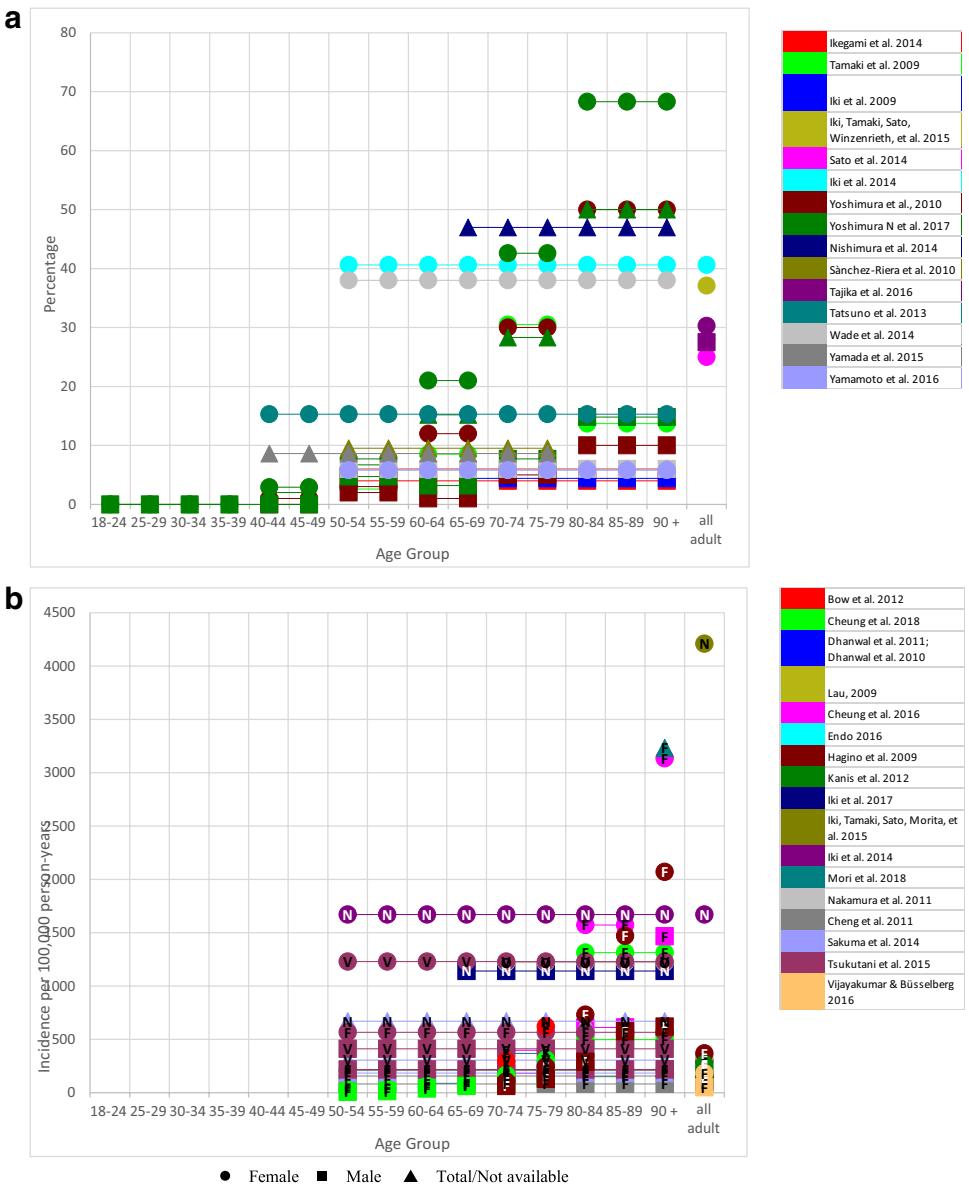

Fig. 5 **a** Japan osteoporosis prevalence. **b** Japan fracture incidence. Connected lines represent "estimated" data reflecting findings for broad age ranges (e.g. 60–75, 50 +); these data were noted as linked data points for all age categories included in the reported range. Each color represents a single study. "All adults" represents generalized data describing broad populations without specified age groups (e.g. "Five percent of Australian men have osteoporosis"). Full citations for studies not cited in-text can be found in the Appendix. Circle = female; square = male; triangle = total/not available. *F*, femoral neck/hip; *V*, vertebrae/spine; *W*, wrist/forearm; *H*, humerus; *M*, multiple; *O*, other; *N*, not specified/general fragility fractures

osteoporosis and related fractures in Australia, China, Hong Kong, Japan, Singapore, South Korea, and Taiwan. The preponderance of evidence from this study suggests that 5–10% or more of all adults in these seven developed economies suffer from osteoporosis. This is likely an underestimate due to a lack of formal or frequent testing, the silent nature of the disease prior to fractures, and the tendency not to medically treat the condition, which may leave many people unaware of their status (even after low-trauma fractures), and result in a lack of data in treatment-based databases. This study reflects a higher osteoporosis prevalence in many populations aged 50 + (20–40% and sometimes much higher), especially among women. High-end estimates of osteoporosis exceeded 50% in elderly female populations in many locations.

In most of the locations, estimates for hip fracture ranged between 500 and 1000 cases per 100,000 person-years, although estimates two or three times that rate became more common with increased age. Vertebral fracture incidence was most often reported between 200 and 600 cases per 100,000 person-years. Estimates of non-specified or general fragility fractures, or data reporting multiple types of fractures as a combined incidence, suggest that these locations have an overall fracture incidence of up to 2000 per 100,000 person-years, with some much higher and many (likely not all-inclusive fracture estimates) slightly below 1000 per 100,000.

Studies published after the period of this review offer further data supporting the substantial prevalence of osteoporosis and related fractures in these locations. A recent

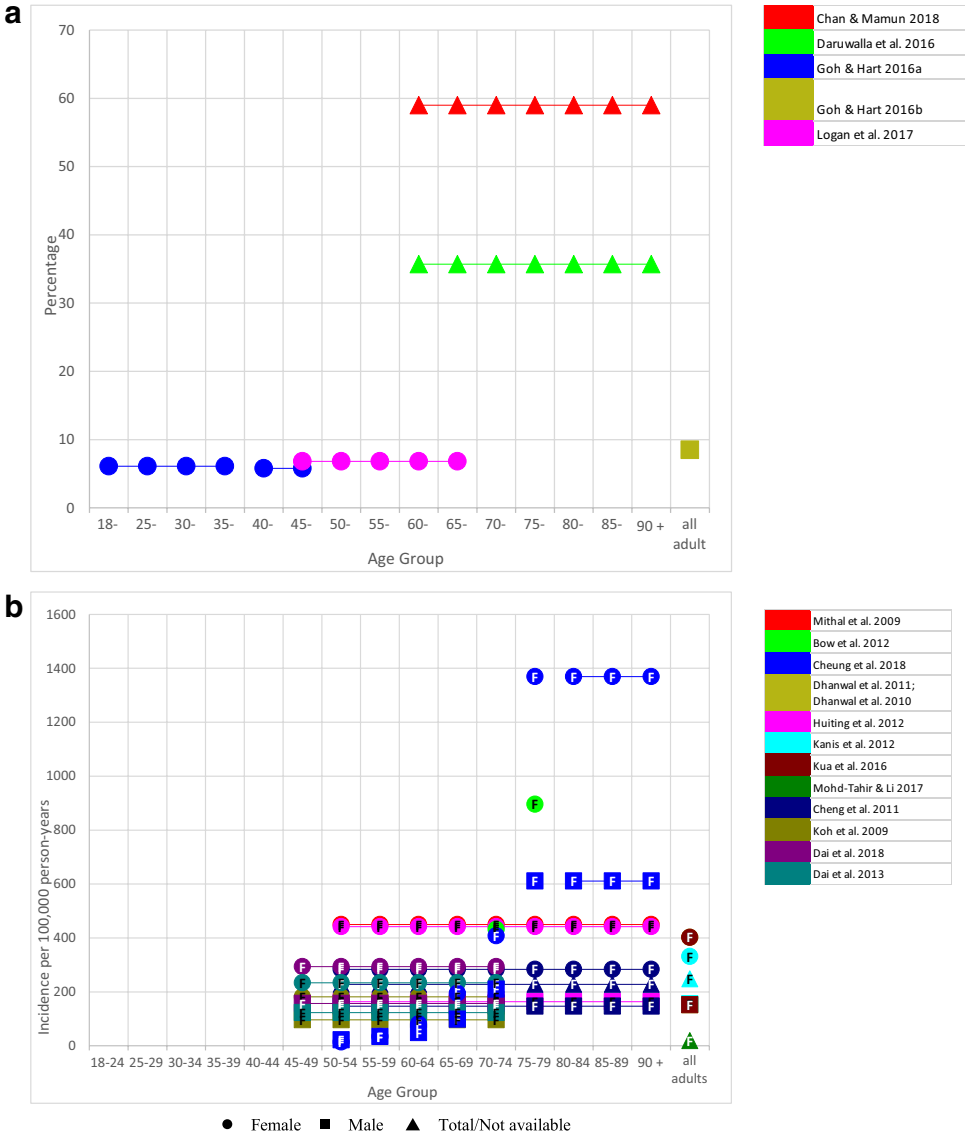

Fig. 6 **a** Singapore osteoporosis prevalence. **b** Singapore fracture incidence. Connected lines represent "estimated" data reflecting findings for broad age ranges (e.g. 60–75, 50+); these data were noted as linked data points for all age categories included in the reported range. Each color represents a single study. "All adults" represents generalized data describing broad populations without specified age groups (e.g. "Five percent of Australian men have osteoporosis"). Full citations for studies not cited in-text can be found in the Appendix. Circle = female; square = male; triangle = total/not available. *F*, femoral neck/hip; *V*, vertebrae/spine; *W*, wrist/forearm; *H*, humerus; *M*, multiple; *O*, other; *N*, not specified/general fragility fractures

Australian study reported secondary data suggesting that 20% of men and women aged 50+ will experience a vertebral fragility fracture and that this risk increases with age [114]. Recent literature in China supported osteoporosis prevalence estimates of 20–40% for women and near or less than 10% among men [115–121], with related fracture incidence in the low hundreds per 100,000 person-years for adults aged 50+ [122]. Recent literature suggested a general osteoporotic fracture incidence of 971 per 100,000 person-years among women in Japan [123]. In Singapore, recent estimates range from 9.3 to 19.4% [124, 125] for the prevalence of osteoporosis among postmenopausal women and 0.7% among men aged 50+ [124]. One large Singaporean fracture database study reported that 7% of women ages 50+ had a history of fragility fracture [126], and a study examining hip fracture incidence in adults ages 50+ reported age-adjusted incidence of 253 per 100,000 among women and 125 among men [127]. Another study from Singapore reported estimated vertebral fracture rates of 300 and 130 per 100,000 for women and men, respectively, and other osteoporotic fracture rates of 465 and 205 per 100,000 for women and men, respectively [128]. In South Korea, osteoporosis prevalence was recently reported to be 22.4% among adults aged 50+ [129]. Another South Korean study found a prevalence of 3.97% and 6.93% among all Koreans taking part in its National Health Insurance and Medical Aid programs, respectively, with an incidence of osteoporotic vertebral fractures of 389–408 per 100,000 person-years in Medical Aid recipients [130]; another study found that 17.9% of patients with a fragility fracture experienced a subsequent fracture, usually in less than 1 year [131]. In Taiwan, a large study reported osteoporosis prevalence of 18.13% in women and 17.95% in men aged 40+ [132]. Another Taiwanese study reported the combined incidence of developing

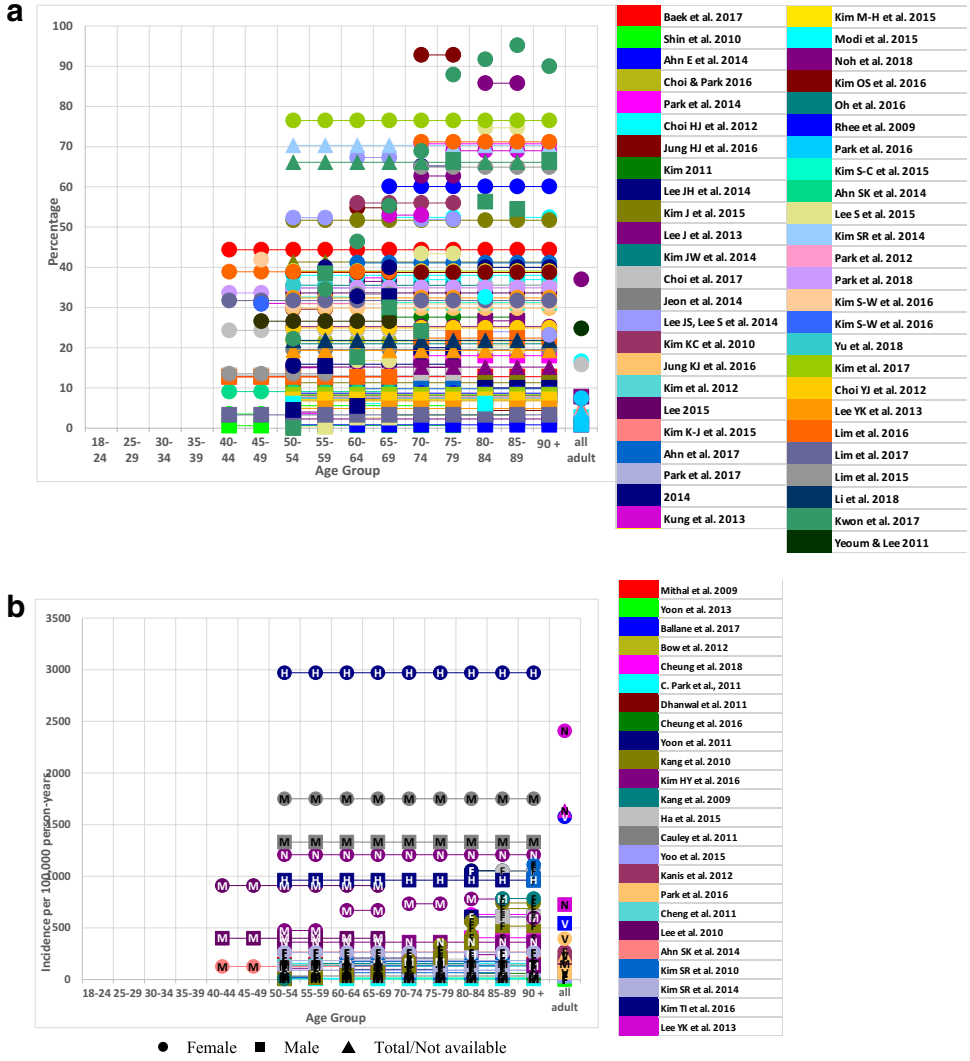

Fig. 7 **a** South Korea osteoporosis prevalence. **b** South Korea fracture incidence. Connected lines represent "estimated" data reflecting findings for broad age ranges (e.g. 60–75, 50+); these data were noted as linked data points for all age categories included in the reported range. Each color represents a single study. "All adults" represents generalized data describing broad populations without specified age groups (e.g. "Five percent of Australian men have osteoporosis"). Full citations for studies not cited in-text can be found in the Appendix. Circle = female; square = male; triangle = total/not available. *F*, femoral neck/hip; *V*, vertebrae/spine; *W*, wrist/forearm; *H*, humerus; *M*, multiple; *O*, other; *N*, not specified/general fragility fractures

osteoporosis or suffering a fragility fracture to be 23.8 per 1,000 person-years [133].

It is clear that osteoporosis and associated fractures are a health issue of significant import for these AP countries and regions. In our review, the most robust data were available for adults in middle to late age, and osteoporosis and related fractures were generally more common among women than men. Due to the large and growing elderly populations in the AP region, the reported rates of osteoporosis can be expected to produce growing numbers of annual hip and other osteoporotic fractures in many nations, with significant mortality and consequences for economic, societal, and population health.

Policy and economic implications

A systematic review in 2017 suggested that the economic burden of hip fracture in Asia may exceed one-third of gross domestic product per capita once indirect and intangible costs are considered [134]. In Singapore alone, it is estimated that increased treatment of osteoporosis could avoid nearly 30,000 fractures from 2017–2035, and result in a cost savings of more than SGD330 million in that time period [128]. As osteoporosis and related fractures can result in significant health expenditures, lost work time and productivity, reduced quality of life, and reduced relative survival [135, 136], it behooves governments and healthcare systems in the AP region to consider how best to implement policies and processes for preventing osteoporosis, identifying it and its risk factors in adult men and women, and managing affected populations, in order to reduce the risk of initial and subsequent fractures.

The data obtained and reviewed for this study can potentially inform additional research on osteoporosis, related fractures, and their impact in the AP region, as well as subpopulation research to better understand osteoporosis

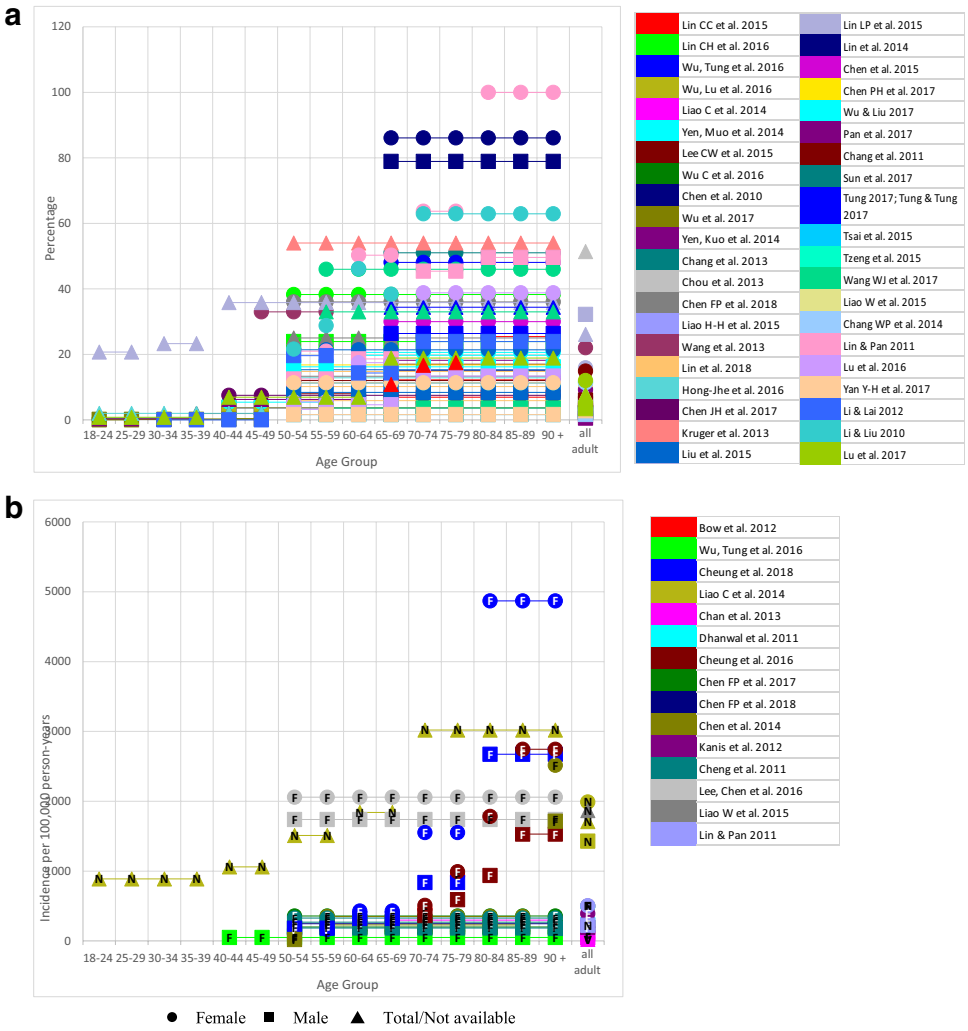

Fig. 8 **a** Taiwan osteoporosis prevalence. **b** Taiwan fracture incidence. Connected lines represent "estimated" data reflecting findings for broad age ranges (e.g. 60–75, 50+); these data were noted as linked data points for all age categories included in the reported range. Each color represents a single study. "All adults" represents generalized data describing broad populations without specified age groups (e.g. "Five percent of Australian men have osteoporosis"). Full citations for studies not cited in-text can be found in the Appendix. Circle = female; square = male; triangle = total/not available. *F*, femoral neck/hip; *V*, vertebrae/spine; *W*, wrist/forearm; *H*, humerus; *M*, multiple; *O*, other; *N*, not specified/general fragility fractures

incidence and prevalence among adults with common comorbidities. This can then translate into public education, awareness, and screening campaigns and pave the way for policy and healthcare funding agency decision-making about osteoporosis treatment and fracture prevention.

Recommendations

Based on the data reviewed in this study and related data available on the known impact of osteoporosis and related fractures, we recommend stage-based opportunities for improvement to healthcare policy decision-makers and ministries of health in the AP region.

Screening, diagnosis, and fracture risk prediction

- Implement broad screening efforts via public health programs or government health services to identify individuals with low bone density requiring treatment, starting at sex-specific ages appropriate for each nation's population and using country-specific screening thresholds.
- Promote innovative, targeted population awareness and risk assessment efforts via targeted and accessible resources, such as web-based health screening campaigns (e.g., the *Know Your Bones*™ online tool).
- Invest in high-quality equipment (e.g., dual-energy x-ray absorptiometry (DXA) scanners) to standardize diagnostic and data collection efforts.
- Recognize the need for ethnic-specific fracture risk prediction tools and encourage their development.

Treatment

- Identify osteoporosis and related fracture management as key national priorities to drive recognition and commitment to improved outcomes.
- Consider applying the APCO Framework of minimum clinical standards to implement standard practices to benchmark care and data monitoring for osteoporosis

screening, diagnosis and management, and fracture prevention [137], or use existing national guidelines where available.
- Implement preventive and therapeutic drug coverage in government health insurance plans. Particularly for generics, drug costs are low and the financial savings compared to treatment of fractures (together with the tangential costs associated with fractures) may be substantial [138–140].
- Identify culturally relevant strategies to improve appropriate drug prescription practice, patient adherence, and lifestyle approaches to disease prevention and management.

Fracture prevention

- Develop and deploy systematic fracture liaison services; these have been demonstrated to be effective programs for individuals at high risk of second/subsequent fractures. They can reduce future fractures, improve quality of life, and reduce costs associated with further fractures [141–144].
- Initiate a fracture registry to track initial (and subsequent) osteoporotic fractures and follow-up clinical care. This data allows national benchmarking and identification of patients eligible for fracture liaison services or osteoporosis treatment.

Research

- Implement data collection efforts to track the prevalence of osteoporosis and related fractures, as well as the impact of any changes in policies or interventions.
- Develop regional or population-specific reference data to better define osteoporosis and low bone mineral density cut-offs in terms of bone density for populations in the AP region.
- Explore, through cost-effectiveness analyses and mortality risk reduction rates, the impact of treatment and prevention efforts targeted at osteoporosis and fragility fractures.

Limitations

There are some limitations to this review. There was substantial variation in the data available and in the probable generalizability of the data. This was expected due to multiple reasons, including differences in resources and variations in reference groups for young BMD comparisons for T-scores. It has been shown that southeast Asians have lower BMD than Caucasians [145], and an overestimation of osteoporosis is likely if Caucasian normative data are used to determine T-scores [146, 147]. It is difficult to draw any conclusive comparisons regarding the rates of osteoporosis and related fractures in the locations of interest, due to the differences in the studies' reported data age ranges; definitions of the conditions of interest and outcomes reported; highly varied cultural, ethnic, and geographic groups; statistical adjustments to data; measurement sites, bone mineral density measurement device types, and reference data for BMD measurements; inclusion of secondary data and self-reported data; and time periods for original data collection. These variations limit comparisons across, and even within, the selected locations. Without further refining the data to allow direct comparison of more standardized populations, it will be difficult to reliably estimate osteoporosis prevalence and related fractures in the AP region.

The quality of some of the data collected may limit the validity of summary conclusions, even within the included locations. Many of the studies included in this review reported secondary data or small group/sub-population findings, which, together with quality limitations for some studies, reduce the generalizability of the findings. It is also probable that many "all adult" estimates reported as secondary data represented narrower groups in their original studies, which could result in overestimations when reported as a figure for the entire adult population. Potential publication bias or bias stemming from oversampling of the most at-risk populations by virtue of gathering participants from hospitals and adults already engaged in bone health cohort studies, as numerous studies did, could also result in overestimation of the problem.

Variation in osteoporosis definitions and technology, such as DXA versus quantitative ultrasound (QUS), makes some of the data difficult to compare; DXA is not widely available in rural or low-income areas, so this problem is likely to persist in the AP region. This is further complicated by a lack of local population reference BMD T-score values for both technologies. Numerous studies reported sizeable differences in prevalence estimates based on the reference data and scan site. It is possible that studies using Caucasian reference data, or even non-native Asian reference databases, do not provide accurate or appropriate estimates for certain AP populations. Until more localized reference datasets for BMD in young, healthy individuals can be obtained, however, this problem will affect many of the region's osteoporosis findings.

Finally, this study did not include local language results or papers older than ten years at the time of execution due to the volume of search results eligible for full-text review.

Conclusion

The highly inclusive nature of the review criteria resulted in a robust collection of estimates for each location of interest. Furthermore, the locations included in this

study are some of the most economically and medically advanced in the AP region. As such, it is likely that our review may represent some of the best osteoporosis research available in this part of the world. It behooves clinicians and governments in the AP region to address the high occurrence of osteoporosis and related fractures through proactive prevention and treatment programs. Economies that ignore the broad population threat of this disease do so at their peril.

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• KB was involved in protocol development, management of the literature review and data abstraction process, data review and verification, data interpretation, and manuscript writing and editing.
• SF was involved in data interpretation and manuscript writing and review.
• YH was involved in data interpretation and manuscript writing and review.
• HT was involved in data interpretation and manuscript writing and review.
• JH was involved in data interpretation and manuscript writing and review.
• JT was involved in protocol development, oversight of the literature review and data abstraction, data verification, and manuscript writing and review.
• JE was involved in protocol development, data interpretation, and manuscript writing and review.

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Declarations

Ethics approval For this type of study, formal consent is not required.

Conflicts of interest • MC has received honoraria from DKSH, Amgen, and Kyowa Kirin for chairing advisory boards and for speaking engagements.
• KB received funding from Amgen to lead the protocol development, oversee the systematic review research and data abstraction, and organize and interpret the data for publication. She has research and marketing consulting and medical writing contract relationships with numerous medical communications and consulting agencies, and therefore indirectly receives compensation from many pharmaceutical companies for her work on clinical trial endpoints, clinician education, medical communications, and medical marketing.
• SF, JH, YH, and HT have no interests to declare.
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