Jurnal Sains Kesihatan Malaysia **5** (2) 2007: 29-38

Relationship between Body Composition and Bone Mineral Density in Healthy Postmenopausal Chinese Women in Malaysia

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ABSTRAK

Kehilangan jisim tulang adalah lebih ketara selepas menopaus. Jangka masa menopaus dan umur yang meningkat dikaitkan dengan penurunan jisim tubuh tanpa lemak, peningkatan lemak badan dan peningkatan berat badan. Kajian ini melihat sumbangan relatif jisim tubuh tanpa lemak dan lemak badan ke atas ketumpatan mineral tulang (KMT) di kalangan 139 wanita Cina posmenopaus sihat di Kuala Lumpur. KMT di kawasan seluruh tubuh, tulang belakang (L2-L4), leher femur dan keseluruhan tulang pinggul diukur dengan alat dual-energy X-ray absorptiometry (DXA). Hasil kajian mendapati 80% daripada wanita posmenopaus Cina mempunyai jisim tulang yang rendah (osteopenia) manakala 8% daripada mereka mengalami osteoporosis di bahagian tulang belakang atau tulang pinggul. Secara keseluruhan, lemak badan mempunyai korelasi yang positif dengan KMT di semua bahagian diukur (keseluruhan tubuh, $r = 0.265$, $p < 0.001$; tulang belakang $r = 0.214$, $p < 0.05$, leher femur, $r = 0.254$, $p < 0.001$; keseluruhan tulang pinggul $r = 0.332$, $p < 0.001$). Jisim tubuh tanpa lemak juga mempunyai korelasi yang positif dengan KMT kebanyakan kawasan diukur (keseluruhan tubuh, $r = 0.239$, $p < 0.001$; leher femur $r = 0.365$, $p < 0.001$; keseluruhan tulang pinggul $r = 0.352$, $p < 0.001$) kecuali tulang belakang. Analisis regresi menunjukkan lemak badan dapat meramal KMT pada keseluruhan badan ($p < 0.0001$) dan tulang belakang ($p < 0.005$) manakala jisim tubuh tanpa lemak dapat meramal KMT pada tulang femur dan tulang pinggul ($p < 0.0001$). Hasil kajian menunjukkan kedua-dua lemak tubuh dan jisim tubuh tanpa lemak memainkan peranan dalam mempengaruhi KMT, di mana lemak badan memainkan peranan yang lebih di kalangan wanita posmenopaus. Oleh itu, wanita posmenopaus perlu elakkan mempunyai berat badan yang terlalu rendah (kurang lemak badan) dan mengekalkan jisim tubuh tanpa lemak untuk mencegah osteoporosis.

Kata kunci: Ketumpatan mineral tulang, wanita posmenopaus, komposisi tubuh, lemak badan, jisim tubuh tanpa lemak, osteoporosis

ABSTRACT

Bone loss is known to be accelerated during menopause. The postmenopausal period with advancing age has also been associated with a decrease in lean body mass, an increase in body fat mass and increase in body weight. This study investigated the relative contribution of lean body mass and body fat mass to bone mineral density (BMD) in 139 healthy postmenopausal Chinese women in Kuala Lumpur. Total body, lumbar spine (L2-L4), femoral neck and total hip BMD were measured using dual-energy X-ray absorptiometry (DXA). Findings revealed that 80% of the Chinese postmenopausal women had low bone mass (osteopenia) and 8% were osteoporotic at the lumbar spine and/or femoral neck. Overall, body fat mass showed a positive correlation with BMD at all sites (total body, $r = 0.265$*,* $p < 0.001$*; lumbar spine* $r = 0.214$*,* $p < 0.05$*, femoral neck* $r = 0.254$*,* $p < 0.001$*; total hip* $r = 0.332$*,* $p < 0.001$*). Similarly, lean body mass was positively correlated with BMD at most sites (Total body* $r = 0.239$*,* $p < 0.001$*; femoral neck* $r = 0.365$*,* $p < 0.001$*; total hip* $r = 0.352$*,* $p < 0.001$*) except at the lumbar spine. In a multiple stepwise regression analysis body fat mass was a significant predictor for BMD for total body (*$p < 0.0001$*) and lumbar spine (*$p < 0.005$*) BMD, while lean body mass was the major determinant of BMD at the femoral neck and total hip (*$p < 0.0001$*). These data suggested that both fat and lean mass were significant determinants of BMD, the former playing a greater role than lean mass in postmenopausal women. Therefore, postmenopausal women need to avoid being too underweight (and thus having too low body fat) and to maintain lean body mass to protect against osteoporosis.*

Key words: Postmenopausal women Bone mineral density, body composition, fat mass, lean mass, osteoporosis

INTRODUCTION

During menopause, women experienced additional bone loss due to estrogen deficiency. There is increased activation of bone remodeling sites and enhanced remodeling imbalances (Heaney, Recker & Saville 1978). The postmenopausal period has also been associated with a decrease in lean body mass, an increase in body fat mass and increase in body weight (Svendsen, Hassager & Christiansen 1995). It is well recognized that body weight is one of the important determinants of bone mineral density (BMD), in which increased body weight is significantly associated with increased bone mineral mass in both pre- and postmenopausal women (Harris, Dallal & Dawson-Hughes 1992; Kroger et al. 1994). Numerous studies indicate that bone mineral mass is closely related to other body composition variables at different age stages (Harris et al. 1992; Compston et al. 1992; Reid et al. 1992; Kroger et al. 1994; Aloia et al. 1995). Adiposity has been postulated to be related to skeletal mass in postmenopausal women. Besides increased mechanical load on bone is associated with increased fat mass, it is also considered to be beneficial to bone mineral mass through the conversion by adipose tissue of adrenal androgens to estrogen (Aloia et al. 1995). Reid et al. (1992) reported that body fat mass is the most significant predictor of BMD in postmenopausal women while still others have found that both lean and fat mass exert independent effects on BMD (Hla et al. 1996; Douchi et al. 1997; Douchi et al. 2000). Some studies have also shown that only lean mass is the important determinant of BMD in both pre and postmenopausal women (Aloia 1995; Chen et al. 1997). Possible reasons for this discrepant findings may include differences in ethnicity, sites in which BMD is measured and as well as menopausal status. Furthermore, some of these studies did not separate pre- and postmenopausal women in their analysis. A better understanding of the relationship between body composition and BMD and their underlying biological mechanisms would play an important role in osteoporosis prevention and management.

In this study, we investigated the relative contribution of lean and body fat mass to BMD among postmenopausal Chinese women in Malaysia.

MATERIALS & METHODS

SUBJECTS

Volunteers were invited by advertisements and subject recruitment was also conducted in various senior citizens clubs, residential areas and religious centers in Kuala Lumpur. A total of 139 healthy postmenopausal Chinese women, aged 53-70 years old were enrolled in this study. A medical history questionnaire was administered to ensure subjects were not suffering from any chronic or acute diseases or taking any medications that were likely to affect bone metabolism such as anti-osteoporotic drugs or anticonvulsant drugs. The women were also non- HRT users. All subjects were fully informed of the study procedures and gave informed consent. The study was approved by the research ethics committee of the Faculty of Medicine in Universiti Kebangsaan Malaysia.

BONE MINERAL DENSITY MEASUREMENT

Bone mineral density (BMD) was measured at the University Malaya Medical Center (UMMC) using a DPX-IQ densitometer (LUNAR Corp., Madison, WI, USA). The instrument is based on the principle of dual energy X-ray absorptiometry (DEXA), which enables quantitative assessment of bone mineral in specific regions of the body. BMD of the total body, lumbar spine (L2-L4), femoral neck and total hip were measured by a radiologist. A daily quality assurance check using aluminium spine phantom was carried out before beginning BMD scans for each day according to the manufacturer's direction and all scans were performed and analyzed by the same operator. The coefficients of variation (CV) of BMD measurements were: 0.4% at the total body, 0.7% at the spine, 1.0% at the femoral neck and 0.6% at the total hip.

ANTHROPOMETRY MEASUREMENT

The anthropometric measurements carried out in the study included weight, height, body fat mass, lean body mass and percentage of body fat was calculated. Weight was measured to the nearest 0.1 kg in light clothing without shoes using a digital weighing scale (SECA, British Indicators LTD., UK). The measurement was done with the subject standing on the center of the scale without support and the weight distributed evenly on both feet. Height was measured to the nearest 0.1 cm with the height attachment on the weighing scale. The subject stood with the feet together and the heels, buttocks and upper back in a straight line. The head was placed in the Frankfurt plane. Body mass index (BMI) was then calculated from the measurements of weight and height as follow: BMI (kg/ m^2) = Weight (kg)/Height (m^2) and classified according to WHO (2000). Body fat mass, lean body mass and percentage of fat were measured using total body scan by DXA. Waist and hip circumference were measured by anthropometric tape using the method as described by the International Society for the Advancement of Kinanthropometry (ISAK). Waist circumference was taken at the level of narrowest point between the lower costal border and the iliac crest. Hip circumference was taken at the level of the greatest posterior protuberance of the buttocks. Waist hip ratio was calculated.

STATISTICAL ANALYSIS

SPSS software version 11.0 (SPSS Inc. Chicago, USA) was used for statistical analyses and the significance level was set at $P < 0.05$. Analysis included descriptive statistics and Pearson correlation tests. All the tests were two-tailed and results were presented as mean ± SD. Multiple stepwise regression analysis by entry method was also carried out to determine the predictors of BMD in postmenopausal women.

RESULTS

The 139 postmenopausal Chinese women had an average age of 62 ± 3 years old and were 13 ± 4 years postmenopausal (Table 1). The weight of the subjects ranged from 39.1 to 101.7 kg with a mean of 56.9 ± 9.6 kg. The mean height of the subjects was 1.54 ± 0.05 m.

TABLE 1. Personal characteristics, anthropometric characteristics and bone mineral density of total body, lumbar spine, femoral neck and total hip (n = 139)

Characteristics	Mean ± SD
Age (years)	62 ± 3
Years since menopause	13 ± 4
Body weight (kg)	56.9 ± 9.6
Height (cm)	154 ± 5
BMI (kg/m²)	24.1 ± 3.9
Waist hip ratio (WHR)	0.83 ± 0.06
Body fat mass (kg)	22.0 ± 6.9
Percentage of body fat (%)	37.4 ± 6.6
Lean body mass (kg)	32.2 ± 3.6
Lean body mass/body fat mass (kg)	1.6 ± 0.5
Bone mineral content, (BMC) (g)	2004 ± 299
BMD total body (g/cm²)	1.061 ± 0.080
BMD lumbar spine (L2-L4) (g/cm²)	1.016 ± 0.164
BMD femoral neck (g/cm²)	0.811 ± 0.114
BMD total hip (g/cm²)	0.878 ± 0.118

SD, standard deviation; BMD; bone mineral density; BMC; bone mineral content

About 31.7% of the subjects were overweight and 6.5% were obese while 58.3% of subjects were of normal weight and only 3.6% were underweight (Table 2). Following WHO (1994) classification for BMD, 81% of the women had low bone mass (osteopenia) (T-score between -1.0 to -2.5) and 8% were osteoporotic (T-score equal to or less than -2.5) at the lumbar spine and /or femoral neck (Figure 1)

TABLE 2. Body Mass Index (BMI) distribution for subjects according to WHO (2000) classification (n = 139)

Body Mass Index (BMI)(kg/m²)	Classification	n	Percentage (%)
<18.5	Underweight	5	3.6
18.5 to 24.9	Normal	81	58.3
25.0 to 29.9	Overweight	44	31.7
≥ 30	Obese	9	6.5

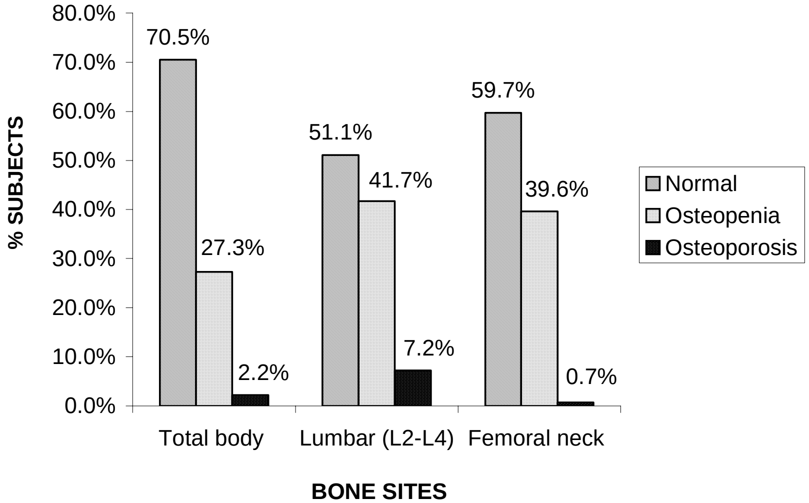

FIGURE 1. Bone status of the subjects.

Table 3 shows the correlation coefficients between age, body composition, anthropometric parameters and BMD measurements in study population. Fat and lean mass were highly correlated with weight ($r = 0.946$, $p < 0.001$ and 0.778 $p < 0.001$, respectively) and were found to be moderately correlated to each other ($r = 0.540$, $p < 0.001$). Body weight, height, fat mass and bone mineral content (BMC) were positively correlated with BMD at all sites. Waist hip ratio (WHR), BMI and lean body mass were significantly correlated with BMD at most sites except at the lumbar spine (L2-L4). Similarly, years since menopause was inversely correlated with BMD for the total body, lumbar spine and femoral neck, while age was negatively correlated with only significant at the total body and femoral neck.

TABLE 3. Pearson correlation coefficients (r value) between age, body composition, anthropometric parameters and BMD (n = 139)

Parameters	Total Body	Lumbar (L2-L4)	Femoral neck	Total Hip
Age	-0.222**	-0.117	-0.188*	-0.165
Years since menopause	-0.206*	-0.183*	-0.173*	-0.114
Body weight	0.292**	0.216*	0.333**	0.384**
Height	0.275**	0.205*	0.274**	0.168*
Body Mass Index	0.204*	0.147**	0.251**	0.345**
Waist hip ratio	0.197*	0.123	0.291**	0.336**
Fat mass	0.265**	0.214*	0.254**	0.332**
Lean mass	0.239**	0.142	0.365**	0.352**
Bone Mineral Content	0.831**	0.697**	0.713**	0.724**

** Correlation is significant at the 0.001 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Relationship between waist hip ratio (WHR), body composition and BMI

Multiple stepwise regression analysis was performed in order to investigate the relative contribution of fat mass and lean mass to BMD, with BMD as in dependent variable while WHR, BMC, fat mass and lean mass as independent variables. The results showed that all of these variables could enter the regression model (r^2 = 0. 897, $P < 0.0001$) with fat mass: $r^2 = 0.850$, $\beta = 0.838$, lean mass: $r^2 = 0.030$, β = 0.207, WHR: $r^2 = 0.009$, $\beta = 0.108$, and BMC: $r^2 = 0.008$, $\beta = -0.121$ respectively.

Body mass index (BMI) and weight were omitted in favor of lean body mass and fat mass to exclude variables that were highly correlated. Body fat mass was a significant predictor for BMD at the total body ($p < 0.0001$) and lumbar spine ($p < 0.005$) while lean body mass was the major determinant of BMD at the femoral neck ($p < 0.001$) and total hip ($p < 0.001$) (Table 4).

TABLE 4. Multiple stepwise regression analysis for anthropometric parameters, body composition and BMD

Independent Variable	Dependant variable	R^2	P-value
Total Body BMD			
	Height	0.073	P < 0.005
	Age	0.120	P < 0.0001
	Body fat mass	0.169	P < 0.0001
Lumbar Spine (L2-L4) BMD			
	Body fat mass	0.045	P < 0.05
	Years since menopause	0.079	P < 0.005
Femoral Neck BMD			
	Lean body mass	0.132	P < 0.0001
	Age	0.171	P < 0.0001
Total Hip BMD			
	Lean mass	0.123	P < 0.0001
	Waist hip ratio (WHR)	0.154	P < 0.0001
	Age	0.181	P < 0.0001

DISCUSSION

In the present study, we confirmed the positive relationship between body weight and BMD as suggested in other studies (Bevier 1989; Reid 1992; Chen et al. 1997). The positive relationship between increased weight and increased BMD is probably the result of weight loading effect of which increased mechanical (gravitational) forces on bone (Slemenda 1995). Our study also showed that BMD inversely correlated with age. This is expected as bone mineral density declines with age (Ross 1996) and age has been shown to be a strong predictor of hip fractures (14).

Multiple stepwise regression analysis between BMI and body composition in our study showed that fat mass could explain nearly 85% variance of BMI while lean mass only explained about 3%, indicating that the influence of fat mass on BMI was stronger than lean mass. Our observation agrees with the report by Reid et al. (1992), demonstrating that body fat mass is the most significant predictor of total body BMD in postmenopausal women. Body fat mass had been shown to mostly affect bone sites with high trabecular content such as lumbar spine because trabecular bone may respond actively than cortical bone to the hormonal effects of fat mass (Hla et al. 1996).

However, Bevier et al. (1989) found that only lean body mass was correlated with the lumbar spine BMD in postmenopausal women. The differences may be attributable to the equipment that was used in the study. They assessed fat mass using skin-fold thickness and bioelectrical impedence and then subtracted fat mass from body weight to calculate lean body mass. It is not clear whether either of these techniques accurately separated fat from lean tissues. Moreover, their calculation of lean body mass included bone mass as a part of lean body mass and this definitely would strengthen its relationship to BMD.

Lean body mass was found to be a significant predictor of femoral neck BMD in our study with r^2 around 0.13 and independent of age. This finding is supported by other studies (Sowers et al. 1992; Reid et al.1996; Douchi et al. 1997; Liu et al. 2004) carried out amongst pre- and postmenopausal women. Our observation also agrees with the report by Li et al. (2004), indicating that lean body mass but not fat mass is a significant contributor to femoral neck BMD in perimenopausal women. The stronger influence of lean than fat mass at the femoral neck could be explained by the muscular activity of this mobile part of the body (Hla et al. 1996). The positive relation between lean mass and femoral BMD indicate higher physical activity and/or potential genetic higher peak BMD in these women.

CONCLUSION

The result of this study provides an important insight into the relative contribution of fat and lean mass to bone mass in postmenopausal women. While both fat and lean mass are significant determinants of BMD, fat mass may play a greater role than lean mass in postmenopausal women. Therefore, postmenopausal women need to avoid being too underweight (and thus having too low body fat) and to maintain lean body mass to protect against osteoporosis. WHO (1994) suggests that a BMI of below 19 kg/m^2 increases the risk of osteoporosis in postmenopausal women.

It is understandable that the subjects enrolled in this study may not represent the general population. Assessment of larger numbers of subjects are necessary to determine whether these factors influencing BMD will be clinically useful as screening tools for predicting risk of osteoporosis in our local population.

ACKNOWLEDGEMENT

We would like to thank Fonterra Milks for the research grant (D-042-2002) and all subjects who consented to participate in the study.

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