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Normal Bone Mineral Density in Anteroposterior, Lateral Spine and Hip of Chinese Men in Taiwan: Effect of Age Change, Body Weight and Height

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Key Words
bone density;
male;
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Background. The purpose of this study was to establish complete normative bone mineral density (BMD) values of Taiwanese men for anteroposterior, lateral spine, and hip.

Methods. Five-hundred and 69 healthy men (aged 20 to 88 years) were recruited to establish normal reference data of lumbar spine and hip, measured by a Hologic QDR 2000 bone densitometer. One-way analysis of variance was used to examine mean difference of BMD between different age groups. The effect of age change, body weight and height on BMD was determined by multivariate linear regression.

Results. The peak BMD values of most anatomic sites occurred in the age 20-30 group, and were 1.017, 0.862, 0.909, 0.860, 0.993 g/cm^2 for anteroposterior spine, lateral spine, femoral neck, Ward's triangle, and total hip, respectively. The BMD values then steadily decreased with increase of age. After age 60-70, there was less age-related reduction of BMD values at the anteroposterior, lateral spines and Ward's triangle. By the 8th decade, the percentage losses in the anteroposterior spine, lateral spine, femoral neck, Ward's triangle, and total hip were 12%, 22%, 30%, 45%, and 22%, respectively. The BMD values correlated better with age and body weight than with body height at all anatomic sites. The body height was insignificant in predicting the BMD values at most anatomic sites. As compared with the normative BMD value provided by the Hologic Corporation, Chinese men had lower BMD value than Caucasian at most sites except Ward's triangle. At the anteroposterior spine, the values of Chinese and Japanese men were similar, whereas at the hip and its subregions, Chinese young male population had higher bone mineral density than Japanese.

Conclusions. The data provided by this study may be used as normal reference values for Taiwanese men, instead of the values for Asians provided by the manufacturer.

Osteoporotic fracture is one of the leading cause of morbidity in elderly people.[1,2] Prevention of osteoporosis is of great importance in maintaining quality of life of the elderly and reducing medical expenditure for treatment of fractures. Although several factors contribute to fracture risk, bone mineral density (BMD) measurement is still the most important element in diagnosing osteoporosis or in screening people at higher risk for fracture.[3] The World Health Organization has defined osteoporosis in terms of bone mineral density, based on prior studies using dual energy X-ray absorptiometry (DXA).[4] However, in order to assure the validity of the results of bone densitometry, those results have to be considered in comparison with the corresponding values that refer to age- and sex- matched healthy persons from the same population. Furthermore, difference in measured value exists between the results derived from the 3 major manufacturers (Hologic, Norland, and Lunar) of DXA bone densitometers, and the reference data supplied by the manufacturers may not be interchange-

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able.[5-7] Therefore, it is necessary to establish normal reference data for our population for each specific machine used. So far as we know, although the normal reference data for Taiwanese women has been reported, there is still no complete set of data available or published regarding the normal range of the spine and hip of men for the Hologic DXA bone densitometer. Therefore, we tried to establish our own normal population reference values.

The aim of our study was, besides the establishment of normal reference data for Taiwanese men, to describe the patterns of annual bone loss at different skeletal sites and anatomic subregions and to compare these values with those of Japanese and Caucasian men.

METHODS

Five-hundred and 69 healthy men (aged 20 to 88 years) were recruited to establish the normal reference data for lumbar spine and hip. These subjects were mainly from our health examination center or on a volunteer basis. None of the subjects had a history of fracture or major bone disease. Persons with major systemic disorders such as renal, hepatic, thyroid, parathyroid, adrenal disease, or history of malignant tumor were excluded. None were taking any agent known to affect bone metabolism, such as steroid, vitamin D, calcium, calcitonin, antiepileptics, and thiazides. All subjects had normal serum levels of calcium and phosphate. Plain roentgenograms of lumbar spine were taken, and persons with compression fracture, significant scoliosis or degenerative disease were excluded from our series.

Body weight and height were measured routinely in typical indoor clothing without shoes. Body mass index (BMI) was calculated according to the following formula: BMI (kg m^{-2}) = body weight (kg) / (body length × body length (m^2)). The patient was considered as being overweight if the BMI was over 25 kg m^{-2}. Areal bone mineral density (BMD) was measured for the lumbar spine (L1-L4 in anteroposterior projection and L2-L4 in lateral projection) and hip (total and subregions) on a Hologic QDR 2000 bone densitometer (Hologic Corp., Waltham, MA). A width-adjusted volumetric BMD (vBMD) was obtained from the manufacturer's lateral spine modules, calculated from the combined AP and lateral DXA measurements based on the formula: Width-adjusted $vBMD = BMC_{lat} / (A_{lat} \times w \times \pi/4)$, where BMC_{lat} represents bone mineral content derived from the lateral DXA measurement, A_{lat} is the projected area of the lateral scan and w is the vertebral width derived from the PA scan. Of the 569 men, all had bone densitometry of the anteroposterior lumbar spine, 329 had lateral lumbar spine study, and 462 had hip densitometry.

The patterns of age-related bone density change at different skeletal sites and anatomic subregions were analyzed. The prevalence of osteoporosis was determined by age group. In this study, definitions of osteopenia and osteoporosis for men were made and adopted from World Health Organization criteria for postmenopausal Caucasian women. Osteopenia was defined as a T-score of more than one standard deviation (SD) below the young mean, but less than or equal to 2.5 SD below. Osteoporosis was defined as having a T-score of over 2.5 SD below the young normal mean.

Statistical analyses were performed using SPSS version 9.0 software (SPSS Inc., Chicago, Illinois). BMD values were analyzed in 10-year intervals by calculating the mean and standard deviations. Normality was confirmed in all age groups except age 80-90, of which sample sizes were much smaller. Seven outliers (2, 3, and 3 in age group 50-60, 60-70, and 70-80, respectively) greater than 3 SD were examined and excluded from this series. One-way analysis of variance was used to examine mean difference and relationships of BMD between different age groups. Independent-samples t-test was used to compare the mean BMD values between the overweight (BMI > 25) and lean (BMI ≤ 25) groups for each anatomic site and age group. For the correlation between BMD and age, body weight and height, partial correlation coefficients and multivariate regression analysis were applied as appropriate.

The established reference data and mean BMD values were compared with the reference values for Japanese and Caucasian men provided by the Hologic company.

RESULTS

The characteristics of the subjects are listed in Table 1.

Tables 2 to 4 present the BMD values of lumbar spines and hips measured in our study. Except for vBMD, the peak BMD values of all anatomic sites measured occurred in the age 20-30 group. The peak BMD value of vBMD was in the age 30-40 group. For each age group, the highest BMD values of spines were at L3 by the anteroposterior approach and at L4 by lateral approach. The BMD values of all sites then steadily decreased with increase of age. After age 60-70, there was less age-related reduction of BMD values at the anteroposterior, lateral spines and Ward's triangle, while at other sites, the BMD values continued to decrease with aging. The decreases of BMD values between different age groups were quite small in the anteroposterior spines as compared with those of the lateral spines and the hips. By the

Table 1. Characteristics of the subjects

Age group	Number	Height	Weight	BMI
20-30	72	173.4 ± 6.1	69.0 ± 13.1	22.9 ± 3.8
30-40	90	170.0 ± 6.2	69.6 ± 11.1	24.0 ± 3.5
40-50	115	169.3 ± 5.9	71.8 ± 10.3	25.0 ± 3.2
50-60	120	168.9 ± 6.1	70.6 ± 8.0	24.7 ± 2.5
60-70	70	166.2 ± 6.7	68.5 ± 10.7	24.7 ± 3.4
70-80	88	164.7 ± 6.0	63.9 ± 10.4	23.5 ± 3.7
80-90	14	164.0 ± 8.4	62.0 ± 10.9	23.0 ± 3.6
total	569	168.8 ± 6.7	69.2 ± 10.8	24.2 ± 3.4

BMI = body mass index.

Table 2. Mean and standard deviation of BMD (g/cm^2) of anteroposterior spine by age groups

Age group	Total (L1-L4)	L1	L2	L3	L4
20-30 (n = 72)	1.017 ± 0.111	0.974 ± 0.118	1.031 ± 0.120	1.041 ± 0.115	1.016 ± 0.113
30-40 (n = 90)	1.009 ± 0.121	0.972 ± 0.126	1.020 ± 0.131	1.030 ± 0.126	1.010 ± 0.130
40-50 (n = 115)	0.964 ± 0.119	0.921 ± 0.120	0.972 ± 0.125	0.985 ± 0.129	0.972 ± 0.129
50-60 (n = 120)	0.941 ± 0.138	0.904 ± 0.133	0.951 ± 0.139	0.953 ± 0.149	0.951 ± 0.151
60-70 (n = 70)	0.913 ± 0.141	0.876 ± 0.147	0.903 ± 0.145	0.932 ± 0.148	0.936 ± 0.154
70-80 (n = 88)	0.895 ± 0.159	0.836 ± 0.153	0.874 ± 0.160	0.912 ± 0.168	0.940 ± 0.178
80-90 (n = 14)	0.892 ± 0.115	0.790 ± 0.094	0.881 ± 0.112	0.915 ± 0.135	0.955 ± 0.151

$P < 0.001$ from ANOVA test among different age group.

Table 3. Mean and standard deviation of BMD (g/cm^2) of lateral spine by age group

Age group	Total (L2-L4)	vBMD (L2-L4)	L2	L3	L4
20-30 (n = 41)	0.862 ± 0.113	0.225 ± 0.024	0.789 ± 0.100	0.852 ± 0.122	0.935 ± 0.141
30-40 (n = 41)	0.845 ± 0.114	0.227 ± 0.029	0.773 ± 0.111	0.820 ± 0.123	0.930 ± 0.151
40-50 (n = 59)	0.810 ± 0.111	0.221 ± 0.028	0.733 ± 0.109	0.814 ± 0.135	0.883 ± 0.127
50-60 (n = 33)	0.760 ± 0.119	0.201 ± 0.028	0.697 ± 0.112	0.754 ± 0.141	0.844 ± 0.142
60-70 (n = 66)	0.695 ± 0.124	0.186 ± 0.03	0.630 ± 0.140	0.682 ± 0.138	0.774 ± 0.127
70-80 (n = 79)	0.674 ± 0.129	0.179 ± 0.031	0.601 ± 0.141	0.660 ± 0.128	0.766 ± 0.158
80-90 (n = 10)	0.676 ± 0.101	0.174 ± 0.026	0.604 ± 0.135	0.658 ± 0.131	0.754 ± 0.074

vBMD = width-adjusted volumetric BMD, unit as g/cm^3; $P < 0.001$ from ANOVA test among different age groups.

Table 4. Mean and standard deviation of BMD (g/cm^2) of hip by age group

Age group	Femoral neck	Trochanter	Inter-trochanter	Ward's triangle	Total
20-30 (n = 66)	0.909 ± 0.119	0.747 ± 0.109	1.147 ± 0.130	0.860 ± 0.157	0.993 ± 0.115
30-40 (n = 89)	0.823 ± 0.119	0.691 ± 0.121	1.099 ± 0.161	0.735 ± 0.158	0.935 ± 0.141
40-50 (n = 96)	0.796 ± 0.109	0.678 ± 0.091	1.067 ± 0.124	0.644 ± 0.127	0.911 ± 0.108
50-60 (n = 106)	0764 ± 0.105	0.673 ± 0.102	1.055 ± 0.139	0.602 ± 0.138	0.890 ± 0.115
60-70 (n = 44)	0.685 ± 0.110	0.615 ± 0.103	0.981 ± 0.159	0.495 ± 0.155	0.829 ± 0.130
70-80 (n = 51)	0.683 ± 0.116	0.594 ± 0.115	0.943 ± 0.160	0.465 ± 0.127	0.809 ± 0.133
80-90 (n = 10)	0.632 ± 0.132	0.549 ± 0.108	0.923 ± 0.141	0.469 ± 0.161	0.777 ± 0.134

$P < 0.001$ from ANOVA test among different age groups.

8th decade, the percentage loss in the anteroposterior spine, lateral spine, spine vBMD, femoral neck, trochanter, intertrochanter, Ward's triangle, and total hip were 12%, 22%, 23%, 30%, 27%, 20%, 45%, and 22%, respectively. Multiple comparisons by post-hoc Scheffe test revealed significant difference of BMD among age groups 1-2 decades apart in the femoral neck and Ward's triangle and 2-3 decades apart in all the other anatomic sites and subregions.

Table 5 lists the cutoff values for diagnosis of osteopenia and osteoporosis, based on the above criteria mentioned in the Method section. The incidences of osteoporosis in different age groups and anatomic sites are shown in Table 6. To avoid statistical error, subjects aged from 80 to 90 were grouped with those from 70 to 80 because of the small sample size of the former. The incidences of osteoporosis gradually increase with age at each anatomic site ($p < 0.001$ from chi square for linear trend analysis). The site of highest incidence was Ward's triangle, followed by spine vBMD, femoral neck, and lateral spine ($p < 0.001$).

The BMD values of the overweight (BMI > 25) sub-

Table 5. Cutoff values for diagnosis of osteopenia and osteoporosis at different anatomic sites

	AP lumbar spine (L1-L4)	Lat lumbar spine (L2-L4)	Spine vBMD (L2-L4)	Femoral neck	Ward's triangle	Total hip
Osteopenia	0.906	0.749	0.198	0.790	0.703	0.878
Osteoporosis	0.740	0.580	0.155	0.612	0.468	0.706

vBMD = width-adjusted volumetric BMD, unit as g/cm^3.

Table 6. Prevalence of osteoporosis in different age groups and anatomic sites

Age group	AP lumbar spine (L1-L4)	Lat lumbar spine (L2-L4)	Spine vBMD (L2-L4)	Femoral neck	Ward's triangle	Total hip
20-30	0% (0/72)	0% (0/41)	0% (0/41)	0% (0/66)	0% (0/66)	0% (0/66)
30-40	0% (0/90)	2.4% (1/41)	2.4% (1/41)	1.1% (1/89)	0% (0/89)	2.2% (2/89)
40-50	2.6% (3/115)	1.7% (1/59)	0% (0/59)	3.1% (3/96)	10.4% (10/96)	4.2% (4/96)
50-60	4.2% (5/120)	3.0% (1/33)	9.1% (3/33)	5.7% (6/106)	17% (18/106)	4.7% (5/106)
60-70	10.0% (7/70)	19.7% (13/66)	24.2% (16/66)	22.7% (10/44)	50% (22/44)	11.4% (5/44)
70-90	15.7% (16/102)	21.3% (19/89)	38.2% (34/89)	32.8% (20/61)	57.4% (35/61)	18.3% (11/61)

vBMD = width-adjusted volumetric BMD.

Table 7. Comparison of mean BMD values (g/cm^2) between lean and overweight groups

Location	BMI > 25 (kgm^{-2})		BMI ≤ 25 (kgm^{-2})		Difference	Statistics[a]
	Number	Mean ± SD	Number	Mean ± SD		
AP spine	213	0.80 ± 0.15	356	0.74 ± 0.13	0.07 ± 0.02	$P < 0.001$
Lateral spine	123	0.80 ± 0.15	206	0.74 ± 0.13	0.07 ± 0.02	$P < 0.001$
Spine vBMD	123	0.21 ± 0.04	206	0.20 ± 0.03	0.017 ± 0.004	$P < 0.001$
Femoral neck	170	0.82 ± 0.13	292	0.76 ± 0.13	0.06 ± 0.01	$P < 0.001$
Ward's triangle	170	0.68 ± 0.20	292	0.63 ± 0.18	0.06 ± 0.02	$P = 0.003$
Total hip	170	0.96 ± 0.13	292	0.87 ± 0.12	0.09 ± 0.01	$P < 0.001$

[a] Independent-samples *t* test, without significant difference in age distribution of both groups.
vBMD = width-adjusted volumetric BMD, unit as g/cm^3.

jects were significantly higher than those of the lean subjects (BMI ≤ 25) at each anatomic site (Table 7). Multivariate linear regression by stepwise selection showed that the body height was insignificant in predicting the BMD values at most anatomic sites. However, at the spine vBMD, the body height was found to be a significant predicting factor by the same analytic method. The regression equations after removal of the insignificant factors are summarized in Table 8.

Strong correlations were observed between total hip and intertrochanter, total hip and trochanter, and also lateral spine and vBMD (r = 0.97, 0.94, and 0.93, respec-

Table 8. Stepwise multivariate linear regression equations between BMD values (g/cm^2) and age (year), weight (kg), and height (m)

Site	Equation	R^2	p
AP spine	BMD = 0.751 - 0.002*Age + 0.0045*weight	0.208	< 0.001
Lateral spine	BMD = 0.652 - 0.0034*Age + 0.0043*weight	0.379	< 0.001
Spine vBMD	BMD = 0.301 - 0.001*Age + 0.0011*weight- 0.0007*height	0.410	< 0.001
Femoral neck	BMD = 0.716 - 0.0041*Age + 0.0039*weight	0.399	< 0.001
Ward's triangle	BMD = 0.784 - 0.0073*Age + 0.0031*weight	0.465	< 0.001
Total hip	BMD = 0.680 - 0.0030*Age + 0.0053*weight	0.365	< 0.001

vBMD = width-adjusted volumetric BMD, unit as g/cm^3.

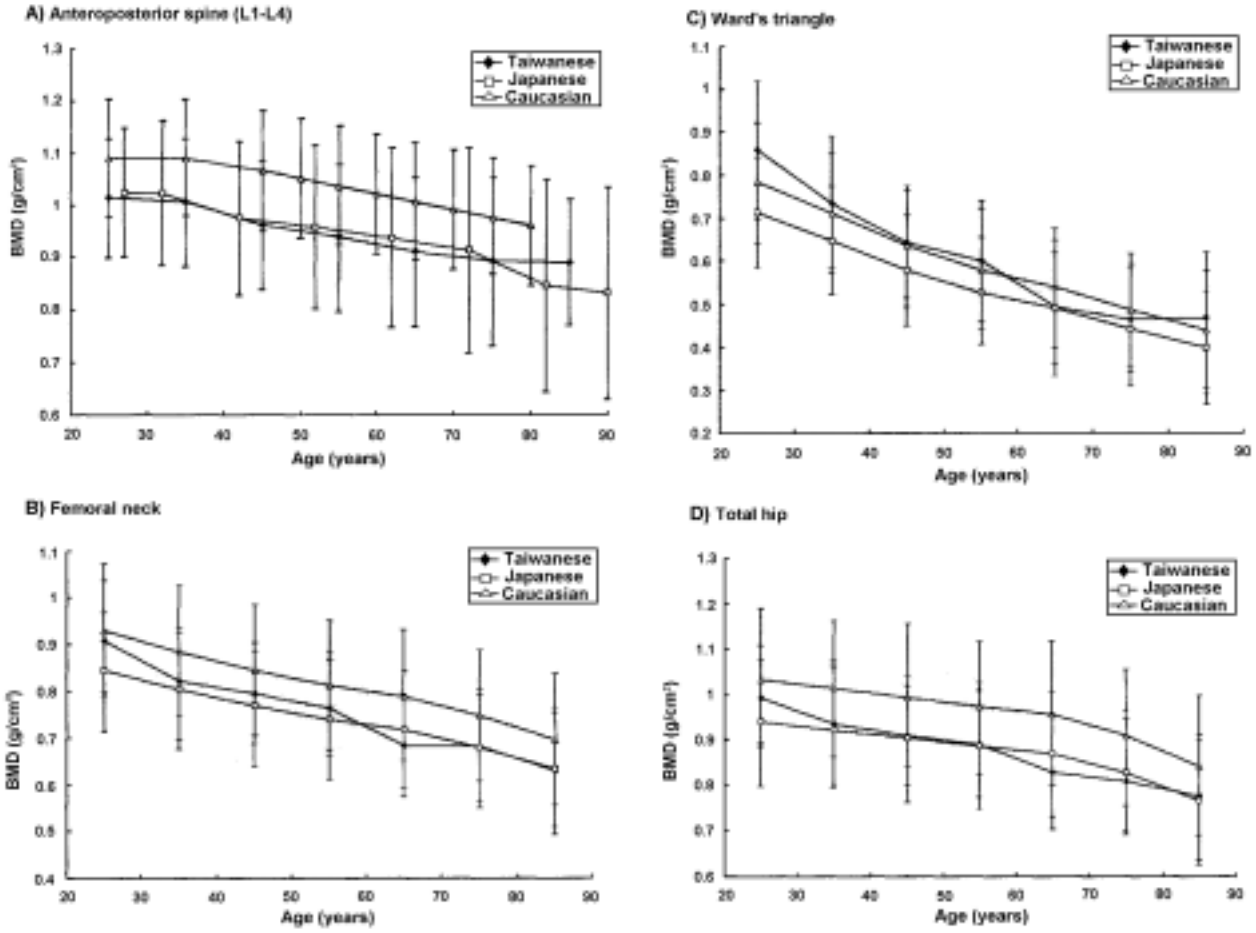

Fig. 1. BMD values of Chinese men in Taiwan compared with the Hologic-supplied reference data for Caucasian and Japanese, displayed by one-direction error bar. (**A**) Anteroposterior lumbar spine (L1-L4), (**B**) femoral neck, (**C**) Ward triangle, (**D**) total hip.

tively). The correlation of vBMD with the anteroposterior spine was much weaker than that of the lateral spine (r = 0.65 *vs* 0.93). For the relationships between different projections (AP spine, lateral spine, and total hip), there were moderate degrees of correlation with r values between 0.67 to 0.75; the highest one was between AP and lateral spine.

Fig. 1 compares the mean BMD values in Taiwanese men of our study with the reference values for Japanese and Caucasian men provided by the manufacturer of our bone densitometer. For the anteroposterior lumbar spine, our values were similar to the Japanese values and were lower than those for Caucasians. For the total hip and its subregions, our values in the age 20-30 group were higher than those of Japanese. After the age of 30-40, with the exception of Ward's triangle, our values were similar to the Japanese values and lower than those for Caucasians. For Ward's triangle, our value was even higher than that of Caucasians in the age 20-30 group, and similar to Caucasians for ages 30 to 60. It declined to the level of Japanese in age 60-70, and then became more steady than that of Japanese and Caucasians. The reference values for lateral and volumetric lumbar spine of men were not provided by the Hologic company, therefore comparisons between different ethnic groups were not available (Fig. 2).

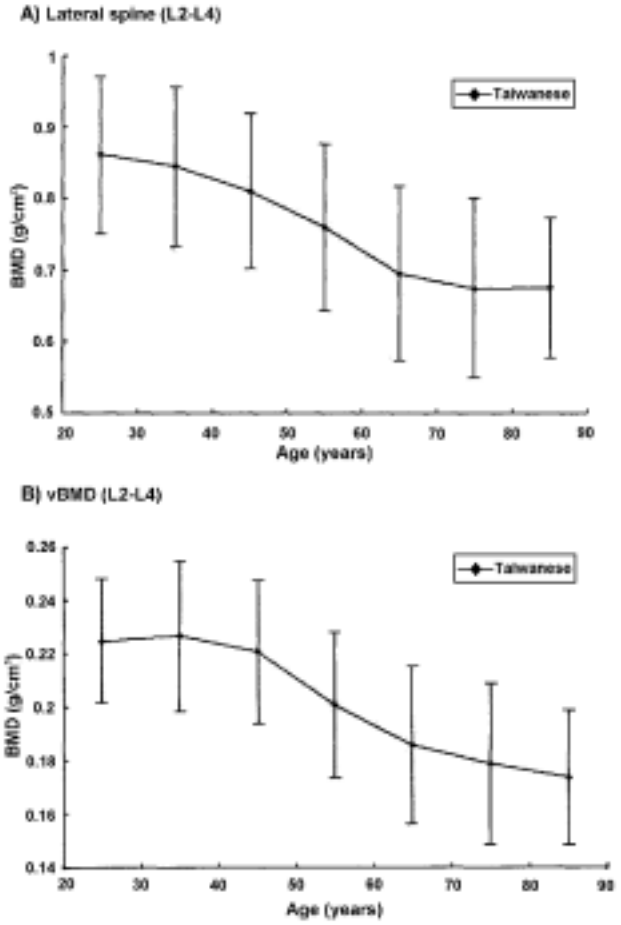

Fig. 2. BMD values of Chinese men in Taiwan, displayed by one-direction error bar. (**A**) Lateral lumbar spine (L2-L4), (**B**) lumbar spine volumetric BMD (L2-L4).

DISCUSSION

Much effort has been made to establish reference values of BMD at different skeletal sites in Caucasian populations, especially for females, but relatively less in Asians. There are arguments over whether the reference ranges supplied by the manufacturers of bone densitometers can be applied to all populations or different populations need to establish their own normative data.[5,7,8] Moreover, different densitometers may have different ranges of scan for different bone sites, for which adequate cross-calibration may not be possible.[5,7,9,10] Although standardized BMD has been proposed for comparison of spine between densitometers of different manufacturers,[11-13] the BMD values at the hip sites (except total hip) are still not interchangeable.[14]

Our study established the Hologic normative data for Chinese men in Taiwan that has never been reported. So far as we know, the only normal DXA reference data for Taiwanese men was reported in 1997 using Norland densitometer for the anteroposterior lumbar spine.[15] As shown in our data and the Hologic-provided reference values for Japanese and Caucasians, the slope of decline in BMD of anteroposterior spine was much less than those of hip and lateral spine. Diagnosing osteoporosis solely based on the anteroposterior spine may result in underestimation of the severity and the prevalence of osteoporosis and thus has important public health implications.

The discordance in diagnosis of osteoporosis using spine and proximal femur BMD has been described. However, different conclusions have been reached concerning the relative sensitivity of spine and hip DXA in diagnosis of osteoporosis based on WHO criteria. In

some literature, it has been shown that total hip and femoral neck DXA identified fewer osteoporotic patients than spine DXA,[16,17] while in other reports DXA of hip was more sensitive for osteoporosis than spine DXA.[18,19] In our series, the prevalence of osteoporosis was apparently higher when determined by DXA of femoral neck and lateral spine than by AP spine. Osteophytosis, which is a natural aging process and usually more prominent at the lumbar spine than the hip, played a role in lowering the sensitivity of DXA in aged groups. Although exclusion of those with degenerative changes from the sample population was associated with higher sensitivity of spine DXA than hip DXA in a prior report,[16] our series, in which people with significant degenerative disease were also excluded, still showed a lower incidence of osteoporosis for the anteroposterior spine than the hip. Some other factors, such as differences in the young adult reference populations used by the various bone densitometry devices and technology-related differences, may also account for the variation.

As stated earlier in the text, with the exception of Ward's triangle, our values were also similar to the Japanese values for the groups age 30-40 and above. For the anteroposterior spine, our value for young adults (age 20-30 group) was similar to that of Japanese, whereas the values for total hip and its subregions were higher than those of Japanese. Although there were discrepancies among our data and the reference values for the Japanese people and Caucasian given by the manufacturer, whether the difference is statistically significant is questionable since the original data was hard to come by. Little reference data for Chinese men has been reported in other areas of Asia. Thoo *et al*. reported that the mean peak BMDs for the average lumbar spine and the neck of femur were 1.006 g/cm2 and 0.97 g/cm2, respectively, taken in the 20 to 24 years age group.[20] The data is close to our result. Woo *et al*. also presented some normal reference data from Hong Kong, but only for men aged 40 to 79. The data was not consistent with ours, with values of the middle-age groups (40-59) lower than and those of the older groups (60-79) higher than our values.[10] Yu *et al*., using Lunar DXA, reported peak bone mass of anteroposterior and lateral spine at the 4th and 3rd decades, respectively. The data was not comparable to ours because of different bone densitometer used and different range of measurement for the lateral spine (L2-3).[21] The reference values for lateral spine of men were not provided by the Hologic company, therefore comparisons between different ethnic groups were not available in this study.

In many prior studies, obesity has been shown to be related to higher BMD values of lumbar spine and hip in both men and women.[22-24] Similar results were found in our study. Further analysis of the relationship of the BMD and anthropometric characteristics revealed that body weight had a much stronger correlation with BMD than body height did. In this study, for all of the anatomic sites and subregions, both age and body weight appeared to be more important influencing factors of BMD values than the height was.

As shown in Table 6, Ward's triangle was also the site with most pronounced age-related bone mineral loss. Because of too rapid age-related bone loss and inconsistency with fracture risk evaluation, Ward's triangle is rarely selected as the site for diagnosis of osteoporosis in the daily practice of our institute.

Our results of correlation coefficients between BMD measurements of different anatomic sites were similar to previous results in other reports.[21,25-27] Based on the finding that the strongest correlation existed between total hip and the subregions of trochanter and intertrochanter, it appeared that measurements derived from the same anatomic site correlated better than those from different anatomic sites, even though these subregions were composed of different proportions of cortical and trabecular bone. Strong correlation was also observed between lateral spine and vBMD. Although the latter was an estimated volumetric BMD derived from calculation of anteroposterior and lateral areal BMD data, its correlation with the anteroposterior spine was much weaker than that of the lateral spine (r = 0.65 *vs* 0.93). This can be explained by the inclusion of posterior element in the anteroposterior technique but not in the lateral and vBMD techniques, and by the formula Hologic used for calculating the vBMD, in which lateral BMD is the dominant factor, adjusted by the AP width, which varies less among people.

Our results revealed more pronounced age-related bone loss for lateral lumbar spine and vBMD than for the anteroposterior spine. Ward's triangle and the femoral

neck also showed more age-related bone loss than other subregions of the hip. This is mostly due to the higher proportion of trabecular bone measured by these techniques or subregions, and the fact that the rate of bone turnover is much higher in the trabecular bone than in the cortical bone. Osteophytosis, which is a natural aging process and usually more prominent at the lumbar spine than the hip, will inevitably increase the measured BMD and also play a role in the decreased bone loss of spine in aged groups. The measurement of anteroposterior spine also suffered from calcification of abdominal aorta and sclerosis or hypertrophy of posterior elements, which were excluded on the lateral spine module.

The reference data for Caucasian and Japanese males provided by Hologic are different from the values for Taiwanese population. The data provided by this study may be used as normal reference values for Taiwanese men, instead of the values for Asians that were provided by the manufacturer and derived from Japanese. To our knowledge, this is the most complete set of male normative values established in Taiwan so far.

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