Bone mineral density of proximal femur in adult Chinese females

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ABSTRACT

Objective: This study was designed to establish bone mineral density (BMD) reference data of proximal femur, research the effect of age, height and weight on BMD of proximal femur, and estimate the prevalence of osteoporosis in a Chinese female population. In addition we compared the results with Lebanese and USA white women reference data.

Methods: Our study was conducted at one center, including 1578 Chinese women, aged 20–79 years. We measured the BMD for proximal femur using dual-energy X-ray absorptiometry, and then established a reference database of proximal femur and set up regression equations of age, height and weight for BMD at proximal femur to research the effects of age, height and weight on BMD. After that, we calculated the standardized BMD and compared them with Lebanese and USA white women reference data.

Results: The peak BMD occurred in the age range 30–39 years for femoral neck and Ward's triangle, and 40–49 years for trochanter in Chinese women, which were later than in Lebanese and USA white women. The BMD of proximal femur in Chinese women were lower than Lebanese and USA white women in most age ranges. Weight profoundly influenced BMD in all age groups, and age and height mainly effected BMD in older age groups. The standardized prevalence of osteoporosis among Chinese women of 50–79 years old was 9.6% in femoral neck, which was higher than Lebanese but lower than USA white women.

Conclusion: The BMD database of proximal femur in Chinese women we established is normative and different from Lebanese and USA white women reference data, which provides more reliable information on the prevalence of osteoporosis in China.

1. Introduction

In the elderly, osteoporosis and related proximal femur fracture is becoming a major health problem as the number of older people in the world increases.¹ Osteoporotic proximal femur fracture has potential serious implications for morbidity, mortality disability, impairment in quality of life as well as subsequent increasing hospital and social costs.² Population aging has become a serious challenge that the world is facing, reliable data show that 11% of the world's population is over 60 years of age, with a projected increase to 22% of the population by 2050.³ Osteoporosis will assume even greater significance for health care. So a comprehensive understanding of the epidemiology of proximal femur osteoporosis will be indispensable for appropriate health care prevention and planning of osteoporosis and osteoporotic fracture in the developing country.

China is a developing country with a population of 1.3 billion, the environment, socioeconomic levels, and culture of which are very different from the other places in the world. Although there are much research of osteoporosis of proximal femur in other countries, the

studies in China are not enough.^{4–6}

According to the definition given by World Health Organization (WHO), osteoporosis is defined as a bone mineral density of 2.5 more standard deviations (SD) below the normal race-and sex-matched reference population's mean peak bone mineral density, (PBMD).⁷ Using dual-energy X-ray absorptiometry (DXA) to measure bone mineral density (BMD) has been proved to be an effective method for diagnosing osteoporosis and assessing the risk of osteoporotic proximal femur fracture.⁸ Although a few studies have focused on accumulating proximal femur BMD reference data, similar databases in the Chinese population are very poor. Establishing more bone mineral density (BMD) reference data base and monitoring its change are essential for the prevention, diagnosis, and treatment of osteoporosis and related proximal femur fracture in China. The goal of our study was to establish BMD reference database of a Chinese female population and compare it with Lebanese⁹ and USA white women,¹⁰ for providing information on the prevalence of osteoporosis of proximal femur in China.

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2. Materials and methods

2.1. Subjects

The sample consisted of 1578 Chinese women, aged 20–79 years. Subjects were recruited through Chinese health organizations and advertisements, as there were no city files containing all possible subjects. Subjects selected for the study were healthy Chinese women. All subjects were ambulatory, free of chronic disease and not taking medications known to affect skeletal metabolism or being with a history of fracture. 72 women with body weight < mean-2SD or > mean + 2SD were eliminated.

2.2. Measurements of bone mineral density

The BMD (g/cm²) was measured at femoral neck, trochanter and Ward's triangle by dual-energy X-ray absorptiometry, using XR-46 (Norland, at swissray, USA). Quality control procedures were followed in accordance with the manufacturer's recommendations. Instrument variation was determined regularly by a daily calibration routine using a phantom supplied by the manufacturer. Precision error of the phantom was 0.3%. Precision error in vivo was less than 2%.

2.3. Calculation of standardized BMD (SBMD)

The following formula¹¹ was used to convert the BMD values of different instruments into standardized BMD.

For Hologic instruments: Standardized BMD = 1.087 *BMD + 0.019

For Lunar instruments: Standardized BMD = 0.939 * BMD – 0.023

For Norland instruments: Standardized BMD = 0.985 *BMD + 0.006

2.4. Calculation of T-scores

The following formula was used to assess the T-score.

T-Score = (Measurement value-PBMD mean)/PBMD SD

2.5. Statistical analysis

A reference database comprising proximal femur BMD values grouped by subject age (10-year intervals) was established. T-scores for all measured proximal femur sites were then calculated. Scores from the subgroup of PBMD were used to estimate the norm mean and SD for the purpose of calculating T-scores, which were then used to determine the prevalence of osteoporosis in the age-specific population. The age-standardized prevalence of 50–79 years was calculated based on the age distribution of the Chinese population for the year 2012.¹² SPSS software version 19.0 (SPSS, Chicago, IL, USA) was used for statistical analyses.

3. Results

3.1. General characteristics of the study subjects

In Table 1, those anthropometric characteristics of the subjects according to age are summarized. The mean height, weight, and body mass index (BMI) were 157.4 ± 5.8 cm, 59.2 ± 7.7 kg, and 23.9 ± 2.9 kg/m², respectively.

Table 1

Age-stratified anthropometric characteristics (mean ± standard deviation) of the subjects.

Age	Number	Height(cm)	Weight(kg)	BMI(kg/m ²)
20–29	26	161.9 ± 4.3	56.3 ± 8.7	21.5 ± 3.2
30–39	93	159.5 ± 5.8	56.7 ± 7.4	22.3 ± 2.7
40–49	306	159.0 ± 5.0	59.8 ± 7.0	23.7 ± 2.7
50–59	407	158.3 ± 5.6	59.6 ± 7.5	23.8 ± 2.7
60–69	393	156.0 ± 5.7	59.6 ± 7.6	24.5 ± 2.9
70–79	281	155.3 ± 6.0	58.7 ± 8.5	24.3 ± 3.1
Total	1506	157.4 ± 5.8	59.3 ± 7.7	23.9 ± 2.9

Table 2

Reference data for bone mineral density (BMD, g/cm²) at various proximal femur sites.

Age	Number	Femoral neck	Trochanter	Ward's triangle
BMD				
20–29	26	0.810 ± 0.154	0.648 ± 0.167	0.638 ± 0.180
30–39	93	0.858 ± 0.118	0.657 ± 0.107	0.698 ± 0.127
40–49	306	0.847 ± 0.124	0.661 ± 0.104	0.655 ± 0.131
50–59	407	0.775 ± 0.125	0.609 ± 0.109	0.570 ± 0.123
60–69	393	0.690 ± 0.112	0.550 ± 0.099	0.490 ± 0.107
70–79	281	0.642 ± 0.116	0.508 ± 0.104	0.432 ± 0.110
SBMD				
20–29	26	0.804 ± 0.152	0.644 ± 0.165	0.635 ± 0.177
30–39	93	0.851 ± 0.117	0.653 ± 0.106	0.694 ± 0.125
40–49	306	0.841 ± 0.123	0.657 ± 0.103	0.651 ± 0.129
50–59	407	0.769 ± 0.124	0.606 ± 0.107	0.568 ± 0.121
60–69	393	0.686 ± 0.110	0.547 ± 0.097	0.489 ± 0.105
70–79	281	0.639 ± 0.114	0.506 ± 0.102	0.432 ± 0.108

The bold values are the peak BMDs and SBMDs.

3.2. Reference database of bone mineral density of proximal femur

Table 2 presents the reference data for the BMD values, grouped according to age of the Chinese women and the conversion of measured BMD values into standardized BMD (SBMD). The peak BMD occurred in the age range 30–39 years for the femoral neck and Ward's triangle, and 40–49 years for the Trochanter. Between the peak BMD values and those of the age group 70–79 years at the same sites, overall declines were observed of 25.2% for the femoral neck, 23.1% for the trochanter, and 38.1% for Ward's triangle ($p < 0.001$). The BMD values for femoral neck, trochanter and Ward's triangle site were converted to SBMD using a published conversion formula,¹¹ which was proved effective.^{13,14}

Fig. 1a shows the age-related declines in T-scores for BMD at the various proximal femur sites. The mean T-scores for BMD of the femoral neck, trochanter, and Ward's triangle were –1.831, –1.471, –2.094 respectively in subjects of 70–79 years.

3.3. Effect of age, height and weight on BMD of proximal femur

Table 3 shows the influence of age, height, weight and BMI on BMD of proximal femur for women aged 20–49 years and 50–79 years, respectively. The age effect on femoral neck BMD was a non-significant –0.1% per year in the 20-49 age groups, but increased about –0.7% per year in the older age group. The age effect on trochanter BMD was a non-significant –0.2% per year in the 20-49 age group, and increased about –0.5% per year in the older age group. The age effect on Ward's triangle BMD was –0.3% per year in the 20-49 age groups, but increased about –0.7% per year in the older age group. The height obviously effected trochanter BMD -0.4% per cm in the 20-49 age group, and only non-significant –0.1% -0.2% per cm in the other sites of all age groups. Weight had significant effects on all femur sites' BMD of all groups, but decreased from 20 to 49 age groups to the older group obviously, whose effect dropped from 0.6% to 0.2% per kg.

Chinese women BMD compares with lebanese and USA white

Fig. 1. Age-related declines in T-scores for BMD at proximal femur of Chinese women and changes in proximal femur SBMD among Chinese, Lebanese, and USA white women.

- Age-related declines in T-scores for BMD at proximal femur of Chinese women.
- Age-related change in femur neck SBMD among three populations.
- Age-related change in trochanter SBMD among three populations.
- Age-related change in Ward's triangle SBMD among three populations.

Table 3

Regression of BMD for proximal femur regions on height, weight and age in Chinese women 20–49 years (n = 425) and 50–79 years (n = 1081).

Region	Regression of BMD	r	P
20–49 years			
Femoral neck	$0.824 + 0.001age$	0.029	0.552
Trochanter	$0.651 + 0.0002age$	0.011	0.814
Ward's triangle	$0.735 - 0.002age$	0.082	0.093
Femoral neck	$0.818 + 0.0002height$	0.008	0.876
Trochanter	$0.817 - 0.001height$	0.047	0.333
Ward's triangle	$0.690 - 0.0002height$	0.006	0.894
Femoral neck	$0.562 + 0.005 wt$	0.284	< 0.001
Trochanter	$0.355 + 0.005 wt$	0.345	< 0.001
Ward's triangle	$0.534 + 0.002 wt$	0.120	0.013
Femoral neck	$0.940 - 0.001age - 0.002height + 0.006 wt$	0.301	< 0.001
Trochanter	$0.988 - 0.002age - 0.004height + 0.006 wt$	0.395	< 0.001
Ward's triangle	$0.881 - 0.003age - 0.002height + 0.003 wt$	0.179	0.003
50–79 years			
Femoral neck	$1.171 - 0.007age$	0.453	< 0.001
Trochanter	$0.908 - 0.005age$	0.397	< 0.001
Ward's triangle	$0.979 - 0.008age$	0.477	< 0.001
Femoral neck	$-0.236 + 0.006height$	0.271	< 0.001
Trochanter	$-0.216 + 0.005height$	0.259	< 0.001
Ward's triangle	$-0.282 + 0.005height$	0.231	< 0.001
Femoral neck	$0.444 + 0.004 wt$	0.269	< 0.001
Trochanter	$0.237 + 0.005 wt$	0.382	< 0.001
Ward's triangle	$0.315 + 0.003 wt$	0.198	< 0.001
Femoral neck	$0.665 - 0.007age - 0.002height + 0.003 wt$	0.518	< 0.001
Trochanter	$0.562 - 0.005age - 0.0002height + 0.005 wt$	0.536	< 0.001
Ward's triangle	$0.615 - 0.007age - 0.001height + 0.002 wt$	0.509	< 0.001

women^{9, 10}

Fig. 1b, c and 1d compare our SBMD data with data from USA white and Lebanese studies of women. In Chinese women, the peak SBMD value for the femur neck was 2.9% higher than that measured at the

same site in Lebanese women, but 8.2% lower than in USA white women. Whereas in trochanter and Ward's triangle, they were 1.6% and 11.5% lower than those measured at the same sites in Lebanese women, 8.8% and 21.0% lower than in USA white women. After 50–59 years, the BMD values for all measured sites were lower in Chinese women than in the other two populations.

Peak BMD values in the femoral neck occurred in Chinese women 30–39 years of age, which was later 10 years than in Lebanese and USA white women. The peak BMD for the trochanter occurred in Chinese and Lebanese women aged 40–49 years but 20 years earlier in USA white women. In Chinese women, BMD values reached a peak in Ward's triangle in women aged 30–39 years which was later 10 years than in the other two populations. The peak BMD values at femoral neck and trochanter in Chinese women were lower than in USA white but higher than in Lebanese women. The peak BMD values of Ward's triangle in Chinese women were lower than the other two populations.

Table 4 compares our regression equations of BMD with the equations from USA white and Lebanese studies of women. We saw that age was a very important influence factor in most measured sites in three populations except in trochanter of 20–49 years age group of three populations and femoral neck of 20–49 years age group in Chinese women. Height was not a significant influence factor in most measured sites in three populations except in Chinese women's trochanter of 20–49 years age group and USA white women's Ward's triangle of 50–79 years age group. Weight was a significant effecter in all sites of three populations. The effect was changed from 0.2% to 0.7% per kg in different sites.

3.4. Prevalence of osteoporosis

Table 5 shows the age-standardized prevalence of proximal femur osteoporosis among Chinese women subjects. A diagnosis of

Table 4

Comparison of regression equations of BMD for proximal femur on height, weight and age among Chinese, Lebanese⁹ and USA white women¹⁰ (constant omitted).

Population	Regression of BMD (20–49 years)	Regression of BMD (50–79 years)
Femoral neck		
Chinese	$-0.001\text{age} - 0.002\text{height} + 0.006\text{ wt}$	$-0.007\text{age} - 0.002\text{height} + 0.003\text{ wt}$
Lebanese	$-0.003\text{age} + 0.001\text{height} + 0.004\text{ wt}$	$-0.006\text{age} - 0.000\text{height} + 0.004\text{ wt}$
USA white	$-0.004\text{age} + 0.002\text{height} + 0.004\text{ wt}$	$-0.006\text{age} + 0.001\text{height} + 0.004\text{ wt}$
Trochanter		
Chinese	$-0.002\text{age} - 0.004\text{height} + 0.006\text{ wt}$	$-0.005\text{age} - 0.0002\text{height} + 0.005\text{ wt}$
Lebanese	$-0.002\text{age} + 0.001\text{height} + 0.004\text{ wt}$	$-0.003\text{age} - 0.002\text{height} + 0.006\text{ wt}$
USA white	$-0.002\text{age} + 0.0003\text{height} + 0.005\text{ wt}$	$-0.004\text{age} - 0.001\text{height} + 0.007\text{ wt}$
Ward's triangle		
Chinese	$-0.003\text{age} - 0.002\text{height} + 0.003\text{ wt}$	$-0.007\text{age} - 0.001\text{height} + 0.002\text{ wt}$
Lebanese	$-0.006\text{age} + 0.000\text{height} + 0.004\text{ wt}$	$-0.007\text{age} + 0.002\text{height} + 0.005\text{ wt}$
USA white	$-0.007\text{age} + 0.001\text{height} + 0.004\text{ wt}$	$-0.008\text{age} + 0.003\text{height} + 0.005\text{ wt}$

Table 5

Age-standardized prevalence of osteoporosis among Chinese women (%).

Age	Femoral neck	Trochanter	Ward's triangle
50–59	2.9	1.2	5.7
60–69	10.2	7.1	17.0
70–79	26.0	14.2	34.9
Total	9.6	5.6	14.9

osteoporosis was made according to WHO criteria and using the PBMD values of subjects as a reference value and the Chinese population in the year 2012 as the standard population.¹² The standardized prevalence of osteoporosis in Chinese women aged 50–79 years was 9.6% at the femoral neck, 5.6% at the trochanter, and 14.9% at Ward's triangle. The prevalence rates of osteoporosis increased rapidly in subjects over 70 years old.

4. Discussion

The purposes of our study were to determine the normal BMD of proximal femur in Chinese women and whether Chinese BMD values at various measurement sites of proximal femur were sufficiently different from USA white and Lebanese women BMD values to warrant separate Chinese women proximal femur BMD reference data.

This report outlines proximal femur BMD values from a large group of ambulatory women in China with exclusion for extremes of body weight, chronic disease and taking medications known to affect skeletal metabolism. Institutionalized or non-ambulatory subjects were not measured. Previous studies had indicated that even if the subjects only came from health organizations and advertisements, the mean values of BMD were still similar to those random selected. When the exclusion criteria of our study were compared with the USA white women from the R. B. Mazess' study, our study selected subjects with strict exclusion criteria recommended by Norland Company and used in most studies of normal BMD reference ranges (i.e., subjects without disease or medication known to affect bone health). The R. B. Mazess' study¹⁰ is a compilation from different measuring centers and different sampling frames, including all subjects, without exclusions. Thus, we repeated analysis of the BMD values of all subjects (without exclusions) and compared this with the BMD values of the selected subjects in our study; we find the exclusion of subjects did not alter the overall results.

The results of our cross-sectional study support the use of the conventional age interval of peak BMD as the basis for adult BMD reference values. There is little diminution of BMD values of most sites in the 30–49 years old women compared with young women (20–29 years). In fact, longitudinal studies demonstrate decrease of BMD in premenopausal women.^{15,16} In our results, femur neck BMD decreased by 0.1% annually in younger women, and trochanter BMD was stable in younger women (20–49 years). At the more trabecular Ward's triangle

site, decline of BMD in younger women was more obvious. There was apparent BMD diminution of Ward's triangle in 30–49 year age groups, which was 0.4% annually. We did not specifically examine the influence of menopause on the results, but bone changes in several years after menopause are more rapid than in subsequent periods, as previous research indicated.¹⁷ Our research demonstrated that femoral bone loss accelerated in menopause and continues after 60 years old but slow down a little. In older age women the bone loss of Ward's triangle is the most serious, which has the lowest BMD. Opposite, the bone loss of trochanter is lightest, which has the highest BMD. Generally, BMD increases with age until a peak is reached and then decreases. In women, the decrease is particularly evident beginning at menopause. Our study showed that bone mass rapidly decreased in women beginning at age 50, in concordance with previous studies.^{18–20} Also, similar to the results shown that the greatest rate of bone loss was at Ward's triangle in Chinese females.^{21,22} The peak BMD occurred in subjects aged 30–39 years at this site, which was earlier than the peak at trochanter. A possible reason is that Ward's triangle is primarily composed of trabecular bone, the density of which is known to decrease earlier than cortical bone.^{23,24} Indeed, as described in other report,²⁵ bone fast loss after 50 years old may be attributable to the change of ratio of androgen to estrogen, which decreases in women.²⁶

Among Chinese women, peak BMD of femoral neck and Ward's triangle all occurred at age 30–39 years but 10 years earlier in USA white and Lebanese women. At the trochanter, peak BMD in Chinese and Lebanese women occurred at 40–49 years, which were later 20 years than in USA white women. Hammoudeh et al. found that the peak BMD of the femur neck and trochanter for the Qatari women was reached in the age group 40–49 years.²⁷ Similarly, studies of Sri Lanka females also found that peak BMD of femur neck occurred at 50 years.²⁸

These differences on the age of peak BMD might be associated with the difference in such factors as genetics, nutrition, lifestyle factors, and physical activity.^{29–31} We found body weight profoundly influenced the proximal femur BMD of Chinese women. Some earlier studies have made the same point.^{32,33} The effect of weight was smaller in our sample of women over age 50 years. In multiple regression that included age, height and weight, the effect of per year, cm and kg were 1:2:6 at neck, 2:4:6 at trochanter and 3:2:3 at ward's triangle in younger years age group, and 7:2:3 at neck, 5:0:2:5 at trochanter and 7:1:2 at ward's triangle in older years age group. So that patients with low body weight, and hence low BMD, could be misconstrued as exceptionally “abnormal” unless an adjustment for body weight was considered. This indicates the potential importance of considering body weight in patient evaluation. Our results also show that body weight is an important factor, as well as age, in postmenopausal BMD and in the frequency of low BMD in Chinese women.

BMD values measured by different DXA manufactures cannot be compared directly because of technical differences in the devices. However, we were able to compare BMD values through converting the

measured BMD values into standardized BMD (SBMD). The BMD values for femoral neck, Ward's triangle, and trochanter site were converted to SBMD using a published conversion formula of Hui et al.,¹¹ which was proved valid by studies.^{13,14}

When our data were compared with USA white and Lebanese women reference data after converted to SBMD. Changes in SBMD with age in Chinese women generally mirrored the pattern established for USA white and Lebanese women, although mean SBMD values in Chinese were generally lower. In the perimenopausal and postmenopausal decades (age 50–79 years), the decrease of all sites' SBMDs was similar to USA white values. Not only Chinese women began adult life with lower SBMD than Lebanese populations, but also there appeared to be a more dramatic SBMD decrease in the femur in postmenopausal years compared with Lebanese women. Those maybe reflect a biological difference of three populations in the rate of bone loss.

Compared with USA white women,¹⁰ SBMD values at all age groups were lower in Chinese women than in USA white women, and data on height and weight of all age group were also smaller values in Chinese women than those in USA white women. Although the body size (weight, and BMI) of Chinese women was smaller than that of Lebanese women in all age groups, among Chinese women aged 30–49 years, the SBMD of femur neck was higher than that in Lebanese women. The peak SBMD values of Chinese women were higher than those of Lebanese women for femur neck. the results suggest that it is difficult to explain BMD differences only in terms of body size, although it might explain the Asians had smaller bones, thicker and denser cortices, and more plate-like trabeculae than Caucasians.³⁴

Even though Chinese women had a higher peak BMD values than Lebanese in femur neck, bone loss was more rapid after the age of 50 years than in USA white and Lebanese women in all proximal femur sites, as determined by comparison with the respective reference databases. From the peak values to the values in the age group 70–79 years, the differences in BMD values for femoral neck, trochanter, and Ward's triangle were about 5%, 14%, and 18% lower than in USA white females and about 6%, 19%, and 20% lower than in Lebanese females, respectively. Thus, observed differences in bone loss may, at least in part, be caused by genetic differences as well as nutritional and lifestyle factors. There was study shown that birth weight had an effect on adolescent bone mass, but less than later growth and BMI in childhood and at adolescence, and underweight was consistently associated with lower BMC and aBMD z-scores.³⁵ China has experienced rapid socioeconomic growth with prominent nutrition transformations since the 1970s. Older Chinese (> 40 years) were, when they were children, exposed to a relative nutritional deficit during the Chinese civil war, subsequent great Chinese famine and the cultural revolution (1942–1977), whereas younger Chinese (< 40 years) have not had such an experience. The rapid socioeconomic improvement in China has also resulted in earlier age at menarche, fewer children, less breastfeeding, more abortions and later age at menopause. Previous studies observed that late menarche,³⁶ long-term breastfeeding³⁷ and early menopause³⁸ were associated with bone loss. It is therefore possible that such changes are also manifested in the different BMD values of younger and older generations of Chinese, and similarly that the environmental exposure of younger Chinese now resembles that of their USA white and Lebanese counterparts. However, since our study is cross sectional, it may not reflect the long term environmental factors' effects.

Regression analyses showed that weight was a significant predictor of female proximal femur BMD for both the premenopausal and postmenopausal decades. Many other studies have shown the effect of body weight on BMD.³⁹ Chinese women averaged 6.3 kg below Lebanese women and 5.5 kg below USA white women in body weight, a difference which is almost commensurate with the observed BMD difference of Chinese with Lebanese and USA white women in femoral neck and trochanter (0.4–0.5% per kg). The effect of weight on BMD of ward's triangle ranged from 0.2% to 0.3% per kilogram. There was only a modest effect (0.2–0.3% per kg) of weight on ward's triangle of Chinese

women. It was not surprising, because those measures of body size are associated with BMD to a greater extent in more weight-bearing sites than in less weight-bearing sites.⁴⁰ Chinese women averaged 157.4 cm in height compared with 155.8 cm for Lebanese and 162.0 cm for USA white women. The effect of height on BMD was generally less than that of weight, and when height and weight were entered into a multiple regression equation, height was generally not significant (0.1–0.2% per cm in most sites). Body mass index (BMI) showed a pattern similar to weight in predicting proximal femur BMD in Chinese women, and was a significant predictor of Chinese female BMD at all proximal femur measurement sites.

The present study established prevalence rates of osteoporosis in a Chinese population. Our values were used to calculate the conventional "osteoporosis" threshold at -2.5 SD which was 0.563 g/cm², 0.401 g/cm², 0.382 g/cm² for femur neck, trochanter and ward's triangle respectively. Of the 1081 women in our sample between 50 and 79 years of age, about 6.7–17.4% were below the conventional -2.5 SD threshold of osteoporosis, and after standardized using Chinese population of 2012 about 5.6–14.9%. The percentage was low (2.9–5.7%) in the immediate postmenopausal decade; it was about 7.1–17.0% in women 60–69 years, and 14.2–34.9% in women 70–79 years. The prevalence rate at Ward's triangle in women age 50–59 was about 2.8% more than at neck and 4.5% more than at trochanter, respectively, whereas after the age of 70 years, the prevalence more rapidly increased at Ward's triangle than at neck and trochanter. The prevalence rate at Ward's triangle in women was 8.9% more than at neck and 20.7% more than at trochanter. The use of neck BMD as a standard region has been considered. Our results showed that the percentage of women below -2.5 SD at this site was 2.9%, 10.2%, and 26.0% at 50–59, 60–69, and 70–79 years, respectively. These values are intermediate to the lower values for ward's triangle BMD and the higher values for trochanteric BMD. The prevalence of femur neck abnormality with age of Chinese women was comparable to the USA white and Lebanese women. The prevalence of osteoporosis at the femur neck is lower in Chinese women than in their USA white age-matched counterparts, whereas higher than Lebanese women. The Lebanese women aged 50–79 years have a very lower prevalence of abnormality (2 versus 11.6%) than their Chinese peers.

There are several limitations of the present study. Our data were cross-sectional in nature and thus provide a survey of current BMD values by age but only an estimate of actual mean BMD changes through time. The subjects were recruited from advertisements and through health organizations and therefore were not randomly selected. This might result in selection bias, which might have influenced the results. These two limitations hold for nearly all DXA reference data. The study subjects more came from urban regions, which might have caused regional differences in the proximal femur BMD values and the anthropometric measurements. Thus, our results could be somewhat limited when applied to a general population. We used WHO guidelines for determining the prevalence of osteoporosis, even though these guidelines were established for Caucasian women and may not be entirely applicable to other ethnic groups. Finally, the number of 20–39 years age groups were quite small ($n = 26$ and 93) and thus may not be entirely representative of the relevant Chinese female population. Clearly, more investigation of relevant Chinese female subjects should be needed. Despite these limitations, our study was based on a large scale Chinese female population, and the sample size was sufficiently large, so oporosis in the Chinese population.

5. Conclusion

In conclusion, our study is based on a large sample population and thus provides DXA-based BMD reference data for the proximal femur. The results will aid in determining the prevalence of osteoporosis in China. The BMD of Chinese subjects tends to mirror rates of loss established for USA white and Lebanese subjects. However, Chinese

subjects have somewhat lower mean BMD at proximal femoral sites than subjects included in the USA white and Lebanese reference data. The PBMD of Chinese women happened later than USA white and Lebanese. The loss of BMD in Chinese women accelerates in menopause and continues after 60 years old but slow down a little. Weight was a significant predictor of BMD at all sites in all age, and was more important than height, which was generally not significant when included with weight in multiple regression analyses. BMI had a same effect as weight. Age was also a significant predictor of BMD at all sites in older age group, but not in younger age group. Lower BMD values for Chinese subjects didn't always result in a substantially higher prevalence of osteoporosis, which higher than Lebanese but lower than USA white. Results suggest that Chinese women BMD values of proximal femur may be sufficiently different from USA white and Lebanese values to warrant a separate reference sample with which to compare individuals for the purpose of diagnosing osteoporosis. However, the practical consequences of our study in relation to proximal femur fracture rates of the Chinese women, secondary to BMD in the osteoporotic range, remain to be established.

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Compliance with ethical standards.

Declaration of competing interest

There is no conflict of interest.

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