Reference values of bone mineral density and prevalence of osteoporosis in Chinese adults

Z-Q. Zhang · S. C. Ho · Z-Q. Chen · C-X. Zhang · Y-M. Chen

Received: 26 November 2012 / Accepted: 10 June 2013
© International Osteoporosis Foundation and National Osteoporosis Foundation 2013

Abstract

Summary We pooled bone mineral density (BMD) data published in 91 articles including 139,912 Chinese adults and then established a national-wide BMD reference database at the lumbar spine and femur neck for Chinese adults. The prevalence of osteoporosis in the middle-aged and elderly Chinese population was also estimated.

Introduction Well-accepted reference value of BMD is lacking in Chinese. We established the reference database and assessed osteoporosis prevalence based on published literature conducted in the Mainland China, Taiwan, and Hong Kong Chinese.

Methods We searched for all published articles indexed in MEDLINE, PubMed, CNKI, and SinoMed up to January 2013. We included cross-sectional studies that examined BMD using a dual-energy X-ray absorptiometry at the femur neck (FN) and/or lumbar spine (LS) in healthy adults. Overall age-specific mean (SD) BMD were pooled after standardization.

Results Ninety-one studies including 51,906 males and 88,006 females (≥20 years) in 38 cities in China were included in this pooling study. Gender- and age-specific reference curves of standardized BMD (sBMD) at the LS and FN were constructed. The sBMD cutoffs for osteoporosis classification were 0.746 and 0.549 in women, and 0.680 and 0.568 g/cm² in men; age-standardized prevalence of osteoporosis was 23.9 % and 12.5 % in women and 3.2 % and 5.3 % in men aged ≥50 years at the LS and FN, respectively. Meta-regression analysis showed that greater age and altitude, lower latitude, smaller city size, earlier detection time, and random sample were correlated to lower sBMD in at least one gender-specific bone sites; the Hologic DXA produced a higher value of FN sBMD than the other two devices (Lunar and Norland).

Conclusion We have established a national-wide BMD reference database at the LS and FN for Chinese adults and estimated the prevalence of osteoporosis in the middle-aged and elderly Chinese population.

Keywords Bone mineral density (BMD) · Chinese · DXA · Osteoporosis · Pooling analysis · Reference value

Introduction

Bone mineral density (BMD) measurements obtained by dual-energy X-ray absorptiometry (DXA) has been proved to be an effective method for diagnosing osteoporosis and assessing the risk of fragility fracture [1]. According to the definition given by World Health Organization (WHO), osteoporosis is defined as BMD 2.5 SD (T-score<−2.5) or more below the normal young adult mean (peak bone mineral density, pBMD) [2]. The International Osteoporosis Foundation (IOF)/WHO study group has recommended reference database of femoral neck BMD in white women aged 20–29 years based on the Third National Health and Nutrition Examination Survey (NHANES III) [3] for application in women or in men worldwide [4]. However, due to...
the facts of the varied BMD between different sexes and ethnicities [5–7], previous studies demonstrated that the application of this recommended reference might lead to misclassification of osteoporosis among other ethnicities [8] as well as in men [9]. Thus, extension of the applicability of this criteria among Chinese population might be also problematic because a lower hip fracture rate but much lower BMD was observed in Chinese than in American Caucasians [3, 6, 10, 11]. Additionally, the T-score at femur neck cannot be used interchangeably at lumbar spine [4], which has also been widely raised for the diagnostic use in clinical practice [12]. Establishing appropriate ethnic and gender-specific BMD reference values would be required for the interpretation of individual values and identification of subjects with osteoporosis.

Two studies based on relatively large sample have reported the BMD reference values for the Chinese population [6, 10]. One study performed by Cheng et al. [6] provided age-related BMDs of female by pooling 8,142 women's records from the existing historical data of several institutions. Another study undertaken by Zhu et al [10] have reported gender-specific references through the cross-calibration of BMD data measured by Hologic and Lunar systems among 3,409 men and 3,633 women. However, the reference samples of these two studies were drawn only from 6 [6] and 10 [10] cities. As China is a country with vast territory and large population, the limited coverage of the study samples would underestimate the variability of the BMD data. The sample sizes were also limited among certain age groups, especially for the young [6] or older adults [10] in the two cited studies. Only 4.2% of the female population in the study of Cheng et al. [6] belonged to the 20–29-year age group, while nearly 50% of the subjects were of the age group 20–29 years in the study by Zhu et al [10]. This may undermine the estimations of pBMD and the prevalences of osteoporosis in the Chinese population. However, more than 350 DXA systems have been in operation in different regions across China [6]. Age- and sex-specific BMD data obtained from nearly 140,000 individuals and from 25 (38 cities) of the 34 provincial-level regions of China have since been reported [13–21]. Many of these studies have provided reference values of normal BMD for their study populations. Pooling these BMD data would help to establish national-wide BMD reference values.

The purpose of this study is to establish a normal BMD reference database based on published data in the Chinese people from wide geographical areas in China, including mainland China, Taiwan, and Hong Kong and to estimate the prevalence of osteoporosis based on the reference value in Chinese people aged 50 years and over.

Materials and methods

Identification of studies

We searched for all published articles indexed in China National Knowledge Infrastructure (CNKI) database and SinoMed up to January 2013 and searched for all published articles indexed in OVID MEDLINE and PubMed database from 1966 to January 2013. We use the following terms as key words in title, abstract: (1) bone mineral, bone density, bone content, BMD, BMC, or osteoporosis*; (2) DEXA, DXA, or dual X-ray energy; (3) total body, whole body, spine, hip, or neck; (4) intervention, trial, random*, allocat*, treat*, therapy, case–control, cohort, follow-up, prospective, CT, or, QCT; (5) Chinese or China or Hong Kong or Taiwan or Taiwanese or Taipei, (6) [(1) and (2) and (3) and (5)] not (4). Studies written in either English or Chinese were accepted.

Inclusion and exclusion criteria

Studies that have fulfilled the following criteria were included: (1) be a cross-sectional study aimed to assess the normal BMD; (2) study participants were apparently healthy, aged 20 years or older; (3) study participants were recruited from a random sample, or volunteers from local communities, or those attending routine health examination; (4) sex-specific BMDs (SD) were reported by age groups at intervals of either 5 or 10 years; (5) BMD was measured using Hologic, Lunar, or Norland DXA scanners; and (6) the skeletal sites measured included lumbar spine and/or proximal femur neck.

Studies were excluded if: (1) subjects had any disease or medication known to affect bone metabolism; (2) study participants were those who had one or more specific diseases (e.g., diabetes, kidney diseases, osteoporosis, fractures, etc.), or regular exerciser, or had a special occupation (e.g., police, armyman, athlete, or workers exposed to hazardous and noxious substances or environments); (3) they were duplication of published data. Among each sex- and age-specific group, we excluded outliers defined as individual mean values of each original study exceeding three standard deviations of these individual values from the pooled mean.

We assumed that the publications were generated from the same study if they were conducted by the same research group based on the same setting and time and had the same study population. For these multiple publications of the same studies, only publications which included the whole study population were included. For the multicenter studies, individual data, rather than the pooled data, were used when available.
Data extraction and assessment of study quality

We extracted the following information from each eligible study: title, authors, year and source of publication, study setting, source of participants, sampling methods, criteria of enrollment, study size at each age group; name and type of the DXA system; bone mass values included sex- and age-specific BMD and SD at the lumbar spine and femur neck. No additional information were further obtained from individual authors.

Statistical analysis

Most studies reported BMD (SD) by age groups at intervals of 5 or 10 years. We combined the BMD data into standard 10-year age groups (20–29, 30–39, …, 70–79 and 80+) if the median age of two or more groups were within the specified 10-year age group overall mean and SD of each standard age group was calculated based on the means and SDs of all eligible studies based on the equations:

\[
\text{Combined Mean BMD} = \left( \frac{n_1 \cdot M_1 + n_2 \cdot M_2 + n_3 \cdot M_3 + \ldots + n_i \cdot M_i}{n_1 + n_2 + n_3 + \ldots + n_i} \right)
\]

where, \( n_i \) and \( M_i \) are the number of subjects and mean value of the group/study \( i \).

\[
\text{CombinedSD}^2 = \left[ \left( A_1 + A_2 + A_3 + \ldots + A_i \right) - (M_1 \cdot n_1 + M_2 \cdot n_2 + M_3 \cdot n_3 + \ldots + M_i \cdot n_i)^2 \right] / (n_1 + n_2 + n_3 + \ldots + n_i) \]

\[
A_i = \frac{\sum x^2}{n_i} = \text{SD}^2 \left( \frac{n_i}{n_i - 1} \right) + \frac{M_i^2}{n_i}
\]

\[
\text{CombinedSD} = \left[ \sum A_i - \frac{\left( \sum (M_i n_i) \right)^2}{N} \right] / \left( N - 1 \right)
\]

SD\( \text{i} \) stands for standard deviation value of the group or study \( i \).

Because of variation of BMD values among different densitometers, we calculated standardized BMDs (sBMD) at the proximal femur using the following equations [22]:

For Hologic instruments : Standardized BMD (sBMD) = 1.087 × BMD\text{Hologic} + 0.019
For Lunar instruments : Standardized BMD (sBMD) = 0.939 × BMD\text{Lunar} - 0.023
For Norland instruments : Standardized BMD (sBMD) = 0.985 × BMD\text{Norland} + 0.006

and we computed the standardized BMDs for the lumbar spine using the equations recommended by the International Dual X-Ray Absorptiometry (DXA) Standardization Committee (IDSC) [23] as follows:

For Lunar : Standardized BMD (sBMD) = 0.9683 × (BMD\text{Lunar} - 1.100) + 1.0436
For Norland : Standardized BMD (sBMD) = 0.9743 × (BMD\text{Norland} - 0.969) + 1.0436
For Hologic : Standardized BMD (sBMD) = 1.0550 × (BMD\text{Hologic} - 0.972) + 1.0436

The cross-calibration equations of lumbar spine were derived from the measurements at the L2–L4 in the anteroposterior. In addition, the BMD value at the L2–L4 was slightly higher than those at the L2–L4 which may lead to an underestimation of the sBMD at the L2–L4 sites [24]. We converted the BMD values of L1–L4 to L2–L4 by using a regression equation (BMD_{L2-L4} = 1.034 × BMD_{L1-L4} + 0.002) developed from our previous BMD data of 430 people detected by Hologic DXA (DQR 4500) (the coefficient value between the predicted value and the observed value was 0.996, \( P<0.001 \)) [25].

The sex-specific peak BMDs (pBMDs) and related SDs at the lumbar spine and femur neck were obtained based on the sBMD data. Osteoporosis was defined as T-score≤−2.5 in accordance with the WHO criteria [26]. Prevalences of osteoporosis in each age group of 50 years or older were estimated using the functions of “Cumulative Distribution Functions.
(CDF). Normal" in the SPSS, assuming that BMD follows the normal distribution in this population. The sex- and age-specific numbers of osteoporosis were also calculated according to the distribution of 2009 population in China [27].

The age-related sBMD reference plots at different skeletal regions in both sexes were constructed using the pooled mean±2SD. According to the recommended formulas aforementioned, we also standardized the BMD reference database of non-Hispanics (NHANES 2005-2008) [28], Korean [5], and Japanese [29] to 10-year interval age-specific standard BMD in order to make comparison of the sBMD from different ethnicities.

Meta-regression was performed to assess the independent association of median age, types of instrument (Hologic/Lunar/Norland), latitude, altitude, city size, methods of sample selection, and the detection time with sBMD. We used the median of the study period or the publication time (if study time was unavailable) to indicate the detection time.

EXCEL, SPSS 13.0, and Stata 10.1 software were used for conducting the statistical analyses.

Results

Search results and study characteristics

Figure 1 shows the detailed process of study selection. We screened 2,571 potentially relevant publications. Ninety-one eligible articles containing 139,912 participants were involved in the estimation of the overall BMD values; among these studies, 71,583 women and 46,476 men had BMD values at the lumbar spine, and 67,161 women and 38,809 men had the neck BMD data. BMD was reported by intervals of 10 years in 42 studies, and 5 years in 49 studies. Sixty-one, 17, and 13 studies had respectively BMD values using the Lunar, Hologic, and Norland densitometry. Lumbar spine BMD values in 23 studies were measured at the vertebral bodies of L₁–L₄ postero-anterior. Study subjects were randomly selected in 24 studies, but convenience samples (volunteers from local populations or attendees of routine health checks) were used in 49 studies. Seventeen studies did not report detailed methods of sample selection. One study included both random samples and volunteers. The studies covered 38 cities in 25 of 34 provincial-level regions of China (Fig. 2). The correlation coefficients between the number of study sample and those of the source population at each provincial regions were 0.647 for female (P<0.001) and 0.568 for male (P<0.001). For more details of the characteristics of the included studies, please refer to the supplemental Table 1.

Age-related changes in BMD

The pooled mean (SD) BMD values by sex and age groups are shown in Table 1, Fig. 3, and supplemental Fig. 1. The peak sBMD based on the age group of 30–39 years were 1.088 g/cm² (LS) and 0.865 g/cm² (FN) in women. For men, the peak sBMD based on age group of 20–29 years were 1.066 g/cm² (LS) and 0.928 g/cm² (FN). The cutoffs of sBMD for osteoporosis diagnosis (T≤−2.5SD) were 0.746 and 0.549 g/cm² at the lumbar spine and 0.568 and 0.549 g/cm² at the femur neck in women and men, respectively (Supplemental Table 2). As compared to the relevant peak BMD, BMDs at the lumbar spine were respectively lower by 14.2 %, 22.5 %, 26.2 %, and 28.8 % in women and 4.4 %, 6.6 %, 8.2 %, and 11.6 % in men, while femur neck BMD were lower by 11.2 %, 21.1 %, 27.0 %, and 32.1 % in women and 11.1 %, 14.9 %, 19.3 %, and 23.2 % in men in the age groups 50–59, 60–69, 70–79, and 80 years and over (Table 2).

Prevalence of osteoporosis

Age-standardized prevalences of osteoporosis in those aged 50 years and over were 23.9 % and 12.5 % in women and 3.2 % and 5.3 % in men, respectively, at the lumbar spine and femur neck. The estimated prevalences adjusted by the WHO world standard population [30] were 24.6 %, 13.3 % in women and 3.5 %, 5.9 % in men, respectively. About one third of the women aged 60–69 years and half of those aged 70 years or over had osteoporosis. Much lower prevalences of osteoporosis were observed in men of similar age groups (Table 2).
Comparison of BMD of among different countries

Age-related sBMD values from others ethnics [5, 28, 29] were grouped into the standard age categories and made comparison with our data. In general, non-Hispanic Whites (NHANES 2005–2008) had greater BMD values than those in Japan, Korea, and our population. Chinese had the lowest sBMD values among the selected ethnic populations (Fig. 4).

Meta-regression analyses

Meta-regression analyses were conducted to explore the potential sources of heterogeneity for the standardized BMD values. Results showed that the average decrease of BMD per 10 years were 0.063 and 0.054 g/cm² in women and 0.023 and 0.041 g/cm² in men at the lumbar spine and femur neck, respectively. Smaller city size and random sample tended to have lower sBMD at the two sites in females and at the femur neck in males. The altitude exerted negative effects on the femur neck BMD in males. The pencil- and fan-beam Hologic DXA produced a higher value of femur neck BMD in females and males (fan-beam only) than the other two devices (Lunar and Norland) (Supplemental Table 3).

Discussion

Our study pooled the BMD data from 91 cross-sectional studies with measurements obtained from the three common DXA systems. According to the pooled BMD data, we established national-wide BMD reference values for Chinese adults and estimated prevalences of osteoporosis in Chinese adults aged 50 years and over. Our findings provided substantial reference data for the evaluation of bone health and the diagnosis of osteoporosis for individuals and groups of the Chinese population.

Our study had several strengths. The study included the BMD data of 51,906 males and 88,006 females. The substantial study samples size would greatly improve the precision of the reference value and the estimated prevalences of osteoporosis. The study had a wide coverage of various regions and good representation of the Chinese populations.
Study participants coming from 38 cites were distributed in 25 (76%) provincial-level regions containing nearly 75.5% [27] of the total population in China. The study size in each provincial region was significantly correlated to the size of its population. In addition, we only pooled studies of which study populations were random samples or community-based or attendees of routine health examinations. The participants were apparently healthy people; 95% studies excluded subjects with potential diseases or treatment or with special occupations that would affect bone mineral metabolism. These measures would improve the representativeness of the study participants of the general population.

### Table 1  
Observed and standardized BMD (grams per centimeter squared) at the lumbar spine and femur neck in Chinese women and men

<table>
<thead>
<tr>
<th>Age group</th>
<th>Observed BMD</th>
<th>Standardized BMD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hologic</td>
<td>Lunar</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
</tr>
<tr>
<td>Female lumbar spine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–29</td>
<td>1,134</td>
<td>1.061</td>
</tr>
<tr>
<td>30–39</td>
<td>1,358</td>
<td>1.090</td>
</tr>
<tr>
<td>40–49</td>
<td>2,409</td>
<td>1.055</td>
</tr>
<tr>
<td>50–59</td>
<td>2,507</td>
<td>0.932</td>
</tr>
<tr>
<td>60–69</td>
<td>2,838</td>
<td>0.846</td>
</tr>
<tr>
<td>70–79</td>
<td>1,583</td>
<td>0.826</td>
</tr>
<tr>
<td>80+</td>
<td>423</td>
<td>0.871</td>
</tr>
<tr>
<td>Total</td>
<td>12,252</td>
<td>53,097</td>
</tr>
<tr>
<td>Female neck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–29</td>
<td>1,134</td>
<td>0.880</td>
</tr>
<tr>
<td>30–39</td>
<td>1,358</td>
<td>0.886</td>
</tr>
<tr>
<td>40–49</td>
<td>2,327</td>
<td>0.789</td>
</tr>
<tr>
<td>50–59</td>
<td>2,253</td>
<td>0.694</td>
</tr>
<tr>
<td>60–69</td>
<td>2,659</td>
<td>0.641</td>
</tr>
<tr>
<td>70–79</td>
<td>1,494</td>
<td>0.569</td>
</tr>
<tr>
<td>80+</td>
<td>409</td>
<td>0.871</td>
</tr>
<tr>
<td>Total</td>
<td>11,634</td>
<td>50,684</td>
</tr>
<tr>
<td>Male lumbar spine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–29</td>
<td>681</td>
<td>1.073</td>
</tr>
<tr>
<td>30–39</td>
<td>796</td>
<td>1.072</td>
</tr>
<tr>
<td>40–49</td>
<td>1,015</td>
<td>1.058</td>
</tr>
<tr>
<td>50–59</td>
<td>1,233</td>
<td>1.044</td>
</tr>
<tr>
<td>60–69</td>
<td>1,493</td>
<td>1.018</td>
</tr>
<tr>
<td>70–79</td>
<td>887</td>
<td>0.995</td>
</tr>
<tr>
<td>80+</td>
<td>119</td>
<td>1.020</td>
</tr>
<tr>
<td>Total</td>
<td>6,224</td>
<td>35,500</td>
</tr>
<tr>
<td>Male neck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–29</td>
<td>690</td>
<td>0.963</td>
</tr>
<tr>
<td>30–39</td>
<td>805</td>
<td>0.924</td>
</tr>
<tr>
<td>40–49</td>
<td>1,011</td>
<td>0.903</td>
</tr>
<tr>
<td>50–59</td>
<td>1,110</td>
<td>0.860</td>
</tr>
<tr>
<td>60–69</td>
<td>1,211</td>
<td>0.822</td>
</tr>
<tr>
<td>70–79</td>
<td>706</td>
<td>0.789</td>
</tr>
<tr>
<td>80+</td>
<td>129</td>
<td>0.753</td>
</tr>
<tr>
<td>Total</td>
<td>5,662</td>
<td>30,186</td>
</tr>
</tbody>
</table>

*a Peak BMD"
Comparison with the previous reports

A recent study by Zhu et al [10] pooled the BMD data of 7,042 healthy adults drawn from ten cities in an effort to establish BMD reference data for Chinese adults. The age-specific sBMD at the femur neck of males and females were 0.2–6.4 % and 4.9–9.9 %, respectively, lower than those in our study. Similar results were observed at the lumbar spine. Variations in equations used for cross-calibration and study populations included might partially account for the different sBMD between the two studies. In our study, the age-specific sBMD obtained from the Hologic and Lunar decreased by

![Fig. 3](reference curves for sBMD at the lumbar spine and femur neck for healthy Chinese women and men. Dash area: line charts based the age-specific pooled means (+2SD) of age-related sBMD. No smoothing (or regression) method was used)

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Spine, L2–L4</th>
<th>Femur neck</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bone</td>
<td>Osteoporosis</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>−14.2</td>
<td>15.0</td>
</tr>
<tr>
<td>60</td>
<td>−22.5</td>
<td>26.9</td>
</tr>
<tr>
<td>70</td>
<td>−26.2</td>
<td>37.7</td>
</tr>
<tr>
<td>80</td>
<td>−28.8</td>
<td>44.5</td>
</tr>
<tr>
<td>Total</td>
<td>23.9</td>
<td>44.5</td>
</tr>
<tr>
<td>WHO</td>
<td>24.6</td>
<td>13.3</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>−4.4</td>
<td>1.5</td>
</tr>
<tr>
<td>60</td>
<td>−6.6</td>
<td>3.7</td>
</tr>
<tr>
<td>70</td>
<td>−8.2</td>
<td>5.2</td>
</tr>
<tr>
<td>80</td>
<td>−11.6</td>
<td>11.8</td>
</tr>
<tr>
<td>Total</td>
<td>3.2</td>
<td>6.0</td>
</tr>
<tr>
<td>WHO</td>
<td>3.5</td>
<td>5.9</td>
</tr>
</tbody>
</table>
2.7–8.4 % in female and 2.4–4.5 % in male at spine and femur neck, respectively, when we adopted the formulas proposed by Zhu et al. Parallel measurements of spine phantoms were used for the cross-calibration of sBMD at the spine and femur neck in the study of Zhu et al. On the other hand, our study used the site-specific calibration equation established by Lu et al. and Hui et al., whereby parallel measurements of the spine and neck BMDs were made based on phantoms as well as 100 healthy Caucasian women. Thus, better accuracy and specificity should be achieved by the present sBMD calculation.

Sex- and ethnic differences of age-specific BMDs

We noted a large decline in BMDs during 50–70 years of age in female but not in male. The average 10-year difference in this age range for female was 8.7 % at the spine and 9.2 % at femur neck compared to 1.8 % and 4.5 % in male. A higher decline in BMDs in female over 50s could be related to the decrease of estrogen at menopause. Similar pattern of BMD changes across the lifespan is observed in other ethnic groups except for the spine BMD values in non-Hispanic White males, among whom an counterintuitive elevation were observed in older age groups. This pattern may be confounded by the inclusion of respondents with spine artifacts such as aortic calcification and osteophytes that increase with age and are more common in men. Peak bone mass was achieved before or around the third decade as described in a number of earlier studies. However, the age-specific values of sBMD in our study population were substantially lower than that observed in the Whites and slightly lower than that in the Japanese and Korean populations. Many studies found that Asian populations had lower area bone mineral density than Caucasians, but the differences in BMD between the ethnic groups greatly decreased or disappeared after adjusted for body size and/or body weight, suggesting that body size or weight are the main determinants of the ethnic variations. In addition, other factors including genetics, diet and physical activity, health behaviors, socioeconomic factors, and other lifestyle factor may also contribute to the ethnic variations.

Osteoporosis prevalence estimation

The prevalences of osteoporosis at the spine and femur neck were 23.9 % and 12.5 % (female) and 3.2 % and 5.3 % (male) in this study. Gender difference of the osteoporosis prevalence was more remarkable at the lumbar spine. Higher BMD values and slower bone decline rates might partially contribute to lower osteoporosis prevalence in men. Although the spine pBMD was essentially identical in men and women (1.066 versus 1.088 g/cm²), a larger SD was observed in men (0.154 versus 0.137 g/cm²). The larger SD in men (vs. women) might be explained by much greater variation in body size (or bone size) and occupational and...
leisure physical activities which could cause much greater differences in BMD in men than in women. Slightly higher prevalences at the two sites were observed in the study of Zhu et al. (26.2% and 15.1% in female and 4.7% and 8.3% in male) [10]. Relatively larger SDs of pBMDs due to much wider coverage of populations and age interval (10 versus 5 years) in our study might explain the differences in the estimated prevalences.

The osteoporosis prevalence at the lumbar spine in adults aged 50–79 was significantly lower (female 23.9%, male 3.2%) in our study as compared to that of the Koreans (female 40.1%, male 6.5%) [5]. Greater BMD decline at the later age and smaller SD of sBMD might explain the ethnic disparities in osteoporosis prevalences between the Korean and our study population. Lower prevalences of osteoporosis were reported in the U.S. National Health and Nutrition Examination Survey (NHANES) 2005–2008. Osteoporosis (10.9% and 2.2%) at the spine was found in non-Hispanic Caucasian women and men aged 50 years and older [38]. A much lower decline in BMD with age in non-Hispanic Caucasians than in our population might partly explain the differences. The percentage difference in sBMD in female aged 70–79 years were 24.6% lower in our study population than that of non-Hispanic Caucasians [28] and 7.5% lower as compared with their corresponding peak sBMD. A higher BMD value might lower the risk of fracture. Although lower prevalences of osteoporosis were also observed at the femoral neck in both sexes (9.6% in female and 2.0% in male) among non-Hispanic Whites, the age-adjusted hip fracture rates per 100,000 in adults over 50 years of age were significantly higher in the Caucasian than that in Chinese females and males [11]. Differences in hip geometry had been regarded as a major factor accounting for the ethnic variation in hip fracture incidence. Longer hip axis lengths were linked to an increased risk of hip fracture [39], and hip axis lengths were reportedly shorter among Asians, even after adjusting for height [40]. Other environmental and lifestyle factors including the risk of falls could also contribute to the fracture risks.

Criteria for osteoporosis classification

According to the cutoff values of NHANES III recommended by IOF/WHO [3], the prevalence of osteoporosis at femur neck in our data increased to 26.7% and 11.1% in women and men, respectively. Different reference ranges might lead to the divergence of the evaluation for osteoporosis, as reported by previous studies [41, 42]. A very small change in SD might result in a notable variation in T-score and in turn exert profound effects on the size of the patient-group fulfilling WHO criteria. The variances of BMD in a specific population are affected by the between-individual variations in body size or bone size, genetics, physical activities, habitual diets, some health-related behaviors, and other factors that may change BMD. In theory, the cutoff for osteoporosis diagnosis is related to the extent of decrease in bone mass or a gender- and ethnic-specific value that can well predict bone fractures, but not related to the within-population variation. A cutoff according to a certain decrease (or percentage decrease) from the peak BMD would avoid the paradoxes caused by different SD among different ethnic populations. Since peak bone mass may also change with time, the appropriate cutoff for the osteoporosis diagnosis would be the gender- and ethnic-specific values that could well predict bone fractures later in life. Large longitudinal studies are needed to address this issue.

Influencing factors of the sBMD

Meta-regression of our study data showed that a greater value of sBMD was obtained by Hologic densitometry than by the other two devices. The age- and sex-specific variations in sBMD among the three types of devices might be due to the variations of the sample distribution in region and socioeconomic factors and/or a systemic error from the cross-calibration equations which were based on Caucasian women (possibly due to ethnic difference). In addition, the cross-calibration equations recommended by Lu et al. [22] and Hui et al. [23] were based on the pencil-beam DXA systems. Fan et al. [43] have validated the equations for state-of-the-art fan-beam DXA systems and discovered that the residual differences still remained especially for the spine. In this study, the pencil-beam and the fan-beam Hologic DXA tended to produce higher sBMD at the neck sBMD in female (both DXA) and in male (fan-beam only). The results suggested that cross-calibrations among different devices in the study population would be required to get a comparable result.

It is noteworthy that larger city size, higher latitude, and lower altitude were associated with higher BMD values. Higher socioeconomic status and the associated healthier lifestyles might confer benefits on bone health and thus the higher BMD values in populations residing in the big cities. Although there was an increase in the duration of the “vitamin D winter” with higher latitudes [44], populations residing in northern China had higher body weight and body mass index than those from southern China [45]. As reported by Zhu et al. [4], the weight-bearing benefits might be more pronounced in influencing the BMD. The influence of altitude on BMD had not been well explored. Higher socioeconomic status among the people living along the coastal regions might partially explain the differences [45].

Limitation

Our study has several limitations. Firstly, the equations we used to cross-calibrate the data were derived from Caucasians and with no discrimination among different types of systems.
made by the same manufacturer. The ethnic and intra-manufacturer difference might have influences on the accuracy of our study results. Secondly, only 23 of the 91 were based on random samples. These populations tended to have lower spine BMD than those from the convenience samples. Thirdly, we did not analyze the influence of body weight and height because few original studies reported the age-specific values of weight and height. Fourthly, most studies were carried out in the more developed regions and larger cities of China. Since there is a great difference in lifestyle between developing and developed regions, rural and urban areas, caution should be taken when reference value is applied to the rural residents. In addition, we did not assess the influence of ethnic factors since the ethnic compositions or ethnic-specific data were not available in most studies. In China, although there are 55 non-Han minorities accounting for <10 % of total population, the majority of them have similar genetic characteristics and lifestyle to Han race except for non-Han populations in Tibet, Xinjiang, and Inner Mongolia. Ethnic-specific references might be required in these regions due to large differences in lifestyle and genetics between the minorities in these municipalities and the majority of Chinese.

In conclusion, we have established a national-wide BMD reference database for the lumbar spine and femur neck for Chinese adults and have estimated the prevalences of osteoporosis in the middle and elderly Chinese populations. The database should serve as valuable reference for health professionals engaged in the prevention, diagnosis, and treatment of osteoporosis.

Acknowledgements The study was jointly supported by the 5010 Program for Clinical Researches of Sun Yat-sen University (No. 2007032) and the National Natural Science Foundation of China (No. 30872100, 81072299).

Conflicts of interest None

References


