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Original Article

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ORIGINAL ARTICLE

TATANGELO ET AL.

COST OF OSTEOPOROSIS, OSTEOPENIA, AND FRACTURES

The Cost of Osteoporosis, Osteopenia, and Associated Fractures in Australia in 2017[1]

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ABSTRACT

Osteoporosis and osteopenia are increasingly prevalent conditions among older adults. Not only do the fractures associated with poor bone health have significant health consequences for the individual, but also their economic impact is placing increasing financial burden on governments and society. This study aimed to determine the direct economic cost of osteoporosis, osteopenia, and fractures among Australians aged 50 years and older in 2017. This study uses previous Australian data on the incidence and prevalence of osteoporosis and osteopenia together with recent Australian data on health service utilization after fracture to provide an estimate of the economic burden of osteoporosis. A bottom-up costing approach was used to determine the average direct health care and non-health care total costs of a fracture, as well as the average community health service costs of managing individuals with osteoporosis or osteopenia. The total direct cost of osteoporosis in Australia in 2017 was estimated to be $3.44 billion (AUD 2017, USD 2.77 billion). Treatment of fractures accounted for 68% of total direct costs, and non-fracture management of osteoporosis accounted for 32%. Hip fractures accounted for the highest proportion (43%) of the total direct cost of fractures, although fractures at "other" sites accounted for 38.5%. Fractures among individuals aged 70 years and older accounted for 74% of the direct costs (55% and 19% in women and men, respectively). Fracture costs in those with osteopenia accounted for 50% of direct fracture treatment costs. This up-to-date cost analysis estimated that costs in 2017 were three times higher than in 2007. These estimates will aid clinicians, policy makers, researchers, and health care organizations to acknowledge the economic importance of reducing osteoporosis-related fractures and associated costs. This provides a strong public health case to promote bone health that will assist in reducing future fracture-related costs.

KEY WORDS: OSTEOPOROSIS; OSTEOPENIA, FRACTURE; HEALTH ECONOMICS
</KWD>

Introduction

The Australian health care system is one of the most accessible and high-quality systems in the world.[1] However, accurate data on the current incidence, prevalence, and associated health care costs of some age-related conditions such as osteoporosis and related fractures are not readily accessible. With a steadily increasing number of older adults in our population, Australian health care, like health care systems in many other developed countries, must adapt to the changing

needs of a rapidly aging population.[2] Osteoporosis and osteopenia are increasingly prevalent conditions that have significant health consequences for individuals who sustain fractures.[3,4] In 2012, estimates showed 4.74 million Australians over 50 years of age (66% of people over 50) had osteoporosis or osteopenia. This number is expected to increase by 31% in 2022, equating to 6.2 million Australians over the age of 50 years.[4] In addition to the significant physical and psychological burden fracture(s) impose on individuals, the economic impact of osteoporosis and fractures places a significant and ever-increasing financial burden on governments and other health funders.[4] In order for steps to be taken to reduce society-wide burden, an accurate estimate of the cost attributable to osteoporosis, osteopenia, and associated fractures in Australia is critical.

An important gap in the estimation of the cost of osteoporosis is the lack of information available for site-specific fractures other than hip fractures. The most common fracture sites associated with osteoporosis and osteopenia are hip, wrist, spine, humerus, and pelvis, although other skeletal sites are also affected.[5] International estimates indicate that fractures at sites other than the hip or vertebrae collectively account for approximately 60% of all fractures and contribute a significant portion of the costs.[6,7] However, the costs associated with fractures at sites other than hip have not been quantified for a large Australian sample. In addition, it is unclear what proportion of total costs associated with poor bone health is attributable to the direct health-related costs of fracture treatment and what proportion is attributable to non-fracture management of osteoporosis and osteopenia and fracture-prevention.[8,9] Non-fracture management and fracture-prevention include the use of anti-osteoporosis medications and supplements, 2.4 medical visits per year, a general blood test for renal function and serum calcium twice a year and serum 25-hydroxyvitamin D test once every two years. Without this information, the ability to develop a targeted plan for an economically sustainable prevention and management approach is limited.

This burden of disease study brings together data from multiple Australian sources on health service utilization, community service utilization, and morbidity. The Geelong Osteoporosis Study (GOS)[10] is an Australian prospective longitudinal cohort study that has provided an accumulating picture of the prevalence of osteoporosis and the incidence of fractures in Australia. The AusICUROS prospective cohort study provides data on health and community service utilization associated with low-energy fractures.[3,11] These data are brought together in a

novel approach that aims to overcome the limitations of previous cost estimates by using a bottom-up (resource use at the patient level) costing economic approach to determine the costs associated with fracture treatment. Epidemiological data and a top-down costing approach (using health administrative data) are used to determine costs associated with management of osteoporosis and fracture prevention. Combined, these two major data components are modeled to determine the total direct costs of osteoporosis.

The aim of this study was to use the best available Australian data on incidence, prevalence, and health and community service utilization to estimate the 2017 direct-cost burden of disease relating to osteoporosis and fractures (prevention and management) in the Australian population aged 50 years and older. Importantly, this study provides a separate cost of fractures associated with osteoporosis and osteopenia by site (hip, wrist, vertebral, and other types of fractures).

Materials and Methods

Overview

There are two major components to the method to determine costs in this study: the data sources that have been used as a basis for the population rates of osteoporosis, osteopenia, and fractures, and the methods used to analyze the cost data. The prevalence of osteoporosis and osteopenia and the incidence of fractures were taken from existing Australian data sources. These data sources, together with population data from the Australian Bureau of Statistics (ABS), were used to estimate the prevalence of osteoporosis, osteopenia, and the incidence of fractures within the Australian population aged over 50 years. The same method was used to estimate costs for each Australian state that were based on population estimates from the ABS.[12] A bottom-up costing approach was used to determine the average direct health care and non-health care total costs of a fracture, as well as the average community health service costs of managing someone with osteoporosis or osteopenia. This method has been described in a previous report.[4] Fracture treatment costs were determined from AusICUROS study. This study collected service utilization data at predetermined intervals from Australians with recent low-trauma fracture. Data from AusICUROS included patient hospital records and self-reported questionnaires about health and non-health service use associated with treatment of the fractures and any related side effects. As per the previous report, the number of fractures was projected using the Australian Bureau of Statistics (ABS) population estimates for 2017.[12] Cost data were based on 2012 estimates and

adjusted by consumer price index (CPI)[13] for 2017 dollars. All costs are presented in 2017 Australian dollars (AUD).

Incidence/prevalence data for osteoporosis, osteopenia, and fractures

ABS population data were used from the estimated resident population for each state and territory for 2017.[12] Population data by sex and 5-year age bands from aged 50 years and older were used to generate population estimates for men and women in two age groups (50 to 69 years and 70+ years). To determine the proportion of the population with osteoporosis and osteopenia, the 5-year age interval data from the GOS[14] were used. This study recruited an age-stratified random sample of the region's population.[2] The 5-year rates were then applied to the 5-year population cohorts from the ABS to determine the weighted average proportions (by population) for osteoporosis and osteopenia for men and women in two age groups (50 to 69 years and 70+ years).

The GOS cohort[10] was followed prospectively for approximately 5 years after baseline for fracture ascertainment.[15,16] Fracture cases were categorized according to their bone mineral density (BMD) scores at baseline (categorized as normal, osteopenia, and osteoporosis). The proportion of all fractures in each BMD category was used to estimate the population-standardized number of fractures for each category over a 5-year period. The fractures arising from those with BMD in the normal category (BMD above a *T*-score of –1) were not attributed to osteoporosis and not included in the analysis of cost and burden of osteoporosis.

The number of fractures at each site (hip, wrist, vertebral, and other), by sex and 5-year age groups, were determined by data from Sanders and colleagues.[5] All fractures were confirmed by medical imaging. Ascertainment of clinical vertebral fractures was through emergency departments (including non-admitted patients), inpatient units, and through medical imaging services. Crisp and colleagues[17] found declining incidence of hip fracture rates by 20% and 13% in women and men, respectively. To account for these changes, a sensitivity analysis was conducted whereby the proportion of hip fractures observed by Sanders and colleagues[5] was reduced in each 5-year cohort by 20% for females and by 13% for males. The sensitivity analysis has been described in a previous report.[4] Because there was no evidence for the reduction in total fracture rates,[9] the proportion of non-hip fractures was then increased so that the overall number of fractures remained the same.[15] Although fracture rates were different between those with osteoporosis and osteopenia, the distribution according to fracture site was assumed to be

the same. “Other” fractures included humerus, ankle, lower limb, rib, pelvic, forearm (not classified as wrist), patella, foot, and hand fractures.[5] Fractures were included in the category of “other” because they occurred in adults aged 50 years and older with osteoporosis or osteopenia and were not pathological fractures or associated with motor vehicle accidents. This is consistent with the total fracture rate, age, and sex-specific distribution, determined from previous population-based fracture ascertainment.[5] Skull, facial, finger, and toe fractures were not included.

Burden of fractures

For each fracture type (hip, vertebral, wrist, other), a clinical pathway was modeled by sex, age (50 to 69 years, 70+ years), and BMD category (osteoporosis, osteopenia).[3] These models were built in Microsoft Excel to replicate clinical pathway steps and estimate costs. In total, 32 clinical pathways were modeled to estimate the burden from fractures. Confidence intervals were not estimated because this is a population-based analysis. Data from the AusICUROS fracture cohort were used to estimate health and community service utilization data after a fracture. From this study, complete fracture-related service utilization for 12 months were available for 505 adults with low-trauma fracture from eight Australian study sites. The distribution of fracture site sustained by AusICUROS participants is detailed elsewhere.[4]

Fracture-related costs included the direct health-related costs and the non-health services. Direct health-related costs included ambulance, hospitalization, emergency department, imaging, medical services, pharmaceuticals, rehabilitation, and community health. Non-health services included community support services (such as meals on wheels, home help, and formal and informal care) and residential care.[3] Costs attributed to residential care were calculated based on the proportion of fracture participants in AusICUROS study who changed their permanent dwelling after the fracture from community to a residential aged-care facility (RACF). An assumption was made that the average stay in RACF was 6 months in this first year. The perspective taken is that of a limited societal perspective with direct costs of fracture management and osteoporosis management included, as well as informal care. Costs associated with productivity loss have not been included in this analysis.

Mortality after fracture was modeled as per the protocol utilized in the ICUROS study.[4] This approach underestimates the mortality rate after fracture as participants were recruited on basis that they were expected to survive at least 18 months after sustaining the fracture.

Costs associated with the ongoing management of osteoporosis (excluding any fracture treatment)

Non-fracture-related costs included routine medical (GP visits) and pathology (including vitamin D) tests, dual-energy X-ray absorptiometry (DXA), and pharmaceuticals for bone health. To determine the total utilization of anti-osteoporosis medications, the volume of dispensed prescriptions from the Australian Pharmaceutical Benefits Scheme (PBS) and Repatriation Pharmaceutical Benefits Scheme (RPBS) using the Item Reports from Medicare Australia[18] were used for the 2011/2012 financial year. All medications where osteoporosis was listed under the authority restriction were included. The analyses were based on the volume of dispensed scripts from the PBS and the Repatriation PBS and does not take into account additional copayment by the patient. Costings were conservative because the cost of the medications were based on the lowest scheduled reimbursement costs determined by the PBS. To determine the total annual cost, the reported number of prescriptions from the PBS and RPBS were multiplied by the schedule fee for each drug and inflated to AUD 2017.[13]

Other services were included based on recommended follow-up investigations for the management of osteoporosis/osteopenia. It was assumed that everyone with a new fracture would have one DXA in the year of the fracture and that the rest of the population with osteoporosis or osteopenia would have one DXA every 3 years (an annual rate of 0.33).[19] The total cost of DXA was determined from the MBS expenditure data (top-down economic approach). It was assumed that the majority of DXA scans are conducted to assess risk of osteoporosis. This assumption is in line with Medicare criteria to receive subsidized DXA scans. The number of DXA scans were calculated assuming 1) patients with fracture underwent one DXA in the year of fracture, and 2) people with osteopenia or osteoporosis underwent one DXA every 3 years. These scan rates are comparable to the number reported by Medicare.[18]

Pathology tests for vitamin D were assumed once every 2 years for the population with osteoporosis or osteopenia, and other relevant routine pathology tests for renal function and serum calcium were based on the assumption of two tests annually.[4] General practitioner visits were assumed at a rate of 2.4 visits annually for the population with osteoporosis or osteopenia irrespective of fracture.

Itemized tables by category of resource with average resource utilization rate for the fracture population and the unit cost for each resource can be found in the report by Watts and

colleagues.[4] For more details, specific assumptions made for each rate and cost, as well as the source of the data, can also be found in the report.[4]

Results

Total cost of osteoporosis, osteopenia, and associated fractures in Australia in 2017 (Table 1) {TBL 1}

The total direct cost of osteoporosis, osteopenia, and associated fractures in Australia in 2017 was estimated to be AUD $3.44 billion (USD 2.77 billion). The treatment of fractures accounted for 68% of the total direct costs (including informal care) of osteoporosis. Of this, hip fractures accounted for the highest proportion (43%) although the direct treatment cost of fractures at 'other' sites accounted for 39% of the cost of all fractures. Treatment costs of vertebral fracture accounted for 11%, and wrist fracture accounted for 7% of the cost of all fractures. The cost for informal care, which includes non-health costs for home care, accounted for 5.3% of the total direct cost of treating fractures. The analysis demonstrates the total cost of treating all fractures in adults with osteopenia is estimated to comprise 50% of the total cost of treating fragility fractures in Australia (Table 2 {TBL 2} <zaq;2> and Supplemental Table S1).

The non-fracture management of osteoporosis (fracture prevention) accounted for 32% of the total direct costs associated with osteoporosis. This includes the use of anti-osteoporosis medications and supplements of calcium and vitamin D but does not include costs associated with exercise therapy or other lifestyle interventions. Routine medical and pathology accounted for 72% of the cost for non-fractures. DXA scans and anti-osteoporosis pharmaceuticals accounted for 4% and 24% of the total non-fracture costs, respectively.

Total cost of all fractures by sex, age group, and cost category (Table 3) {TBL 3}

Fractures among those aged 70 years and older accounted for 74% of the total direct costs of fracture treatment. Twenty-seven percent of total direct costs of fracture treatment were attributable to men.

Almost 70% of the total direct cost of all fractures was for hospital care with half of this cost attributable to fractures among women aged 70 years and older. Rehabilitation (inpatient and outpatient combined) accounted for the second highest component of direct costs (14%) with almost three-quarters of this cost attributable to women 70 years and older.

Cost by fracture type, sex, age group, and cost category

Tables 4 to 7 provide cost estimates for hip, wrist, vertebral, and other fracture sites (grouped). The direct total cost for fractures includes all health care and community services (directly related to fracture care), as well as costs attributable to residential aged care.

The total direct cost of hip fractures was $1.01 billion of which hospital care contributed 65.5% (Table 4). {TBL 4} Forty-three percent of hospital costs were attributable to women aged 70 years and older, and 16.5% to men aged 70 years and older. Rehabilitation represented 19% of direct costs for hip fractures, of which 14% of costs were for women aged 70 years and older, and 4% were attributable to men aged 70 years and older.

The total cost of wrist fractures was $164 million, of which hospital care contributed 69%. Ninety percent of these hospital costs were attributable to women (Table 5). {TBL 5} Rehabilitation represented 16% of direct costs for wrist fractures, of which the majority was attributable to women aged 70 years and older (95%).

The total cost of vertebral fractures represented 11.4% of the total direct costs of treating all fractures ($267 million; Table 6). {TBL 6} Hospital care represented 53% of which more than half (56%) was attributable to women aged 70 years and older. Rehabilitation represented 14% of direct costs for vertebral fractures. The cost associated with informal care was $38 million, representing 14% of the cost of vertebral fractures.

The total cost of fractures at other sites represented almost 40% of the cost of treating all fractures ($903 million; Table 7). {TBL 7} Hospital care represented 73% of direct costs for other fractures. Hospital care for women aged 50 to 69 years represented 24% of total cost of other fractures, the same proportion of costs as hospital care for women as in the age group 70 years and older. For men aged 70 years and older, the cost of hospital care represented 13% of the total costs for other fractures. Rehabilitation represented 9% of direct costs for other fractures, and informal care was almost $90 million, representing another 10% of the cost of other fractures.

Fig. 1 {FIG1} shows the cost of osteoporosis, osteopenia, and associated fractures across Australian states in 2017 for people aged 50 years and older. Also displayed is the proportion of cost in each state that was attributable to people aged 70 and older. Thirty-four percent of the total national cost of fracture was from NSW (including ACT); this equates to $809 million. Victoria accounted for 25% of the total national costs ($589 million). Queensland, Western Australia, South Australia, Tasmania, and the Northern Territory accounted for 19%, 10%, 8%,

3%, and 0.5% of the total national costs, respectively. The total cost within each state and territory were largely driven by the cost associated with osteoporosis and fractures among people aged 70 years and older. For example, 74% of the total cost of fractures in NSW and the ACT were attributable to osteoporosis and fractures among people aged 70 years and older.

Discussion

The total direct cost associated with osteoporosis, osteopenia, and fractures among Australians aged 50 years and older in 2017 was estimated to be AUD 3.44 billion. This indicates that the economic costs associated with osteoporosis are significant and had previously been underestimated.[4,20,21] By using Australian data on fracture incidence and prevalence of osteoporosis, together with a bottom-up costing approach to estimate resource utilization, our research provided a more accurate and detailed account of the direct costs. The findings show the distribution of the cost burden of this disease across the cost categories of fracture treatment and the clinical management of osteoporosis. In contrast to previous estimates, our findings demonstrated the majority of cost was attributable to fracture treatment, rather than non-fracture management of osteoporosis. In addition, this is the first Australian study to provide a detailed breakdown of the costs associated with specific fracture sites (hip, wrist, vertebral, and other). These new estimates also demonstrated that men accounted for 27.5% of costs, and show that the burden of osteoporosis is not only attributable to women. Using the derived mean cost of fracture by site, age group, and sex, the direct cost of fractures in adults with osteopenia (*T*-score between 1 and 2.49) is estimated to be equal to the cost burden of those with osteoporosis (*T*-score $\leq$2.5). No previous Australian burden of illness study had used a bottom-up approach to capturing actual resource utilization in a large number of adults followed for 18 months after a fracture. Before this study, the direct health cost of osteoporosis was estimated to be $1.9 billion in 2007[8] based only on the cost of hospitalized fracture cases in adults aged 20 years and older, classified as low trauma and without consideration of bone mineral density. This new research, in line with other international burden of disease studies, targeted adults from 50 years and older studies.[6,7,17,22–24] The current study also used Australian epidemiologic and cost data to confine the burden of osteoporosis to adults with low bone mineral density and included direct costs from both hospitalized and non-hospitalized fractures.

The large burden of disease attributable to osteoporosis was predominantly due to fractures, with fractures representing 68%, or two-thirds, of total direct costs. This cost estimate does not

include indirect costs such as productivity loss and the impact on disability and quality of life. Thirty-two percent of the burden of disease attributable to osteoporosis is due to the cost of management and prevention of further bone loss in Australians with either osteoporosis or osteopenia. In contrast, Access Economics[8] found that the cost of non-fracture management of osteoporosis and osteopenia outweighed the cost of fractures. However, as previously discussed, this earlier study is likely to have significantly underestimated the total fracture cost, as the estimates were based on hospitalized fractures only. The current finding provides evidence to support that efforts to reduce the prevalence of fractures may significantly reduce the economic burden across the health care system.[25] In the majority of countries, population screening approaches targeted to the prevention of osteoporosis-related fractures have not been adopted due to the perception of cost inefficiency.[26] However, recent research has demonstrated the efficacy of screening approaches in reducing the incidence of fractures among community-dwelling older people.[27] There is substantial evidence including Australian data that demonstrates the mid- to long-term cost efficiencies of fracture liaison services.[28,29] These services that aim to "capture" adults when they are seeking treatment for recent fracture and offer assessment and referral to existing bone health services have been shown to be effective in reducing the rate of subsequent fracture among fracture patients by up to 80%.[30]

In line with previous studies,[6,7] treatment and management of hip fractures had the highest cost, representing 43% of the direct cost of all fractures in the current Australian study. In Canada, hip fractures accounted for 53% of acute care costs and represented 50% of hospitalizations attributable to osteoporotic fractures,[7] while the significant costs imposed by fragility fractures on the United States Medicare system have been documented,[31] with hip fractures in this country estimated to account for 72% of total hospital costs but represented only 14% of all fractures.[6] Although hip, wrist (7%), and vertebral fractures (11%) together accounted for 61.5% of the direct costs of fracture treatment, the economic burden of osteoporosis would be significantly underestimated by not including the 38.5% of direct costs used in the treatment and management of other (non-hip, non-wrist, and non-vertebral) fractures. In Canada, Tarride and colleagues[6] found that other fractures represented 40% of all fractures, and Burge and colleagues[7] reported these other fractures accounted for almost 20% of direct costs in the USA. As such, there is a growing evidence for the importance of prevention, treatment, and education

that is concentrated on skeletal fracture sites other than hip, vertebral, and wrist[6] that have traditionally been the focus of osteoporosis reports.

There are some important limitations to the study that should be noted. Both the prevalence of osteoporosis and osteopenia and fracture incidence were taken from one large region located in southeastern Victoria. Although the analysis specifically used age and sex-specific fracture rates in adults with osteoporosis and osteopenia, the fracture site distribution was assumed to be the same for all adults irrespective of bone mineral density. Our estimates incorporated an observed decline in hip fracture rates of 20% in women and 13% in men.[17] Although some data suggested the decline is restricted to hip fracture incidence, there are no recent international studies published that use reliable data for incidence of non-hip fractures.[32,33] However, recent Canadian data suggested there may also be a decline in other major osteoporotic fracture sites.[25] There are no published Australian data to identify changes in fractures occurring at other sites.[9] Furthermore, the cost burden of other fractures could be overestimated because AusICUROS recruitment was through a combination of emergency department, inpatient wards, and some public hospital medical imaging services. Fractures of a less serious nature may have been managed without visiting an emergency department and confirmed using private radiology services not included in our recruitment procedures. It is very likely that there are differences in fracture rates among Indigenous Australians consistent with racial differences identified between individuals of First Nations and white Canadians[34] and in the USA between black Americans, Hispanic, and white Americans.[35] However, there were no reliable published Australian data available to incorporate such differences into the analysis. The Australian Indigenous population accounts for less than 1.2% of Australian adults aged 50 years and older.[8] Service utilization collected from a bottom-up approach using individual patient records and self-reported questionnaire may underestimate health services attributable to other medical conditions that may be associated with the fracture. Kilgore and colleagues[31] have reported increases in fracture-related expenditure when using a cost modeling approach that compared health care utilization after the fracture with a period of 6 months before fracture. These “attributable” expenditures included incremental changes in recorded conditions such as pneumonia, aftercare, joint pain, pressure ulcers, and other musculoskeletal conditions.[31]

The cost related to change of residence to an aged care facility after the fracture are likely to be underestimated and costs are restricted to a 12-month period. In addition, our costing estimates

did not include those who fractured while residing in a nursing home. Fractures among this group may have important implications for both screening and prevention protocols. The AusICUROS study participants may have a healthy volunteer bias because individuals who sustained a fracture at more than one site and/or those who sustained another fracture during the 12-month post-fracture period were excluded as were potential participants who did not have a life expectancy of 18 months post-fracture. The increased mortality rate after hip and other fractures is well documented.[31,36] Our estimate of a 50% cost burden of treating fractures among adults with osteopenia relative to that of adults with osteoporosis is novel and highlights the economic cost-benefit of promoting strategies to promote bone health in those who are classified as osteopenia rather than osteoporotic.

This up-to-date information on the costs of osteoporosis in Australia will aid clinicians, government policy makers, researchers, and health-care organizations and funding bodies to assess the economic importance of reducing both osteoporosis-related fractures and associated costs, promoting bone health and identifying further resource needs. This will be particularly important in planning for a health care system capable of addressing the needs of an increasing number of older Australians who will be at significant risk of fracture. The comparison of attributable fracture costs across the seven Australian states and Northern Territory demonstrating the cost burden of treating fractures was largely driven by the proportion of the women aged 70 years and older. However, although hip fractures accounted for the largest proportion of the burden of osteoporosis and osteopenia, fractures at other sites accounted for a significant proportion of the cost for all fractures and should not be ignored in future planning of resource needs. People with fracture at skeletal sites other than hip represent a group at high risk of subsequent fracture including hip fracture.[37] With appropriate assessment of falls risk and bone health, these people may benefit from implementation of osteoporosis prevention and management. The current study also highlights the need for greater awareness that osteoporosis is not only a condition affecting women; men account for about 30% of all fractures and their associated costs.

Disclosures

All authors state that they have no conflicts of interest.

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Authors' roles: GT drafted the manuscript. KMS, JW, and FB conceived of the study, contributed to its design, collected data, and helped to draft the manuscript. KL, JA-O, and CC conducted the data analyses. JA-O, FB, GCN, CS-L, ALS, SI, ES, RP, LM, MC, TW, LLL, GD, and PRE contributed to the study design and conducted the AusICUROS study site data collection. All authors participated in interpretation of the findings and read and approved of the final manuscript.

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Table 1. Total Costs in AUD Millions of Osteoporosis and Osteopenia[a] and Fractures in 2017

	Direct cost[b]	Informal care	% Direct fracture cost	Total cost and %
Component 1: fracture treatment costs				
Hip fractures	962.55	49.20	43.1%	
Wrist fractures	154.88	9.43	7.0%	
Vertebral fractures	229.33	37.66	11.4%	
Other fractures	816.05	86.98	38.5%	
Total direct fracture cost (including informal care)	2168.3	183.3	100%	2346.08
Proportion of total overall costs				68.2%
Component 2: non-fracture/prevention cost[a]				
Routine medical and pathology	792.46		72.3%	
DXA	42.83		3.9%	
Pharmaceuticals—bone health	260.96		23.8%	
Non-fracture/prevention cost[a]	1096.3		100%	1096.25
Proportion of total overall costs				31.8%
Total overall costs			100.0%	3442.33

[a]Refers to fracture prevention including anti-osteoporosis pharmaceuticals, doctor visits for prescription of these drugs, DXA scans, and calcium and vitamin D supplements.

[b]Refers to direct costs not including informal care (number of hours of care given by family and friends,[4] etc., which has been costed at the rate of community service "home help" in Australia[35]).

Table 2. Mean Individual and Total Cost in AUD ($ Millions) of Fractures by BMD Category, Sex, Age Group, and Cost Category in Australia for 2017

	Women		Men	Total,	Total,

Fracture	Age 50–69 years		Age 70+ years		Total, all women	Age 50–69 years		Age 70+ years		all men	all
	Osteoporosis	Osteopenia	Osteoporosis	Osteopenia		Osteoporosis	Osteopenia	Osteoporosis	Osteopenia		
Hip											
No. of fractures	759	1039	10,807	6827	19,431	448	956	2292	4536	8233	27,665
Mean cost per patient	$23,893	$23,893	$39,192	$39,192		$25,482	$25,482	$35,444	$35,444		
Total direct cost	$18.14	$24.82	$423.54	$267.55	$734.05	$11.43	$24.37	$81.25	$160.78	$277.83	$1011.88
% Cost – osteoporosis[a]					60.2%					33.4%	52.8%
Wrist											
No. of fractures	4010	5487	6952	4392	20,841	397	847	457	904	2606	23,447
Mean cost per patient	$5299	$5299	$8736	$8736		$4607	$4607	$5818	$5818		
Total direct cost	$21.25	$29.08	$60.73	$38.37	$149.42	$1.83	$3.90	$2.66	$5.3	$13.7	$163.1
% Cost – osteoporosis[a]					54.9%					32.9%	53.0%
Vertebral											
No. of fractures	3069	4199	9829	6209	23,307	796	1698	1449	2868	6812	30,118
Mean cost per patient	$6666	$6666	$10,500	$10,500		$6807	$6807	$7637	$7637		
Total direct cost	$20.46	$28.00	$103.20	$65.19	$216.85	$5418.46	$11.56	$11.07	$21.91	$49.5	$266.80
% Cost – osteoporosis[a]					57.0%					33.0%	52.5%
Other											
No. of fractures	12,569	17,200	14,378	9083	53,231	5962	12,718	3983	7882	30,545	83,776
Mean cost per patient	$9449	$9449	$13,544	$13,544		$7214	$7214	$14,274	$14,274		
Total direct cost	$118.77	$162.53	$194.74	$123.02	$599.06	$43.01	$91.75	$56.85	$112.50	$304.12	$903.17
% Cost – osteoporosis[a]					52.3%					32.8%	45.8%
Cost of fracture (total)	$178,616.52	$244,421.53	$782,217.81	$494,127.98	$1,699,383.84	$61,684.59	$131,587.45	$151,822.41	$300,454.94	$645,549.39	$2,344,933.23
% Cost – osteoporosis[a]					56.5%					33.1%	50.1%

[a]Refers to the percentage of costs relating to fracture treatment/management that occur in adults aged 50 years and older with osteoporosis at the hip and/or lumbar spine (defined as bone mineral density *T*-score

equal to or less than negative 2.5). The entire analysis only includes adults with either osteoporosis or osteopenia (defined as *T*-score at hip and/or lumbar spine between negative 1 and negative 2.5). Therefore, the treatment cost of fractures in adults with osteopenia is estimated to be 49.9% of the total cost of treating fragility fractures.

Table 3. Total Cost in AUD of All Fractures by Sex, Age Group, and Sector in Australia for 2017

	Total cost for women $AUD (%)		Total cost for men $AUD (%)		Total $AUD (%)
All fractures	Age 50–69 years	Age 70+ years	Age 50–69 years	Age 70+ years	Age 50+ years
Hospital total	322,171,823 (13.7)	790,200,737 (33.7)	150,038,191 (6.4)	311,999,675 (13.3)	1,574,410,425 (67.1)
Ambulance	13,799,492 (0.6)	33,225,817 (1.4)	7,650,458 (0.3)	14,097,776 (0.6)	68,773,542 (2.9)
Community fracture management	11,188,565 (0.5)	15,864,557 (0.7)	5,424,421 (0.2)	6,919,843 (0.3)	39,397,386 (1.7)
Rehabilitation	27,540,242 (1.2)	235,534,461 (10.0)	9,005,572 (0.4)	63,673,123 (2.7)	335,753,398 (14.3)
Nursing home	0	61,981,786 (2.6)	0	20,504,990 (0.9)	82,486,776 (3.5)
Community services	9,449,127 (0.4)	41,573,333 (1.8)	210,425 (0.0)	10,758,147 (0.5)	61,991,032 (2.6)
Informal care	38,811,884 (1.7)	99,343,875 (4.2)	20,897,734 (0.9)	24,215,432 (1.0)	183,268,925 (7.8)
Total direct Cost	422,961,132 (18.0)	1,277,724,566 (54.5)	193,226,800 (8.2)	452,168,986 (19.3)	2,346,081,485 (100.0)

Note: Fracture management includes GP, physio, med spec, X-ray, pharmaceutical (pain relief, etc.), and supplements. Total direct cost includes informal care.

Table 4. Total Cost in AUD of Hip Fractures by Sex, Age Group and Cost Category in Australia for 2017

	Total cost for women $AUD (%)		Total cost for men $AUD (%)		Total $AUD (%)
Hip fractures	Age 50–69 years	Age 70+ years	Age 50–69 years	Age 70+ years	Age 50+ years
Hospital total	34,036,336	435,139,563	26,549,016	167,430,327	663,155,242
	(3.4)	(43.0)	(2.6)	(16.5)	(65.5)
Ambulance	1,177,140	12,465,618	951,506	5,095,523	19,689,788
	(0.1)	(1.2)	(0.1)	(0.5)	(1.9)
Community fracture management	843,311	4,849,128	625,767	3,065,488	9,383,693
	(0.1)	(0.5)	(0.1)	(0.3)	(0.9)
Rehabilitation	6,566,198	140,630,408	7,600,995	40,297,927	195,095,528
	(0.6)	(13.9)	(0.8)	(4.0)	(19.3)
Nursing home	0	40,203,163	0	19,861,292	60,064,455
		(4.0)		(2.0)	(5.9)
Community services	94,606	11,567,781	0	3,501,348	15,163,735
		(1.1)		(0.3)	(1.5)
Informal care	239,352	46,155,736	70,359	2,732,960	49,198,407
		(4.6)		(0.3)	(4.9)
Total Direct Cost	42,956,943	691,011,397	35,797,644	241,984,865	1,011,750,848
	(4.2)	(68.3)	(3.5)	(23.9)	(100)
Percentage of total direct cost for all fractures	1.8	29.5	1.5	10.3	43.1

Note: Fracture management includes GP, physio, med spec, X-ray, pharmaceutical (pain relief, etc.), and supplements. Total direct cost includes informal care.

Table 5. Total Cost in AUD of Wrist Fractures by Sex, Age Group, and Cost Category in Australia for 2017

	Total cost for women $AUD (%)		Total cost for men $AUD (%)		Total $AUD (%)
Wrist fractures	Age 50–69 years	Age 70+ years	Age 50–69 years	Age 70+ years	Age 50+ years
Hospital total	40,295,819 (24.5)	61,532,004 (37.4)	5,238,007 (3.2)	5,913,400 (3.6)	112,979,230 (68.8)
Ambulance	1,215,013 (0.7)	2,419,943 (1.5)	177,952 (0.1)	409,797 (0.2)	4,222,705 (2.6)
Community fracture management	1,910,265 (1.2)	2,472,267 (1.5)	211,847 (0.1)	234,520 (0.1)	4,828,900 (2.9)
Rehabilitation	3,468,462 (2.1)	20,877,942 (12.7)	74,070	1,288,985 (0.8)	25,709,459 (15.6)
Nursing home	0	4,791,079 (2.9)	0	35,496	4,826,575 (2.9)
Community services	133,016 (0.1)	2,139,423 (1.3)	0	38,156	2,310,595 (1.4)
Informal care	3,306,264 (2.0)	6,091,947 (3.7)	31,558	0	9,429,769 (5.7)
Total direct cost	50,328,839 (30.6)	100,324,607 (61.1)	5,733,433 (3.5)	7,920,354 (4.8)	164,307,233 (100)
Percentage of total direct cost for all fractures	2.1	4.3	0.2	0.3	7.0

Note: Fracture management includes GP, physio, med spec, X-ray, pharmaceutical (pain relief, etc.), and supplements. Total direct cost includes informal care.

Table 6. Total Cost in AUD of Vertebral Fractures by Sex, Age Group, and Cost Category in Australia for 2017

	Total cost for women $AUD (%)		Total cost for men $AUD (%)		Total $AUD (%)
Vertebral fractures	Age 50–69 years	Age 70+ years	Age 50–69 years	Age 70+ years	Age 50+ years
Hospital total	28,264,433	79,584,211	10,495,679	22,538,470	140,882,793
	(10.6)	(29.8)	(3.9)	(8.4)	(52.8)
Ambulance	2,894,108	8,457,902	1,178,742	1,360,241	13,890,993
	(1.1)	(3.2)	(0.4)	(0.5)	(5.2)
Community fracture management	1,775,868	3,131,270	559,766	764,523	6,231,427
	(0.7)	(1.2)	(0.2)	(0.3)	(2.3)
Rehabilitation	2,767,765	28,731,990	168,147	5,460,229	37,128,131
	(1.0)	(10.8)	(0.1)	(2.0)	(13.9)
Nursing home	0	6,593,429	0	150,362	6,743,791
	(0.0)	(2.5)		(0.1)	(2.5)
Community services	3,236,925	20,935,673	0	284,994	24,457,591
	(1.2)	(7.8)		(0.1)	(9.2)
Informal care	9,429,901	21,361,595	4,522,230	2,348,322	37,662,049
	(3.5)	(8.0)	(1.7)	(0.9)	(14.1)
Total direct cost	48,369,000	168,796,070	16,924,563	32,907,141	266,996,774
	(18.1)	(63.2)	(6.3)	(12.3)	(100)
Percentage of total direct cost for all fractures	2.1	7.2	0.7	1.4	11.4

Note: Fracture management includes GP, physio, med spec, X-ray, pharmaceutical (pain relief, etc.), and supplements. Total direct cost includes informal care.

Table 7. Total Cost in AUD of Other Fractures by Sex, Age Group and Cost Category in Australia for 2017

	Total cost for women $AUD (%)		Total cost for men $AUD (%)		Total $AUD (%)
Other fractures	Age 50–69 years	Age 70+ years	Age 50–69 years	Age 70+ years	Age 50+ years
Hospital total	219,575,234 (24.3)	213,944,958 (23.7)	107,755,489 (11.9)	116,117,478 (12.9)	657,393,160 (72.8)
Ambulance	8,513,230 (0.9)	9,882,354 (1.1)	5,342,258 (0.6)	7,232,215 (0.8)	30,970,057 (3.4)
Community fracture management	6,659,121 (0.7)	5,411,892 (0.6)	4,027,041 (0.4)	2,855,312 (0.3)	18,953,366 (2.1)
Rehabilitation	14,737,816 (1.6)	45,294,121 (5.0)	1,162,359 (0.1)	16,625,982 (1.8)	77,820,279 (8.6)
Nursing home	0	10,394,115 (1.2)	0	457,841 (0.1)	10,851,955 (1.2)
Community services	5,984,580 (0.7)	6,930,456 (0.8)	210,425	6,933,649 (0.8)	20,059,111 (2.2)
Informal care	25,836,367 (2.9)	25,734,596 (2.8)	16,273,587 (1.8)	19,134,150 (2.1)	86,978,701 (9.6)
Total direct cost	281,306,350 (31.2)	317,592,493 (35.2)	134,771,160 (14.9)	169,356,626 (18.8)	903,026,630 (100)
Percentage of total direct cost for all fractures	12.0	13.5	5.7	7.2	38.5

Note: Fracture management includes GP, physio, med spec, X-ray, pharmaceutical (pain relief, etc.), and supplements. Total direct cost includes informal care.

Fig. **1.** Total costs of osteoporosis, osteopenia, and fractures in 2017 by state