Osteoporos Int (2009) 20:1651–1662
DOI 10.1007/s00198-009-0925-y

REVIEW

Osteoporosis in China

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Received: 25 August 2008 / Accepted: 11 March 2009 / Published online: 5 May 2009

Abstract
Summary Based on related studies published between 1980 and May 2008, we examine the prevalence of osteoporoses in mainland China, Hong Kong, and Taiwan. Overall, the prevalence of osteoporosis among these Chinese populations remains low compared to other Caucasian populations; in the mainland, it was approximately 13%.
Introduction Osteoporosis is a significant public health problem and has received great attention in industrialized countries. However, limited is known in many developing countries including China, where aging and changing lifestyles likely contribute to increased osteoporosis. The objectives of the study is to examine the disease burden (prevalence) and time trends of osteoporosis in mainland China, Hong Kong, and Taiwan.
Methods Related studies published in English and Chinese between January 1980 and May 2008 were reviewed and analyzed.
Results The prevalence increased with age and varied dramatically based on local versus international diagnosis criteria. In the mainland, reported overall prevalence of osteoporosis based on nationwide surveys ranged from 6.6% to 19.3% (average=13.0%). The prevalence varied considerably across studies, and by regions, gender, and bone sites, but the urban to rural difference was small. In Hong Kong, the prevalence among women ≥50 years ranged from 34.1–37% in the spine; was 7% in the same aged men. In Taiwan, among those aged ≥50 years, average prevalence of osteoporosis was 11.4% in women and 1.6% in men.
Conclusions Future national programs need to monitor the burden of osteoporosis in China though available data indicate that the prevalence of osteoporosis remains low compared to that of other Caucasian populations.

Keywords Bone density · China · Hong Kong · Osteoporosis · Taiwan

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Introduction

Adequate calcium intake is important for bone health [1]. However, calcium intake inadequacy is a common nutrition problem worldwide and is a particularly serious problem in developing countries; those populations that have plant-based diets, including China. Osteoporosis is a condition in which bones become weak and more likely to break. The density of bones developed early in life, along with a healthy diet (in particular, with adequate intakes of calcium and vitamin D) and adequate physical activity throughout life, helps determine one's risk for osteoporosis [2, 3]. Osteoporosis has become a significant public health problem and has received great attention in industrialized countries. In the United States, osteoporosis affects approximately ten million

Americans; and more than 34 million have low bone mass, placing them at increased risk for osteoporosis [3, 4].

However, limited research has been conducted in many developing countries such as China, the most populous country. Considering the steady increase in people's life expectancy and the dramatic changes in lifestyles, such as changes in dietary intake and occupation (e.g., fewer people are engaged in farm work), reduced physical activity, increased sedentary behaviors, and reduced parity that have been happening in China over the past two to three decades, we suspect that osteoporosis may become more prevalent, and the prevalence may continue to increase in the near future. However, the improvements in people's awareness of health and dietary intakes in recent years may prove to slow this trend.

The present study is aimed to examine the prevalence of osteoporoses in China, the secular trends, and the differences between sociodemographic groups. We focused on mainland China, but also described the situation in Hong Kong and Taiwan based on limited data.

Methods

Literature search strategy

PubMed was searched for studies published between January 1, 1980 and May 15, 2008. Several keywords were incorporated in our search, including osteoporosis, bone density, China, Hong Kong, and Taiwan. We searched the related studies that provided the prevalence of osteoporosis for mainland China, Hong Kong, and Taiwan, respectively. In addition, related papers published in Chinese, mainly for mainland China, were searched using the same keywords as described above with the "Chinese Biology and Medicine Library" database, which is the most comprehensive biomedical research-related electronic database in China. Titles and abstracts of studies uncovered by the electronic searches were examined on screen first. Only studies that provided results regarding the prevalence of osteoporosis were included. In addition, some studies identified in the course of reading or brought to our attention by colleagues and experts consulted were included.

Study inclusion and exclusion criteria

Studies were included if they met the following criteria: (1) presenting sufficient detailed results about prevalence of osteoporosis; (2) having a sample size of greater than 300. Studies with smaller sample sizes were excluded because of concerns regarding their representativeness and the wide confidence intervals of their estimates (3) being cross-sectional or cohort studies. Related nationally representative data (e.g., census data) published in review articles were included; and (4) included subjects aged 20 years and over to estimate the prevalence in adults. Note that studies that included subjects younger than 20 years could still be included if pooled results for older subjects were reported. In such cases, whenever possible, we calculated the prevalence of osteoporosis for subjects aged 20 years and older based on reported results.

Our literature search resulted in a total of 1,100 studies in the first round of PubMed screening. After reviewing their titles and abstracts, 31 papers were further examined for exclusion and inclusion criteria, which resulted in 13 studies that met our inclusion criteria. Using a similar approach, we identified 15 papers published in Chinese that met our inclusion criteria, but two of them [5, 6] and another paper published in English [7] were found to be based on the same survey. Thus, only the study published in English was kept in our table [7].

In total, 26 studies were identified as meeting our inclusion criteria. Of them, 23 were about mainland China (21 cross-sectional studies and two review articles), one about Hong Kong, and two about Taiwan. Two were national or nationwide studies in mainland China. Of these 26 studies, 24 were cross-sectional studies, and the other two were review articles, but provided estimates of the prevalence of osteoporosis in China based on unpublished data. Of the 26 studies, 14 included both genders, 11 included women, one included only men.

Measurement techniques of bone mineral density and diagnosis of osteoporosis

Bone mineral density (BMD) measurement techniques include dual-energy X-ray absorptiometry (DXA), quantitative ultrasound (QUS), and single photon absorptiometry (SPA). Some studies classified osteoporosis using the WHO criteria, while others were based on the Chinese criteria. The WHO criteria were based on BMD cutoff values of less than 2.5 standard deviations (SD) below the young adult mean [8]. According to the Chinese criteria, patients with cumulative bone loss of more than 25% of the mean value of a young adult of the same sex were diagnosed with osteoporosis [9].

To describe the overall prevalence, we calculated the crude means and proportions by pooling findings from different studies when appropriate using Microsoft Excel.

Results

The prevalence of osteoporosis in mainland China

The reported prevalence of osteoporosis varied considerably across studies, by gender, age, diagnosis criteria, and bone sites (Table 1 and Fig. 1). Five studies [7, 9, 10, 17, 28] reported overall prevalence of osteoporosis in adult

Table 1 Characteristics and main findings of selected studies: osteoporosis in mainland China, Hong Kong, and Taiwan

Source	Location	Survey time	Subject, sample size, sex, age (years)	Measurement[a]	Diagnosis criteria[b]	Bone site[c]	Overall prevalence of osteoporosis[d]	Prevalence in those aged ≥50years	Notes
Mainland China									
Nationwide									
Liu et al. 1997 [9]	1994 census data	1994	Adults, age was not specified	DO based on "Liu's physiological age prediction method"	CC	NA	Overall PO=6.6%	NA	Results were reported in this review article
Li et al. 2002 [7]	Nationwide surveys of 5 major cities (Jilin, Sichuan, Shanghai, Beijing, Guangzhou)	1997–1999	5,593 men and women, 40–97 years	DXA	WHOC	L2–4, neck, Ward's, troch	Overall PO=16.1%; 11.5% in men (9.9% for L2–4; 8.3% for neck; 11.7% for Ward's; 11.8% for troch) and 19.9% in women (16.1% for L2–4; 19.3% for neck; 20.7% for Ward's; 11.8% for troch)	NA	Results were reported in this review article
Liu et al. 2002 [10]	2000 census data	2000	Adults, age was not specified	NA	NA	NA	Overall PO=7.0%	NA	Results were reported in this review article
Cheng et al. 2007 [11]	Nationwide survey of 6 cities (Beijing, Shanghai, Guangzhou, Chengdu, Nanjing, and Jiaxing)	2007[e]	8,142 women, 20–89 years	DXA	WHOC	L2–4, neck, Ward's, troch	NA	28% for the spine, 15% for any femur site, and 31% for any spine or femur site	
Local studies									
Li et al. 2001c [12]	North China (Beijing, Hebei province)	1997–1999	918 men and women, 40–89 years	DXA	WHOC	L2–4, neck, Ward's, troch	4.4% in men and 10.6% in women; 8.2% in urban area (men/women: 4.3%/11.5%) and 8.1% in rural area (men/women: 4.9%/10.5%)	4.6% in men and 11.8% in women	
Liao et al. 2002 [13]	Changsha City, Hunan province	2002[e]	2,702 women, 5–96 years; including 2,497 women, 20–96 years	DXA	WHOC		26.7%	40.7%	
Wu et al. 2003 [14]	Changsha and surrounding areas, Hunan province	1996–2002	2,728 women, 5–96 years	DXA	WHOC	AP spine, LS, Neck, Troch, intertrochanter, Ward's, Total hip, ultradistal forearm	NA	36.4% for AP spine; 53.7% for LS; 10.1% for neck; 18.3% for troch; 16.2% for intertroch; 48.2% for Ward's; 19.8%	

Table 1 (continued)

Source	Location	Survey time	Subject, sample size, sex, age (years)	Measurement[a]	Diagnosis criteria[b]	Bone site[c]	Overall prevalence of osteoporosis[d]	Prevalence in those aged ≥50years	Notes
								for total hip; 44.9% for ultradistal forearm	
Shen et al. 2004 [15]	Beijing	1999	2,429 postmenopausal women, 45–60	SPA	CC2	Left forearm	37.9%; 41.5% in urban area and 36.2% in rural area	NA	
Wu et al. 2004 [16]	Changsha City, Hunan province	1996–2003	3,406 women, 10–90 years; including 2,998 women aged 20–90 years	DXA	WHOC and CC	L2–4, neck, Ward's, troch	NA	Chinese vs. WHO criteria: PO (50–90y): 41.5% vs. 32.1% at the PA (posteroanterior) spine, 53.9% vs. 34.9% at the lateral spine, 34.2% vs. 16.3% at the femoral neck, 30.7% vs. 18.9% at the total hip, and 51.4% vs. 45.2% at the R+UUD.	
Bo et al. 2006 [17]	Huaian, Jiangsu province	2006[e]	884 men and women, 10–79 years; including 820 aged ≥20 years	QUS	Unmentioned	Calcanus	19.3%; 12.8% in men and 26.0% in women	20.6% in men and 40% in women	
Fang et al. 2006 [18]	Guixi, Guangxin province	2006[e]	415 men and women, 40–79 years	SPA	NA	Radio	29% in men and 42.8% in women	36.1% in men and 51.8% in women	
Gao et al. 2006 [19]	Jiangmen, Guangdong province	1999–2005	2,454 men and women, 20–89 years	DXA	CC	L2–4, Neck, Ward's, troch	19.2% in men and 25.2% in women	27.9% in men and 42.1% in women	
Hsu et al. 2006 [20]	Anhui Province (one of the poorest province in China)	2003	7,137 men and women, 25–64 y	DXA	WHOC	Whole-body and total-hip scans	2.2% in men, 1.8% in premenopausal women, and 12.4% in postmenopausal women	NA	
Liu et al. 2006 [21]	Zhanjiang, Guangdong province	2006[e]	344 women, ≥20 years	QUS	CC	Calcaneus	50.0%	59.10%	
Liu et al. 2006 [22]	Zhejiang province		2,769 men and women, 20–79	QUS	WHOC	Calcanus	6.9% in men and 11.3% in women	26.7% in men and 27.6% in women	
Meng et al. 2006 [23]	Liuzhou, Guangxi province	2006[e]	1,230 men and women, 40–88 years	DXA	CC	Femur neck	35.25% in men and 57.65% in women	41.1% in men and 65.2% in women	

Xiang et al. 2006 [24]	Guiyang, Guizhou province	2006[e]	803 women, ≥50 years	QUS	NA	Radius	48.7% in women	NA
Zhang et al. 2006 [25]	Shanghai (the largest and most economically developed city in China)	2006[e]	1,385 men, 20–89 years	DXA	WHOC	L2–4, top hip, neck, Ward's, troch	NA	5.4% for L2–4; 3.8% for top hip; 6.3% for neck; 1.8% for troch; 2.8% for intertroch
Zhang et al. 2006 [26]	Shenzhen, Guangdong province	2006[e]	419 men and women, 50–95 years, in rural area	DXA	CC	Forearm	29.2% in men and 50% in women	NA
Zhou et al. 2006 [27]	Ziyang, Sichuan province	2006[e]	1976 men and women, 20–95 years	QUS	WHOC	Right calcaneus	0.5% in men and 2.5% in women	0.76% in men and 3.2% in women
Jiang et al. 2007 [28]	Chongqing, Sichuan province	2004	1,801 men and women, ≥40 years	DXA	NA		Overall PO=16.1%	NA
Lu et al. 2007 [29]	Yinchuan, Nixia Province	2001–2003	971 postmenopausal women, aged ≥40 years	QUS	NA	Calcanus	28.0% in women	31.24% in women
Zhang et al. 2007 [30]	Guangzhou, Zhejiang province	2007[e]	470 women, 40–70 years	QUS	NA	Calcanus	9.4% in women, 3.2% in premenopausal and 12.5% in postmenopausal	NA
Hong Kong								
Lynn et al. 2005 [31]	Representative sample	2005[e]	3,207 men and women, 40–94 years	DXA	WHOC	L2–4, neck, Ward's, troch	2% at the LP site and 0% at the total hip in men aged 40–59; 9% at the LP site and 4% at the total hip in women aged 40–59	7% for spine and 6% for total hip in men; 37% for spine and 16% for total hip in women
Taiwan								
Yang et al. 2004 [32]	Representative sample	1994–1998	4,689 women, aged 20–80 years	DXA	WHOC	L2–4, neck, Ward's, troch	10.1% for L2–4; 7.5% for Neck	13.3% for L2–4; 14.4% for Neck
Yang et al. 2006 [33]	Representative sample	1999–2001	33,633 men and women, ≥50 years	DXA	WHOC	L2–4, neck, Ward's, troch	1.63% in men and 11.4% in women	1.63% in men and 11.4% in women

[a] *DO* diagnosis of osteoporosis, *DXA* dual-energy X-ray absorptiometry, *QUS* quantitative ultrasound (QUS), *SPA* single-photon absorptiometry

[b] *CC* Chinese criteria, *WHOC* WHO criteria

[c] *L2–4* lumbar spine 2–4, *neck* femoral neck, *AP spine* anteroposterior spine, *LS* lumbar spine, *R+UUD* radius and ulna ultradistal

[d] *PO* prevalence of osteoporosis

[e] Survey time was not reported, publication date was listed

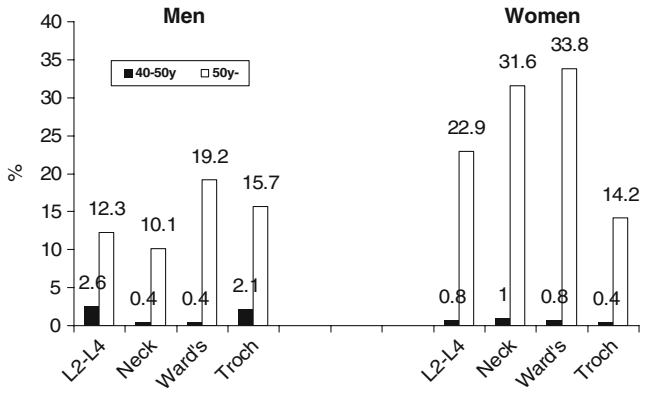

Fig. 1 Comparison of the prevalence (%) of osteoporosis by age, gender, and bone site measurements. Based on a 1997–1999 nationwide survey that included 2,523 men and 3,070 women aged 40–97 years from five major cities and provinces throughout China, namely, Jilin, Sichuan, Shanghai, Beijing, Guangzhou [7]. *L2–4* lumbar spine 2–4, *neck* femoral neck, *AP spine* anteroposterior spine, *LS* lumbar spine, *R+UUD* radius and ulna ultradistal

men and women aged 20 years and older, which ranged from 6.6% to 19.3%, with an average of 13.0%. For example, Fig. 1 shows considerable differences by age, sex, and measured bone sites based on a nationwide survey that included five cities and provinces [7].

Gender differences

Overall, these studies indicated large gender differences in the prevalence of osteoporosis; much higher in women than in men, by approximately 50%. Twelve [7, 12, 17–20, 22, 23, 26, 27, 31, 33] of the 15 studies [7, 9, 10, 12, 17–20, 22, 23, 26–28, 31, 33] included both men and women and provided gender-specific prevalence, which ranged 0.5–35.3% (crude average was 15.1%) in men (including the results of the other one study [25] that just included men subjects) and 2.5–57.3% (crude average was 29.90%) in women (including the results of the other ten studies [11, 13–16, 21, 24, 29, 30, 32] that only included women subjects). Such a big gender difference in mainland China was consistent with findings from other countries such as the United States: 3.8% in men versus 26.1% in women [3].

Age differences

Ten studies included both genders, and four studies among women provided age-specific prevalence. Compared with the overall prevalence, the prevalence was higher among those aged 50 years and over, both in men (0.75%~51.8%, average 22.4%) and women (3.2–65.2%, average 40.1%). Two studies [20, 30] reported the prevalence of osteoporosis in pre- and postmenopausal women, while another two studies [15, 19] only reported the prevalence in postmenopausal women. The prevalence in premenopausal women (1.8–3.2%) was much lower than that in postmenopausal women (9.4% to 37.9%). For example, Fig. 1 shows that the prevalence of osteoporosis was much lower among those aged 40–50 years old than that among those aged 50 years and older, by approximately 20–40 times [7].

Urban–rural differences

Although we suspected that the urban–rural difference in the prevalence of osteoporosis would exist in China due to the considerable differences in people's lifestyles, thus far, only three studies compared the prevalence, but did not show much difference. Only one study reported higher prevalence in urban women than rural women (Fig. 2), based on bone mass assessed in L2–4, 19.0% versus 13.9% [7]. The other two studies showed similar overall prevalence, one reported 41.5% versus 36.2% [15]; in the other, 8.2% versus 8.1% [12].

Regional differences

The limited available data suggested large regional differences in the prevalence. The average prevalence of osteoporosis reported in local studies was 13.0%, and 9.9% in the nationwide studies. One nationwide survey that included five major cities and provinces selected throughout China reported that osteoporosis prevalence varied considerably across the surveyed cities—osteoporosis prevalence in men was Jilin (15.5%)>Shanghai (14.2%)>Sichuan (11.3%)>Guangzhou (10.2%)>Beijing (5.2%). In women, it was: Jilin (24.5%)>Shanghai (21.0%)=Sichuan (21.0%)>Guangzhou (20.2%)>Beijing (11.8%) [7]. Consistently, the prevalence was the highest in Jilin in both men and women, which is located in North China where people may have much less exposure to sunshine, especially during the winter and fall seasons, while the prevalence in Beijing

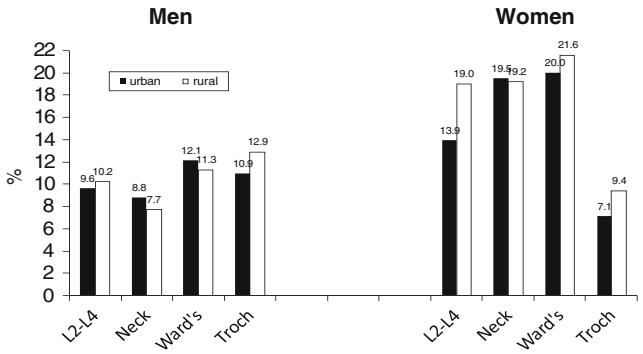

Fig. 2 Comparison of osteoporosis prevalence (%) in rural and urban areas. Based on a 1997–1999 nationwide survey that included 2,523 men and 3,070 women aged 40–97 years from five major cities and provinces throughout China, namely, Jilin, Sichuan, Shanghai, Beijing, Guangzhou. The urban–rural difference was not significant in men, but was significant in women ($p<0.05$) [7]

was the lowest (was only one third to one half of that in Jilin). We suspected that this might be due to people's higher calcium intake thanks to their better access to calcium-rich food and/or calcium supplements, although Beijing is also located in North China.

On the other hand, calcium intakes in Guangzhou and Beijing residents were similar based on China's 1992 and 2002 National Nutrition Survey [34, 35], although the prevalence in Guangzhou was higher than that in Beijing. Further research is needed to understand the underlying causes of these remarkable regional differences.

Time trends in the prevalence of osteoporosis

The available comparable data are limited to allow for a meaningful examination of the related time trend in China. Nevertheless, findings of the related nationwide and local surveys seemed to indicate an increase over time (see Table 1 and Fig. 3). For example, based on reported census data, the prevalence increased slightly from 6.6% in 1994 to 7.0% in 2000 [9, 10]. Two nationwide surveys reported that the prevalence in middle-aged women increased from 19.9% in 1997–1999 to 31.0% in the early 2000s, although which might also be due to their different osteoporosis diagnosis criteria (peak BMD and SD 1.14±0.119 vs 0.996 ±0.151 were used) [7, 11]. The mean *t* score of the 50- to 59-year group in Cheng's study was 44% lower than that of Li's study (−1.255 vs. −0.702), while percentage difference of the 50- to 59-year group in Cheng's study was only 19% lower than that of Li's study (−13.102 versus −10.643). The variations in SD may account for the difference of 44% versus 19%. Future research is needed to examine the time trends in the prevalence of osteoporosis in China based on nationally representative data.

The prevalence of osteoporosis in Hong Kong

The prevalence of osteoporosis among women 50 years and older ranged from 34.1% to 37.0% in the spine. In men aged 50 years and older, the prevalence of osteoporosis in the spine versus total hip was 7.0% versus 6.0%, respectively [31]. In addition, two studies reported fracture rate in men aged 50 years and older. One reported that 30.4% of subjects reported at least one low-trauma fracture after 50 years of age [36], while another study, which included 2,000 subjects aged 65–92 years old, reported that only 6.6% had a history of fracture after 50 years [37].

The prevalence of osteoporosis in Taiwan

Good data have been collected in Taiwan to examine the scope and time trend of the problem of osteoporosis based on representative samples (see Fig. 3b and c) [32, 33]. One study included both women and men [33], and the other included just women [32]. However, these two studies did not provide comparable data because one reported an overall prevalence of osteoporosis, where as the other provided the osteoporosis rates solely by skeletal site. A

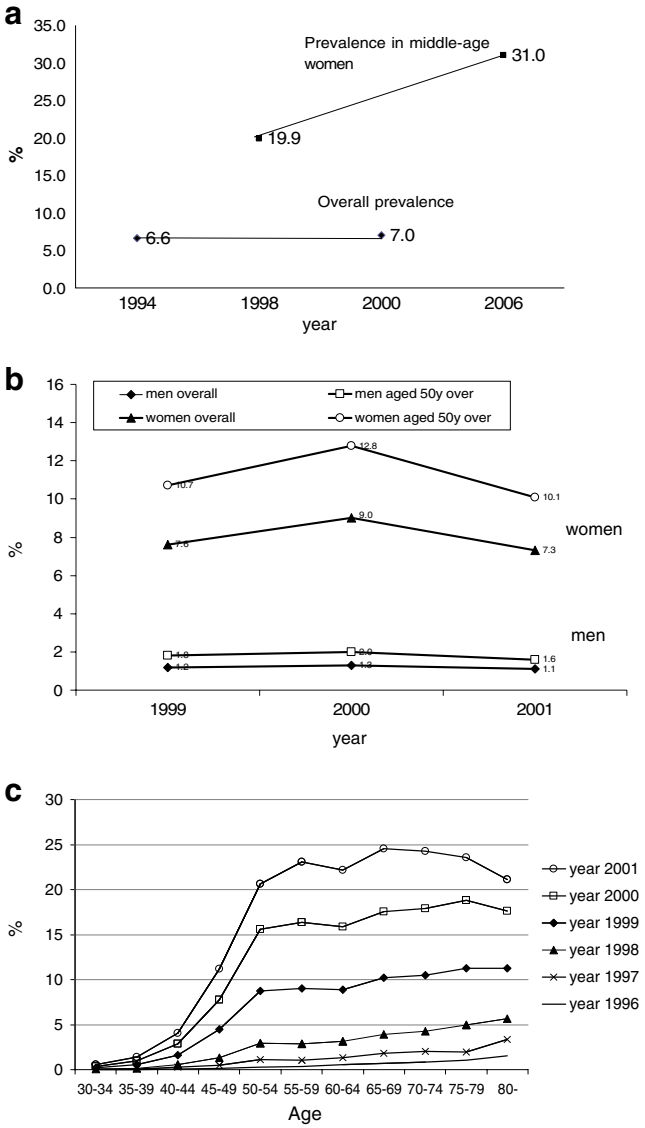

Fig. 3 Time trends in the prevalence (%) of osteoporosis in Mainland China and Taiwan. **a** Mainland China, based on two nationwide surveys [9, 10]. The prevalence of osteoporosis in middle-age women data were based on two other nationwide studies [7, 11]. One is a 1997–1999 survey that included 3,070 women aged 40–97 years from five major cities and provinces throughout China, namely, Jilin, Sichuan, Shanghai, Beijing, Guangzhou [7]; the other is a survey of six cities (Beijing, Shanghai, Guangzhou, Chengdu, Nanjing, and Jiaxing), which surveyed 8,142 women aged 20–89 years old [11]. **b** Taiwan, among adults by age and gender: 1999–2001. Based on Taiwan's National Health Insurance (NHI) database collected in 1999–2001, which included 33,633 men and women aged 50 years and over [33]. **c** Taiwan: time trends in age-specific prevalence, 1996–2001. Based on Taiwan's National Health Insurance (NHI) database [33]

recent study examined the prevalence of osteoporosis in 1996–2001 by sampling Taiwan's National Health Insurance (NHI) database, and used data from 102,763 men (51.3%) and 97,654 women (48.7%). The study showed a gender difference in the prevalence of osteoporosis based on the WHO criteria, e.g., among those aged 50 and over, it was 1.6% in men vs. 11.4% in women (Fig. 3b) [33]. The study also indicated an increase in the prevalence from 1996 to 2001 when analyses were stratified by age (Fig. 3c), although the prevalence seemed to be stable during 1999–2001 (Fig. 3b). However, we cannot rule out the possibility that the lower rates during the first 3 years of 1996–1998 might also be contributed by differences in data coding.

Influence of diagnosis criteria, measurement methods, and bone sites on the estimated prevalence of osteoporosis

Diagnosis criteria

The estimated prevalence of osteoporosis based on the Chinese versus WHO criteria differed considerably. For example, it was higher by approximately 10% to 100% according to the Chinese criteria, which varied by age and examined bone sites. Ten studies used WHO criteria, four used the Chinese criteria, and one used both, which allowed for a direct comparison [16]. Based on the data collected during 1996–2003 from approximately 3,000 women in Changsha City, Hunan province, Wu et al. [16] compared the differences in the estimated prevalence based on these two criteria (see Fig. 4)—compared with the WHO criteria, the prevalence of osteoporosis according to the Chinese criteria was 31% higher at the lumbar spine, 109% higher at the femoral neck, and 14% higher at the ultradistal forearm.

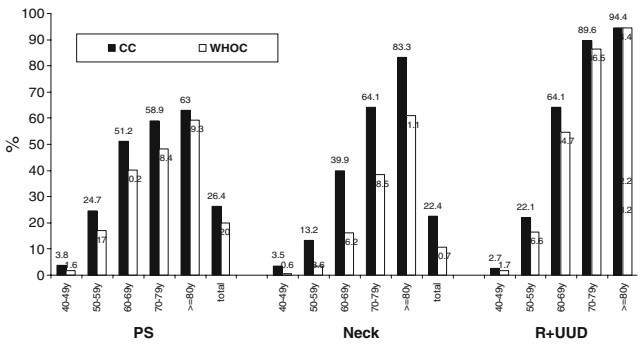

Fig. 4 Comparison of the prevalence of osteoporosis according to the Chinese and WHO diagnosis criteria: by age and bone sites. Based on data collected in Changsha City, Hunan Province in China from 1996 to 2003, which included 2,998 women aged 20–90 years [16]. *PS* posteroanterior, *neck* femoral neck, *R+UUD* radius + ulna ultradistal *CC* Chinese criteria, *WHOC* WHO criteria

Bone density measurement methods

The majority (15 studies, 62.5%) of the 24 cross-sectional studies assessed bone density using DXA, seven used QUS, and only two used single photon absorptiometry (SPA). The reported prevalence of osteoporosis in women ranged between 10.1% and 57.7% (average=28.6%) according to DXA measures; and 2.5–50% (average=24.6%) measured by QUS.

Bone sites

Six studies reported the prevalence by various bone sites simultaneously, and all reported the prevalence based on BMD in the spine, which ranged from 5.4% to 53.7% (average=26.1%). The prevalence of osteoporosis based on BMD in the spine was consistently the highest among different bone sites across all these six studies [7, 11, 14, 16, 19, 24].

Discussion

A few nationally representative studies have been conducted in mainland China to examine the osteoporosis prevalence, although some nationwide surveys provide some crude estimates. The present study examined the findings from 26 studies that met our study inclusion criteria, which provided the prevalence of osteoporosis in mainland China, Taiwan, and Hong Kong. These studies varied considerably regarding the regions covered, study samples (e.g., age and sample size), bone density measurement methods, diagnosis criteria (e.g., different *t* scores) and reference values (e.g., different peak BMD), which made it difficult to make meaningful across study comparisons. The available data indicate that the overall prevalence of osteoporosis in mainland China might be approximately 7% among all adults, 10–20% in urban areas, 22.5% among men aged 50 years or older, and 40.1% among women aged 50 years or older.

The aging of the population and lifestyle changes make osteoporosis a major public health problem throughout the world, not only in North America and Europe, but also in developing countries such as China. Nevertheless, the prevalence in China is still lower than that in industrialized countries such as the United Kingdom, where the prevalence among people aged 50 years or over was 55% in women and 68% in men [38]. In the United States, nationally representative data collected in 1988–1994 showed that the prevalence was 10.1% among people aged 50 years or over [3], 13–18% among older women, and 3–6% among older men [39]; while others estimated that almost 20% of US men aged

50 years or over had osteoporosis of the hip, spine, or wrist [40]. It was estimated that roughly four in ten white US women aged 50 years or older will experience a hip, spine, or wrist fracture sometime during the remainder of their lives [3].

Osteoporosis is the most common generalized disease of the skeleton. It is the result of biological, behavioral, and environmental factors. Genetics, gender, age, and postmenopausal status are common biological factors. While low-calcium diet, less exercise, less outdoor activity, smoking, and high alcohol consumption are behavioral and environmental factors [3]. Similar to findings from other countries, our analysis of the data in China indicated a large gender difference in the prevalence of osteoporosis. Overall, the prevalence was much higher among Chinese women (≥50 years) than men (40% versus 22%). Previous studies conducted in the U.S. showed that American women were four times as likely as men to develop osteoporosis. In fact, 80% of osteoporosis patients in the US are women [4].

Age is an important predictor of osteoporosis. In adult women, bone mineral density changes little until the onset of menopause when estrogen levels decline and FSH levels increase. Postmenopausal women continue to lose bone mass obviously. Our analysis shows that the average prevalence of osteoporosis in Chinese adults aged 50 years and over was 22.4% in men and 44.1% in women, which was much higher than the overall prevalence. Thus, older women are a key group that needs screening for osteoporosis.

There are many large urban–rural differences in people's lifestyles in China, which affect people's dietary intake and physical activities, which might in turn affect their risk of osteoporosis. However, to our surprise, the available data do not suggest clear rural–urban differences in the prevalence. One may suspect that rural residents have a higher prevalence because they have lower consumption of dairy products or other calcium-rich foods, while it is also true that rural residents are more active and are more likely to participate in outdoor activities and thus have more exposure to sunshine. Only one of the three studies that compared the urban–rural difference reported a slightly higher prevalence in urban women than their rural counterparts ($p<0.01$). Another study reported that rural women had lower BMD than their urban counterparts across all skeletal sites [41], but the researchers did not report the prevalence of osteoporosis. Calcium consumption and exercise are two important predictors for osteoporosis. In China, usually urban residents have higher calcium intake from foods and calcium supplements, while rural residents participate in more physical activities and outdoor activities. Future larger scale studies are needed to examine the urban–rural differences.

The estimated prevalence of osteoporosis based on the Chinese versus WHO criteria differed considerably; estimated prevalence based on the Chinese criteria could be 20–50% higher (see Fig. 3) [16]. Some researchers have argued that the WHO criteria might not be suitable for the Chinese. For example, a comparison of DXA data from studies in China and elsewhere demonstrated that the peak bone mass of the Chinese was 5–15% lower than that of Caucasians [42]. It has argued that lower BMD cut points should be used in China [10, 11, 16]. For example, patients with cumulative bone loss of more than 25% of the mean value of a young adult of the same sex in China are diagnosed as having osteoporosis, as per Chinese criteria [11].

Comparable data are very limited to examine the time trend in the prevalence of osteoporosis in mainland China, but findings from related nationwide and local surveys seem to indicate an increasing trend. Better data are available in Taiwan and show that the prevalence has increased steadily between 1996 and 2001, especially among older people [33]. The increased osteoporosis prevalence is likely due to population aging and people's changing lifestyles; for example, reduced physical activity.

Considering the large population size and the many factors that are likely to contribute to the increase in osteoporosis in China, the related health and financial consequences of osteoporosis could be enormous. Table 2 shows some related findings regarding fracture in Mainland China, Hong Kong, and Taiwan. For example, a large nationwide study in mainland China included 48,164 subjects aged 50 years and older who answered questions and performed lateral spine X-ray test on 10% of the subjects. The study reported a prevalence of fractures of 26.6% [43]. A local study conducted in Chongqing City reported a prevalence of 14% [28]. The frequency of fractures increases with a decrease in t score values [44]. Results of prospective studies showed that almost all types of fracture were increased in patients with low bone density [45]. In Hong Kong, we found two studies having reported fracture rates. One reported that 30.4% of men aged ≥50 years reported at least one low-trauma fracture [36], while the other reported that 6.6% had a history of fracture after 50 years [37]. The big difference might be due to differences in their study samples and data collection procedures.

Taiwan reported a prevalence of vertebral fracture of 18% in women and 12% in men [33]. Another study examined the incidence rate of hip fracture from 1996 to 2000 in Taiwan based on an inpatient database of the National Health Insurance Program, and reported similar high rates compared to those the United States. The database provided data for 54,199 patients, who had a first-time admission for a diagnosis of hip fracture on discharge from January 1996 through December 2000 and aged 50–100 years. The age-adjusted incidence rates (per 100,000, 95% confidence interval) of hip fracture in Taiwan

Table 2 Characteristics and main findings of selected studies regarding fracture in mainland China, Hong Kong, and Taiwan

Source	Location	Subject, age (year)	Outcome assessment	Main findings
Mainland China				
Meng et al. 2005 [16]	Nationwide	NA, aged 50 years and over	NA	Prevalence of vertebral fracture ranged from 13.3% to 16.2%
Li et al. 2003 [43]	Nationwide sample from 5 major cities (Jilin, Sichuan, Shanghai, Beijing, Guangzhou)	47,985 men and women, aged 50–108 years	Questionnaire and 1/10 took the X-ray test	Prevalence of fracture was 26.6%
Shen et al. 2004 [15]	Beijing	2,429 postmenuporal women, aged 45-60 y	Questionnaire	Bone fracture rate was 5.9%, 7.5% in urban areas and 5.1% in rural areas
Jiang et al. 2007 [28]	Chongqing	1,801 men and women, aged 40 years and over	DXA	Total osteoporotic fracture rate was 14%, 10.6% in men, 21.4% in women
Hong Kong				
Cheung et al. 2005 [36]	Hong Kong	407 males, aged 50 y and over, mean age 68.4 (10.4) years	DXA	30.4% of subjects reported at least one low-trauma fracture after 50 years old
Lau et al. 2006 [37]	Hong Kong	2000 men, 65-92y	DXA	6.6% had a history of fracture after 50 years old
Taiwan				
Tsai 1997 [46]	Representative sample	NA, 65 years and older	NA	Prevalence of vertebral fracture was 18% in women and 12% in men
Chie et al. 2004 [47]	Representative sample	54,199 patients aged 50–100 years	Hospital diagnosis	Age-adjusted incidence (95% CI, per 100,000) of hip fracture was 225 (188–263) in men and 505 (423–585) in women (adjusted to US white population of 1989, compared with US white rate of 187 in men and 535 in women)

were 225 (188–263) in men and 505 (423–585) in women (adjusted to US white population of 1989, compared with US white rate of 187 in men and 535 in women) [47]. These data demonstrate the impact of osteoporosis and fractures in China in the near future with the rapid aging of the population and changes in people's lifestyles.

The financial and health consequences of osteoporosis can be enormous. Although to our knowledge, no published studies have examined the total national economic cost of osteoporosis in China, it was estimated that each hip fracture may cost approximately US $1,200 to $4,000 in China based on local data, which varied between urban and rural areas, across regions, and increased over time [48, 49]. For example, one study examined the health care cost of osteoporotic fractures in a hospital in Shanghai, the largest city in China. Based on data collected during 2000–2004, the average hospital stay was 22 days, and the average total cost was around 11,967 Chinese yuan (about US $1,710) with an average yearly increase of 6.5% [49]. In the United States, it is estimated that osteoporosis results in 1.5 million fractures each year and lead to more than half a million hospitalizations, over 800,000 emergency room encounters, more than 2,600,000 physician office visits, and the placement of nearly 180,000 individuals into nursing homes. Annual direct care expenditures for osteoporotic fractures range from $12 to $18 billion per year in 2002, while indirect costs (e.g., lost productivity) would likely add up to billions of dollars [2]. Furthermore, it is projected that that these costs could double or triple in the coming decades [2, 3]. The U.S. Surgeon General's Report on Bone Health and Osteoporosis states that, by 2020, half of all Americans over age 50 will be at an increased risk for fractures from osteoporosis and low bone mass if no immediate steps are taken [3].

Our study has several limitations. Most of the involved studies were based on local, selective study samples, which may not be representative of the prevalence of osteoporosis in China. In addition, the differences between study samples, in related assessment and diagnosis criteria make it difficult to compare the related findings across studies. Nevertheless, to our knowledge, this is the first such comprehensive investigation to examine the osteoporosis problem in China, which could help provide many important insights for future research and related public health efforts to address the growing osteoporosis problem in China.

Future national studies are needed to monitor the burden of osteoporosis in China although overall, available data indicate that the current prevalence remains lower than that of other industrialized countries. Considering the aging

population, longer life expectancy, and many dramatic changes in people's lifestyles during recent years in China, the prevalence of osteoporosis in China is likely to increase in the near future. More effort should be made to increase people's awareness and knowledge regarding osteoporosis and to promote good bone health.

Acknowledgements The study was supported in part by the Johns Hopkins Center for a Livable Future. Yexuan Tao is a postdoctoral research fellow at Johns Hopkins Bloomberg School of Public Health and is supported in part by a fellowship provided by Shanghai Jiao Tong University Xinhua Hospital. Melanie E. Hyman was supported by the Johns Hopkins Bloomberg School of Public Health 2007 Diversity Summer Internship Program (DSIP). The authors declare no conflicts of interest.

Conflicts of interest None.

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