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·*Original Article*·

Bone mineral density of the spine and femur in healthy Chinese men

Zhen-Lin Zhang, Yue-Juan Qin, Qi-Ren Huang, Yun-Qiu Hu, Miao Li, Jin-Wei He, Hao Zhang, Yu-Juan Liu, Wei-Wei Hu

Center for Preventing and Treating Osteoporosis, Osteoporosis Research Unit, The Shanghai Sixth People's Hospital, Shanghai Jiaotong University, Shanghai 200233, China

Abstract

Aim: To establish bone mineral density (BMD) reference database in healthy Chinese men of Han ethnicity, and to estimate the prevalence of osteoporosis in the population. **Methods:** The BMD in the lumbar spine 1-4 (L1-4) and proximal femur was measured using dual energy X-ray absorptiometry in a total of 1 385 healthy Chinese men of Han ethnicity aged 20–89 years old in Shanghai. **Results:** The highly significant negative correlation between age and BMD at any sites of proximal femur was found in the studied population, wheras no correlation between age and BMD at lumbar spine was observed. The peak BMD of the lumbar spine and any sites of hip in Chinese men was defined as the mean BMD for the subjects aged 20–39 years. According to World Health Organization (WHO) criteria, the BMD cut-off values for osteoporosis of the L1-4, total hip, femoral neck, trochanter and intertrochanter in Chinese men are 0.719, 0.638, 0.575, 0.437 and 0.725 g/cm^2, respectively. Using the current Chinese reference data, the prevalence of osteoporosis at the L1-4, total hip, femoral neck, trochanter and intertrochanter is 5.4%, 3.8%, 6.3%, 1.8% and 2.8% in 1 084 men aged 50 years or older, respectively. However, using a database for US non-Hispanic white men (NHANES III), the prevalence of osteoporosis or osteopenia at any sites of the hip was significantly higher than that while using the current Chinese reference data. **Conclusion:** The BMD reference database was established in healthy Chinese men of Han ethnicity, and will facilitate more accurate diagnosis of osteoporosis in Chinese men. (*Asian J Androl 2006 Jul; 8: 419–427*)

Keywords: bone mineral density; men; Chinese; osteoporosis

1 Introduction

Osteoporosis is characterized by low bone mineral density (BMD) and structural deterioration of bone tissue, leading to bone fragility and increasing susceptibility to fractures. Dual energy X-ray absorptiometry (DXA) is the most commonly used method to measure BMD at the lumbar spine and proximal femur. BMD is the gold standard in the diagnosis of osteoporosis using DXA. The definition of osteoporosis has been set by a working group in the World Health Organization (WHO) based on a measurement in postmenopausal women. Osteoporosis is defined as BMD more than 2.5 standard deviation

Correspondence to: Prof. Zhen-Lin Zhang, Center for Preventing and Treating Osteoporosis, Osteoporosis Research Unit, The Sixth People's Hospital, Shanghai Jiaotong University, 600 Yishan Road, Shanghai 200233, China.
Tel/Fax: +86-21-6408-1474
E-mail: ZZL2002@medmail.com.cn
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(SD) below the mean for young adult women (later clarified as T-score $\leqslant -2.5$). Osteopenia is defined as BMD between 1.0 and 2.5 SD below the mean for young adult women (T-score > –2.5 and < –1.0) [1]. Although this guideline was established for women, up to now, the diagnosis standard for osteoporosis has been adapted to men.

Although osteoporotic fractures are less common in men than in women, these fractures in men are associated with higher morbidity and death [2]. Besides age, the best way of identifying men at high risk for fracture is to measure their BMDs. As a result, it is very important that osteoporosis or osteopenia is diagnosed as early as possible using BMD values. BMD values vary in different ethnic groups. It is known that the BMD values of Asians are lower than those of the Americans or Europeans [3, 4]. However, many DXA manufactures have used US Caucasian reference databases, resulting in inaccurate prevalence of osteo-porosis or osteopenia in non-Caucasian populations. The purpose of our study was to establish BMD reference database in healthy Chinese men of Han ethnicity, and to estimate the prevalence of osteoporosis in the population.

2 Materials and methods

2.1 Study subjects

A total of 1 385 healthy Chinese men (aged ranging from 20 to 89 years) living in Shanghai participated in the present study. Study subjects were recruited using public advertising from universities, and social and community centers. All participants were of Chinese Han ethnicity, identified by a combination of self-report and identification cards. Clinical data consists of medical history, medication and a survey of the incidence of diseases. All the participants were given a physical examination and all proved to be in good health. No participant had medical complications or was receiving treatment for conditions known to affect bone metabolism, including hyperthyroidism, diabetes mellitus, primary hyperparathyroidism, renal failure, pituitary and adrenal diseases, and rheumatic diseases. The study protocol was approved by the Committee of the Ethics of Human Research in the Affiliated Sixth People's Hospital of Shanghai Jiaotong University. The BMD for Chinese women was used to analyze our results according to the previously published data [5, 6].

2.2 Bone mineral density measurements (BMD)

BMD (g/cm^2) of the anteroposterior lumber spine 1-4 (L1-4) and left proximal femur including total hip, femoral neck, trochanter and intertrochanter was measured by DXA on a Hologic QDR 2000 (Hologic, Bedford, MA, USA). The DXA scanner was on fan-beam mode with software version 7.20B. The machine was calibrated daily. The coefficient of variability (CV) values was obtained from five repeated measurements on 7 individuals. CV values of the DXA measurements at L1-4, total hip, femoral neck, trochanter and intertrochanter were 0.9%, 0.8%, 1.93%, 1.48% and 1.31%, respectively [5, 6]. The long-term reproducibility of our DXA instrument during the trial based on weekly repeated phantom measurements was 0.45% [5, 7]. Lumbar BMD was measured from L1 to L4 in the anteroposterior view with fractured vertebrae being excluded from the analysis.

2.3 Statistical analysis

Data were expressed as mean ± SD. Coefficient of BMD with age, height and weight was analyzed using Pearson correlation. The association of BMD with age, height and weight was analyzed using multiple linear regression. Age-related changes of BMD were evaluated using linear and polynomial regression. Osteoporosis was defined as BMD more than 2.5 SD below the mean for young adults according to the WHO criteria. The differences between proportions of osteoporosis or osteopenia in the Chinese reference database and in the database for US non-Hispanic white men (NHANES III) were analyzed using the χ^2-test [8, 9]. All statistical analyses were performed using SPSS Statistical Package version 11.0 (SPSS Inc., Chicago, IL, USA). $P < 0.05$ was considered significant.

3 Results

The basic anthropometry of the 1 386 men is shown in Table 1. Subjects were divided into 14 age groups for cross-sectional analysis. The mean BMD and SD at various sites in the lumbar spine and hip of each age group are presented in Table 2. Pearson correlation coefficient of BMD at different sites with age, height and weight in men is shown in Table 3. The results show that there is a significant negative correlation between age and BMD at any sites of hip in men. However, this correlation could not be established when BMD of lumbar spine was used for analysis. Furthermore, BMD values at L1-4

Table 1. Anthropometric characteristics (mean ± SD) of Chinese men.

Age group (year)	Number	Age (year)	Weight (kg)	Height (cm)	BMI (kg/m^2)
20–24	55	21.6 ± 1.1	66.7 ± 11.8	172.3 ± 5.6	22.4 ± 3.6
25–29	47	27.4 ± 1.3	67 ± 10.1	170.7 ± 5.3	23.0 ± 3.0
30–34	43	32.6 ± 1.2	69.5 ± 12.2	170.8 ± 5.8	23.1 ± 3.8
35–39	46	37.5 ± 1.4	65.4 ± 10.3	171.2 ± 5.6	22.3 ± 3.0
40–44	45	42.6 ± 1.5	66.6 ± 11.2	167.8 ± 6.3	23.5 ± 2.5
45–49	65	47.9 ± 1.4	71.0 ± 9.8	169.7 ± 5.5	24.7 ± 3.2
50–54	112	52.5 ± 1.5	70.7 ± 9.2	168.8 ± 6.0	24.8 ± 2.9
55–59	150	57.6 ± 1.4	69.1 ± 10.1	166.6 ± 14.7	24.7 ± 2.7
60–64	257	62.7 ± 1.5	68.1 ± 8.8	166.7 ± 5.9	24.5 ± 2.7
65–69	238	67.4 ± 1.4	67.8 ± 10.2	164.9 ± 11.9	24.8 ± 3.1
70–74	204	72.2 ± 1.4	67.8 ± 11.9	164.4 ± 9.5	24.8 ± 2.9
75–79	75	77.5 ± 1.3	64.9 ± 0.9	163.9 ± 6.4	24.2 ± 3.6
80–84	36	82.1 ± 1.6	62.3 ± 10.9	162.2 ± 7.0	23.4 ± 3.0
85+	12	87.6 ± 3.4	55.7 ± 8.4	157.3 ± 6.2	22.0 ± 2.2

Table 2. Mean bone mineral density and standard deviation at each measurement site by age group.

Age group (year)	L1-4	Total hip	Femoral neck	Trochanter	Intertrochanter
20–24	0.960 ± 0.090	0.984 ± 0.115	0.899 ± 0.098	0.745 ± 0.103	1.139 ± 0.147
25–29	0.941 ± 0.088	0.948 ± 0.117	0.866 ± 0.121	0.685 ± 0.106	1.100 ± 0.145
30–34	0.944 ± 0.116	0.880 ± 0.133	0.788 ± 0.127	0.664 ± 0.103	1.019 ± 0.153
35–39	0.957 ± 0.097	0.907 ± 0.121	0.817 ± 0.113	0.665 ± 0.098	1.064 ± 0.142
40–44	0.918 ± 0.129	0.871 ± 0.113	0.794 ± 0.108	0.638 ± 0.103	1.014 ± 0.139
45–49	0.929 ± 0.127	0.898 ± 0.131	0.792 ± 0.123	0.658 ± 0.102	1.049 ± 0.154
50–54	0.938 ± 0.121	0.906 ± 0.112	0.779 ± 0.108	0.666 ± 0.092	1.062 ± 0.136
55–59	0.933 ± 0.128	0.892 ± 0.105	0.765 ± 0.104	0.654 ± 0.089	1.045 ± 0.122
60–64	0.944 ± 0.145	0.872 ± 0.119	0.754 ± 0.115	0.647 ± 0.101	1.017 ± 0.139
65–69	0.958 ± 0.164	0.856 ± 0.122	0.732 ± 0.110	0.635 ± 0.101	1.001 ± 0.146
70–74	0.959 ± 0.185	0.844 ± 0.123	0.729 ± 0.113	0.629 ± 0.107	0.984 ± 0.147
75–79	0.968 ± 0.196	0.801 ± 0.130	0.705 ± 0.127	0.590 ± 0.102	0.936 ± 0.151
80–84	0.963 ± 0.186	0.821 ± 0.100	0.715 ± 0.112	0.611 ± 0.090	0.949 ± 0.122
85+	0.833 ± 0.180	0.690 ± 0.144	0.599 ± 0.116	0.506 ± 0.124	0.808 ± 0.182

were relatively stable from 20 to 89 years, as revealed by linear regression analysis of correlation between BMD and age, height and weight in men. In contrast, significant decreases were found in the hip BMD at the rate of 0.3% per year in total hip, 0.4% per year in femoral neck, 0.3% per year in trochanter, and 0.4% per year in intertrochanter in men between 20 and 49 years old. This rate of bone loss was similar to that of men between 50 and 89 years old. Moreover, height or weight showed highly significant positive correlation with BMD at L1-4 and any sites of proximal femur ($P < 0.05$ or $P < 0.01$) (data not shown).

We used all relevant mathematical models (including linear, logarithmic, quadratic, cubic, compound, power, growth and exponent) in SPSS 11.0 to fit BMD association with age. The cubic regression model had the best goodness of fit, and R^2 were consistently maximized in all skeletal regions. The changes of BMD with age in Chinese men are demonstrated in curves derived from the cubic regression (Figure 1). A highly significant negative correlation between age and BMD at any sites of hip was found in Chinese men ($R^2 = 0.081$–0.130, $P < 0.001$),

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Table 3. Pearson correlation coefficient of bone mineral density (BMD) at different sites with age, height and weight in men. Statistically significant at the *P*-values presented in parentheses.

	Age	Height	Weight	L1-4	Total hip	Femoral neck	Trochanter	Intertrochanter
Age	—							
Height	–0.249	—						
	(0.000)							
Weight	–0.08	0.381	—					
	(0.004)	(0.000)						
L1-4	0.020	0.096	0.322	—				
	(0.475)	(0.001)	(0.000)					
Total hip	–0.302	0.134	0.426	0.655	—			
	(0.000)	(0.000)	(0.000)	(0.000)				
Femoral neck	–0.360	0.159	0.385	0.596	0.873	—		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
Trochanter	–0.268	0.141	0.365	0.653	0.924	0.810	—	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
Intertrochanter	–0.290	0.111	0.443	0.621	0.974	0.801	0.851	—
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

Table 4. Bone mineral density (BMD) (g/cm^2) (mean ± SD) of the L1-4 and total hip in men as a function of age: Reference database of Chinese men and US non-Hispanic white men (NHANES III) (without lumbar spine data).

Age group	BMD data for Chinese men			BMD data for NHANES III	
(year)	*n*	L1-4	Total hip	*n*	Total hip
20–29	102	0.955 ± 0.089	0.975 ± 0.116	382	1.041 ± 0.144
30–39	89	0.953 ± 0.102	0.898 ± 0.124	416	1.024 ± 0.143
40–49	110	0.926 ± 0.127	0.891 ± 0.126	409	0.988 ± 0.139
50–59	262	0.935 ± 0.125	0.898 ± 0.108	393	0.977 ± 0.142
60–69	495	0.951 ± 0.155	0.865 ± 0.121	477	0.955 ± 0.155
70–79	279	0.961 ± 0.188	0.832 ± 0.126	445	0.915 ± 0.150
80–89	48	0.928 ± 0.194	0.789 ± 0.126	408	0.846 ± 0.159

but not at lumbar spine.

We found that the mean BMD values of any site in all age groups in Chinese men were significantly lower than that of the same age groups in US non-Hispanic white men (NHANES III reference database) (Tables 4, 5) [8, 9]. Although the peak BMD at any sites occurred in age 20–24 years, we used a broader age range for defining the mean peak BMD. The fitted curve of cubic regression showed that BMD decreased after age 40 in Chinese men. The peak BMD of the lumbar spine and any sites of hip in Chinese men was defined as the mean BMD for the subjects aged 20–39 years. Therefore, according to WHO criteria, the cut-off values for osteoporosis of the L1-4, total hip, femoral neck, trochanter and intertrochanter in Chinese men were 0.719, 0.638, 0.575, 0.437 and 0.725 g/cm^2, respectively. The corresponding values for US non-Hispanic white men (NHANES III) are shown in Table 6.

Using the mean peak BMD of the 20–39-year-old group, T-scores were calculated and the percentages of subjects with osteoporosis (T-score ¡Ü –2.5) and osteopenia (T-score < –1 to –2.5) are presented in Tables 7 and 8**,** respectively. In reference to the current data for the Chinese population, the prevalences of osteoporosis at the L1-4, total hip, femoral neck, trochanter and intertrochanter were 5.4%, 3.8%, 6.3%, 1.8% and 2.8% in men aged 50 years or older, respectively. The prevalences of osteopenia at the L1-4, total hip, femoral neck, trochanter and intertrochanter were 25.2%, 34.7%, 47.9%, 34.9% and 33.5% in men aged 50 years or older, respectively.

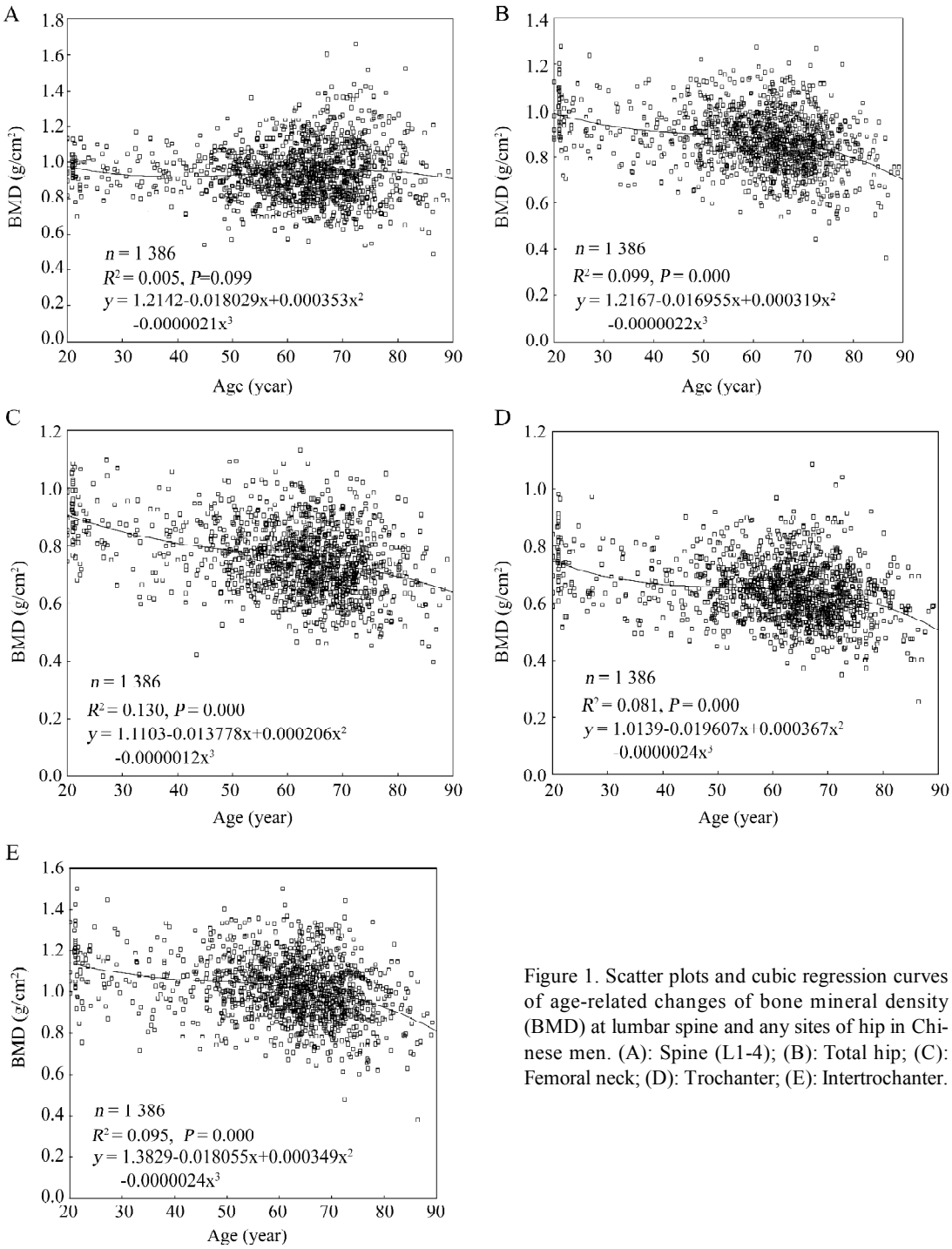

Figure 1. Scatter plots and cubic regression curves of age-related changes of bone mineral density (BMD) at lumbar spine and any sites of hip in Chinese men. (A): Spine (L1-4); (B): Total hip; (C): Femoral neck; (D): Trochanter; (E): Intertrochanter.

However, using the database for US non-Hispanic white men (NHANES III) as a reference, the prevalence of osteoporosis or osteopenia at the any sites of hip was all significantly higher than that of using the current Chinese reference data (Tables 7, 8).

4 Discussion

The present study is the first large-scale report on reference values on the BMD of the lumbar spine and femur in healthy Chinese men of various age groups (20–

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Table 5. Bone mineral density (BMD) (g/cm^2) (mean ± SD) of the femoral neck in men as a function of age: Reference database of Chinese men and US non-Hispanic white men (NHANES III).

Age group	BMD data for Chinese men				BMD data for NHANES III			
(year)	*n*	Femoral neck	Trochanter	Intertrochanter	*n*	Femoral neck	Trochanter	Intertrochanter
20–29	102	0.891 ± 0.104	0.731 ± 0.106	1.130 ± 0.147	382	0.934 ± 0.137	0.778 ± 0.118	1.205 ± 0.172
30–39	89	0.807 ± 0.117	0.664 ± 0.098	1.049 ± 0.145	416	0.887 ± 0.134	0.762 ± 0.112	1.199 ± 0.171
40–49	110	0.793 ± 0.118	0.653 ± 0.102	1.039 ± 0.150	409	0.839 ± 0.124	0.737 ± 0.107	1.162 ± 0.171
50–59	262	0.771 ± 0.106	0.659 ± 0.090	1.052 ± 0.128	393	0.813 ± 0.125	0.740 ± 0.120	1.151 ± 0.172
60–69	495	0.743 ± 0.113	0.641 ± 0.103	1.010 ± 0.143	477	0.788 ± 0.135	0.736 ± 0.129	1.116 ± 0.187
70–79	279	0.723 ± 0.117	0.618 ± 0.107	0.971 ± 0.149	445	0.754 ± 0.131	0.711 ± 0.127	1.064 ± 0.179
80–89	48	0.688 ± 0.121	0.585 ± 0.110	0.914 ± 0.151	408	0.698 ± 0.140	0.670 ± 0.137	0.979 ± 0.190

Table 6. Chinese male reference bone mineral density BMD database (20–39 years old) compared to the reference database for US non-Hispanic white men (20–29 years old).

	L1-4	Total hip	Femoral neck	Trochanter	Intertrochanter (%)
Chinese men reference BMD (g/cm^2)					
Mean BMD (peak)	0.954	0.948	0.862	0.707	1.102
SD	0.094	0.124	0.115	0.108	0.151
2.5 SD	0.235	0.310	0.288	0.270	0.378
BMD at –2.5 SD	0.719	0.638	0.575	0.437	0.725
BMD at –1 to –2.5 SD	0.719–0.860	0.638–0.824	0.575–0.747	0.437–0.599	0.725–0.951
US reference database (NHANES III)					
Mean BMD (peak)	–	1.041	0.934	0.778	1.205
SD	–	0.144	0.137	0.118	0.172
2.5 SD	–	0.360	0.343	0.295	0.430
BMD at –2.5 SD	–	0.681	0.592	0.483	0.775
BMD at –1 to –2.5 SD		0.681–0.897	0.592–0.797	0.483–0.66	0.775–1.033

Table 7. Prevalence of osteoporosis in Chinese men (aged 50 years or older) using reference databases for Chinese and US non-Hispanic white men.

Age group (year)	*n*	L1-4 (%)	Total hip (%)	Femoral neck (%)	Trochanter (%)	Intertrochanter (%)
Chinese reference database						
50–59	262	4.2	0.8	1.5	0.4	0.4
60–69	495	4.6	2.8	5.5	1.2	1.8
70–79	279	7.5	7.2	10.8	2.9	5.4
80–89	48	8.3	10.4	14.6	10.4	10.4
Total (≥ 50 years)	1 084	5.4	3.8	6.3	1.8	2.8
US reference database (NHANES III)						
50–59	262	–	1.5	3.4	1.9	1.9
60–69	495	–	6.1	7.1	4.6	4.8
70–79	279	–	10.4	14.7	9.3	9.3
80–89	48	–	20.8	16.7	18.8	14.6
Total (≥ 50 years)	1 084	–	6.7	8.6	5.8	5.7

Table 8. Prevalence of osteopenia in Chinese men (aged 50 years or older) using reference databases for Chinese and US non-Hispanic white men.

Age group (year)	*n*	L1-4 (%)	Total hip (%)	Femoral neck (%)	Trochanter (%)	Intertrochanter (%)
Chinese reference database						
50–59	262	21.4	24.0	42.4	25.2	21.4
60–69	495	25.7	35.6	48.3	35.4	34.3
70–79	279	26.5	48.0	51.9	41.6	40.9
80–89	48	33.3	47.9	52.1	45.8	47.9
Total (≥ 50 years)	1 084	25.2	34.7	47.9	34.9	33.5
US reference database (NHANES III)						
50-59	262	—	47.5	59.2	49.6	41.9
60-69	495	—	56.9	62.2	54.9	53.5
70-79	279	—	62.4	60.9	59.9	56.6
80-89	48	—	66.7	70.8	58.3	68.8
Total (≥ 50 years)	1 084	—	56.5	61.5	55.1	52.2

89 years) in Shanghai. The mean values for the BMD of lumbar spine or proximal femur (including total hip, femoral neck, trochanter and intertrochanter) in Chinese men are lower than those reported previously for US non-Hispanic white men (NHANES III database) [8, 9]. Looker *et al.* [8, 9] used DXA (Hologic 1000) measurements of femoral BMD from the third National Health and Nutrition Examination Survey (NHANES III, 1988–1994) to estimate the overall scope of the disease in the older US population. In their study, BMD in 14 646 men and women at age of 20 years and older (including 6 181 non-Hispanic whites, 4 021 non-Hispanic blacks and 3 858 Mexican Americas) was measured at five sites of proximal femur [8, 9].

According to the present study, the peak values of BMD in Chinese men of Han ethnicity appeared in the age range of 20–24 years at both the lumbar spine and any sites of hip. The findings at any site of hip were similar to those reported for US non-Hispanic white men [8, 9], but were different to those previous reported for Chinese women [5, 10]. We previously reported that peak BMD at the lumbar spine and femoral neck occurred in the age range of 30–34 years and 20–24 years in Shanghai Chinese women, respectively [5]. In another Chinese population study of a different geographic area, Wu and colleagues [10] reported that the peak BMD occurred in the age range of 35–39 years at both the lumbar spine and femoral neck.

Age-related bone loss demonstrated different patterns in various skeletal sites of the Chinese men. BMD was significantly decreased with age at any site of proximal femur, whereas no such change was observed at the lumbar spine in either the 20–49-year-old or the 50–89-year-old groups. BMD at the sites of proximal femur decreased 0.3–0.7% per year. Our results are in accordance with previously published cross-sectional and longitudinal studies in Caucasian men [11–13]. Szulc *et al.* [12] studied 934 healthy French men aged 19–85 years. There was a insignificant association between BMD of spine and age after 55 years in their study ($n = 637$, $r = 0.06$, $P = 0.06$), but a substantial decrease in BMD with age at the proximal femur was observed. Of 915 healthy Saudi men, little loss in lumbar spine in young men (age 20–49 years), and a slight loss (0.3% per year) in older men (age 50–79 years) are reported [13]. Our findings show no significant decrease in spine BMD with age but there was an enormous increase in the age-specific standard deviation. Similarly, in the study by Szulc *et al.* [12], there was a significant increase in the variability of spine BMD with age calculated as SD in two groups after age 55 years. These data suggest that degenerative artifacts within the spine confounded age-related changes and were probably responsible for this large increase in variance. In the elderly men, bone loss in the lumbar spine was masked by osteoarthritis. In fact, the coexistence of bone loss and osteoarthritis has been shown to increase BMD variability [14].

Similar to the findings in previous studies in women, weight and height were positively associated with BMD in Chinese men [3, 9]. Ensrud *et al.* [15] measured body

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weight and hip BMD in a cohort of 1 342 older men enrolled in the Osteoporotic Fractures in Men (MrOS) study, and followed them prospectively for an average of 1.8 years for changes in weight and BMD. The results showed that the adjusted average rate of change in total hip BMD was 0.1% per year in men with weight gain, –0.3% per year in men with stable weight and –1.4% per year in men with weight loss. In fact, low body weight was a significant risk factor for hip fracture in women and men [16].

The role of the T-score for osteoporosis diagnosis was solidified in reference to the WHO Study Group report. However, several researchers pointed out the shortcomings of using T-scores for individual diagnosis [17]. Large variations in the prevalence of osteoporosis were reported using the –2.5 definition at different skeletal sites [18]. Because of the dependence of the T-score on both the mean and SD of the reference population, it was recognized that the use of disparate reference populations on different densitometry systems would lead to T-score differences, even when the measured BMD was the same. Moreover, T-scores at various skeletal sites were different. The SD stands for the deviation of BMD from the mean BMD of a young healthy reference population, therefore the SD value affects the cut-off value of osteoporosis. The SD values were relatively small in our peak BMD group of age 20–39 years using Hologic DXA, and were lower than those of US non-Hispanic white men aged 20–29 years from the NHANES III database. Using our reference data, the cut-off values of osteoporosis were below that of US non-Hispanic white men. As a result, the prevalence of osteoporosis was significantly different in Chinese men 50 years or older using local younger-men reference values and US non-Hispanic white younger-men reference values. For L1-4, total hip, femoral neck, trochanter and intertrochanter, using a database of local men, the prevalences of osteoporosis were 5.4%, 3.8%, 6.3%, 1.8% and 2.8%, respectively. However, using the database of US men, the corresponding values were 6.7%, 8.6%, 5.8% and 5.7%, respectively. Of course, the prevalence of osteopenia in any site of measurement was also significantly higher when the database of US men was used as a reference in comparison with that of using reference values for local men. However, the findings of the current study were consistent with a Hong Kong study of Chinese men [19]. In that study, 1859 men aged 9–94 years old were recruited to measure BMD of lumbar spine and total hip using Hologic QDR 2000 and 4500. They reported that the prevalence of osteoporosis in lumbar spine and total hip in the groups of aged 40–59 years, 60–69 years, 70–79 years and over 80 years was 2% and 0%, 4% and 2%, 9% and 7%, and 8% and 12%, respectively. Consistent with our findings, in Hong Kong Chinese men, prevalence of in both lumbar spine and entire hip was significantly higher using a database of US Caucasian men as the reference [19]. In fact, Chinese have lower hip and vertebral fracture incidence than US Caucasians [20]. Accordingly, it will be more accurate to estimate prevalence of osteoporosis using a database of local men. In addition, because the lumbar spine BMD was slightly decreased in Chinese men over 50 years, we recommend that total hip and femoral neck BMD measurements should be used to diagnose osteoporosis in Chinese men. However, because the association between fracture incidence and BMD at lumbar spine and any site of hip in Chinese men has not been fully unfolded, the cut-off values in diagnosing osteoporosis need to be further confirmed in Chinese men.

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References

1 World Health Organization. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis. Technical report series No. 813. Geneva: WHO; 1994.
2 Center JR, Nguyen TV, Schneider D, Sambrook PN, Eisman JA. Mortality after all major types of osteoporotic fracture in men and women: An observational study. Lancet 1999; 353: 878–82.
3 Liao EY, Wu XP, Deng XG, Huang G, Zhu XP, Long ZF, *et al*. Age-related bone mineral density, accumulated bone loss rate and prevalence of osteoporosis at multiple skeletal sites in Chinese women. Osteoporos Int 2002; 13: 669–76.
4 Thoo FL, Chng SM, Lam KS, Lee JB, Tan MC, Teh HS, *et al*. To establish the normal bone mineral density reference database for the Singapore male. Ann Acad med Singapore 2002; 31: 21–5.
5 Huang QR, Zhou Q, Lu JH, Hu YQ, Liu YJ, Qin YJ, *et al*.

Bone mineral density and age-related bone loss in 2111 healthy women in Shanghai. Chin J Osteoporos 2002; 8: 191–4.
6 Qin YJ, Shen H, Huang QR, Zhao LJ, Zhou Q, Li MX, *et al*. Estrogen receptor alpha gene polymorphism and peak bone density in Chinese nuclear families. J Bone Miner Res 2003; 18: 1028–35.
7 Zhang ZL, Qin YJ, He JW, Huang QR, Li M, Hu YQ, *et al*. Association of polymorphisms in the low-density lipoprotein receptor-related protein 5 gene with bone mineral density in postmenopausal Chinese women. Acta Pharmacol Sin 2005; 26: 1111–6.
8 Looker AC, Orwoll ES, Johnston CC, Lindsay RL, Wahner HW, Dunn WL, *et al*. Prevalence of low femoral bone density in older U.S. adults from NHANES III. J Bone Miner Res 1997; 12: 1761–8.
9 Looker AC, Wahner HW, Dunn WL, Calvo MS, Harris TB, Heyse SP, *et al*. Update data on proximal femur bone mineral levels of US adults. Osteoporos Int 1998; 8: 468–89.
10 Wu XP, Liao EY, Huang G, Dai RC, Zhang H. A comparison study of the reference curves of bone mineral density at different skeletal sites in native Chinese, Japanese, and American Caucasian women. Calcif Tissue Int 2003; 73: 122-32.
11 Burger H, van Daele PL, Algra D, van den Ouweland FA, Grobbee DE, Hofman A, *et al*. The association between age and bone mineral density in men and women aged 55 years and over: the Rotterdam Study. Bone Miner 1994; 25: 1–13.
12 Szulc P, Marchand F, Duboeuf F, Delmas PD. Cross-sectional assessment of age-related bone loss in men: the MINOS study. Bone 2000; 26: 123–9.
13 Ardawi MS, Maimany AA, Bahksh TM, Nasrat HA, Milaat WA, Al-Raddadi RM. Bone mineral density of the spine and femur in healthy Saudis. Osteoporos Int 2005; 16: 43–55.
14 Wishart JM, Need AG, Horowitz M, Morris HA, Nordin BE. Effect of age on bone density and bone turnover in men. Clin Endocrinol (Oxf) 1995; 42: 141–6.
15 Ensrud KE, Fullman RL, Barrett-Connor E, Cauley JA, Stefanick ML, Fink HA, *et al.* Voluntary weight reduction in older men increases hip bone loss: The osteoporotic fractures in men study. J Clin Endocrinol Metab 2005; 90: 1998–2004.
16 Joakimsen RM, Fonnebo V, Magnus JH, Tollan A, Sogaard AJ. The Tromso study: Body height, body mass index and fracture. Osteoporos Int 1998; 8: 436–42.
17 Faulkner KG, von Stetten E, Miller P. Discordance in patient classification using T-scores. J Clin Densitom 1999; 2: 343–50.
18 Greenspan SL, Maitland-Ramsey L, Myers E. Classification of osteoporosis in the elderly is dependent on site-specific analysis. Calcif Tissue Int 1996; 58: 409–14.
19 Lynn HS, Lau EM, Au B, Leung PC. Bone mineral density reference norms for Hong Kong Chinese. Osteoporos Int 2005; 16: 1663–8.
20 Xu L, Lu A, Zhao X, Chen X, Cummings SR. Very low rates of hip fracture in Beijing, People's Republic of China the Beijing Osteoporosis Project. Am J Epidemiol 1996; 144: 901–7.