WALAILAK JOURNAL
http://wjst.wu.ac.th Health Sciences

Waist Circumference: A Key Determinant of Bone Mass in University Students

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Received: 26 February 2013, Revised: 31 May 2013, Accepted: 7 September 2013

Abstract

This study aimed to assess bone mineral density (BMD) status, and to explore association between lifestyle behaviors, body mass index (BMI), waist circumference (WC) and BMD status of 217 students (55 males and 162 females) aged between 17 - 23 years studying at Walailak University. The BMD was measured at distal-third radius, and confirmed at mid-shaft tibia by Quantitative ultrasound analysis. BMI and WC were recorded to assess obesity, and lifestyle behaviors were evaluated using a questionnaire. Results showed 10.9 % males and 16 % females had low BMD (Z-score < −1) at both sites, while 29.1 % males and 11.8 % females were classified in the risk group. Proportions of the obese subjects assessed by BMI and WC were found to be greater in males (10.9 and 21.8 %) than females (6.8 and 18.5 %). Lifestyle behaviors of both genders were not much different. Only 45.2 % consumed milk ≥ 3 packs/week. Most subjects (87.1 %) consumed high cholesterol diets (≥ 3 days/week), while 24 % did exercise ≥ 3 times/week. Both factors are of concern for the obese group. Crude analysis showed BMI, WC and milk intake are potential determinants of BMD. Final analysis indicated students with normal WC are found greater in a high BMD group than in a normal BMD group (RRR = 4.38), and the expected risk in the BMD group is lower for female students (RRR = 0.37). We suggest that to prevent osteoporosis in later life, healthy lifestyle practices should be promoted and obesity must be careful monitored during the age of peak bone mass.

Keywords: University students, peak bone mass, body mass index, waist circumference, obesity

Introduction

A reduction in bone mineral mass and a change of bone structure are the key determinants of fracture risk that are the characteristics of osteoporosis. It is currently reported that the amount of bone gained during adolescence is the main contributor to peak bone mass (PBM) and represents the major determinant of osteoporosis and fracture risk in older adults [1]. PBM is the amount of bone present in the skeleton at the end of its maturation process that appears to be established before the third decade of life [2]. There was evidence confirmed that the fracture risk increased approximately twice with each standard deviation of bone loss from PBM [3]. WHO [4] reported that the determinants of PBM include heredity, sex, dietary factors, endocrine factors, mechanical forces and exposure to risk factors. More than 60 % of the variance of PBM is genetically determined, and the remainder is likely influenced by lifestyle factors. It has been accepted that adequate milk intake and regular exercise can contribute to the prevention of osteoporosis by increasing PBM, at the same time, low nutrient dense beverages such as carbonated drinks are increasing in adolescents' diet, and concern has been raised that these beverages, particularly colas, reduce bone mass [5]. A recent study revealed that achieving optimal PBM can be limited by a lack of physical exercise, low body weight, inadequate intake of calcium, smoking, excessive alcohol and caffeine intake [6].

In addition, body weight is considered a strong predictor of BMD irrespective of age and gender. However, the effects of body weight on bone have been debated. Evidence shows a positive effect of overweight or body mass index (BMI) more than 25 kg/m^2 on bone mineral content (BMC) in adolescent girls [7], whereas weight changes were strongly related to bone measurement changes in an obese adolescent female population [8]. Moreover, evidence indicates that waist circumference (WC), which has long been used as an anthropometric surrogate for measuring abdominal fat and for diagnosis of abdominal obesity [9], is a positive determinant of total hip BMD in adolescent girls (aged 13 - 20 years) [10]. In contrast, a previous result indicated greater amounts of body fat relative to weight could be a marker for lifestyles that do not support attainment of optimal PBM [11].

In a behavioral study, data indicated young people having low level of knowledge and awareness regarding the prevalence of osteoporosis, and they were not being educated to promote bone health [12]. These results reflect the need for educational intervention to promote specific osteoprotective practices. Therefore, before motivating young adults, particularly university students, to partake in these practices, we proposed to assess BMD status of the university students, and correlate factors such as lifestyle behaviors, BMI and WC to their BMD status. We expect that our results obtained from this study will be of great advantage for promoting bone health during PBM and preventing osteoporosis in later life.

Materials and methods

Subjects

This is a cross-sectional survey study. The population of this study is 217 healthy students (55 males and 162 female) aged between 17 - 23 years (mean age = 19 years) in Walailak University (WU students). Students with chronic and bone diseases, and other diseases such as asthma, allergy and gastritis were excluded from this study. We undertook the personal information using a self-administered questionnaire. Anthropometric data and BMD were assessed by the researcher. The study protocol was approved by the Ethics Committee in Human Experimentation of Walailak University, and all the participants gave their written informed consent.

Measurement of bone mineral density

BMD is evaluated by the new Quantitative Ultrasound (QUS) prototype-the Omnisense-developed by Sunlight (multi-sites bone sonometer, Sunlight Omnisense® 7000S). The Omnisense 7000S instrument was used to measure speed of sound (SOS; m/s), and instrumental quality control was performed daily. SOS was recorded at the distal-third radius of the non-dominant arm, and was confirmed at the left mid-shaft tibia when the Z-score is less than -1 [13,14]. The SOS result was compared with the SOS of an age-matched population, using an embedded reference database, and reported the comparison in form of a Z-score. The Z-score is defined as the difference between a patient's SOS result and the mean SOS of the age and gender-matched normal population, and are described in units of standard deviation (SD) of the population [15]. In addition to the T-score that is the WHO criteria for diagnosing osteoporosis in adults, the Z-score is often used to determine how a child's BMD compares with other children's, and the Z-score is a more appropriate method of comparison of BMD in pediatrics including young subjects up to about 20 years of age [16]. A normal BMD is determined when a Z-score value is equal or more than -1.00. Osteopenia is defined when a Z-score value is between -1 and -2, and osteoporosis is indicated when a Z-score value is equal or less than -2. In this study, a normal BMD was sub-divided into 3 groups: high BMD (Z-score > 1), normal BMD ($-0.45 \leq$ Z-score ≤ 1), and risk ($-0.99 \leq$ Z-score < -0.45), whilst both osteopenia and osteoporosis (Z-score < -1) were grouped in a low BMD group.

Anthropometric measurement and lifestyle assessment

Anthropometric data and lifestyle behaviors were collected using the methods of Khwanchuea *et al*. [13]. Body weight (kg) and height (m) were measured with a balance-beam scale and a stationary vertical height board. Body mass index or BMI (kg/m^2) was calculated by dividing weight in kilograms by the square of height in meters. The subjects were classified into 4 groups according to their BMI based on WHO Asian BMI classifications are (1) < 18.5 kg/m^2: underweight; (2) 18.5 to < 23 kg/m^2: normal weight; (3) 23 to < 27.5 kg/m^2: pre-obesity; and (4) ≥ 27.5 kg/m^2: obesity [17]. WC (cm) was measured at a level midway between the lowest lateral border of the ribs and the uppermost lateral iliac crest with the subjects standing. Using Asian references [9,18], students were grouped into normal and abnormal WC; WC ≤ 90 cm in men and WC ≤ 80 cm in women were categorized as normal groups, whilst abnormal groups were determined at WC values higher than those normal levels.

The questionnaire assessed 5 components of lifestyle behaviors: exercise, beverage consumption, diary food intake, smoking and genetic bone diseases. Each component asked for yes or no responses, if yes data would be future collected for details, type and frequency (regularity or irregularity by indicating times per week or per month). Data for exercise, beverage consumption and diary food intake were assessed over the six month collection periods. Subjects with regular exercise were grouped into low and normal exercises according to their frequency. For beverage consumption, it was subdivided into the topics of (1) tea or coffee (caffeine contained beverages), (2) alcohol beverages (alcohol, beer or wine), (3) soft drinks (including carbonated sugary beverages such as cola beverages), and (4) milk intake. In addition, data for other supplementary foods (such as high calcium diets or drugs) were also collected. The quantity of the beverage intake was categorized according to an average unit of consumption; cups per week or per month. For milk intake, 2 groups of the subjects were assigned as low (less than average unit) and normal (equal or more than average unit). The subjects with coffee/tea or soft drink intake were divided into the groups of normal (less than average unit) and high (equal or more than average unit). In addition to high calcium diets, high protein and high cholesterol diets were also recorded for their type and frequency.

Statistical analysis

The normal distribution of data was explored before using parametric statistics in the calculation. Firstly, descriptive statistics was indicated by mean, standard deviation (SD) and frequency of the sample characteristics and behaviors. Then Pearson's Chi-square and Fisher's Exact test were calculated in order to explore the association of BMD status and potential risk factors (anthropometric and lifestyle characteristics) in crude analysis. Finally, Multinomial Logistic Regression analysis was employed to estimate the relative risk ratio (RRR) and 95 % confidence interval among BMD status and all potential risk factors with *p-value* less than 0.1 in crude analysis which were stratified by gender. Statistical analyses were performed using the R program version 2.11.0 and Package Epicalc [19].

Results

Anthropometric data and BMD status

Table 1 shows anthropometric data of BMI (kg/m^2) and WC (cm), and BMD status of 217 students at Walailak University (55 males and 162 females aged between 17 - 23 years). The subjects were divided into four groups according to the BMI values; underweight, normal weight, pre-obesity, and obesity. Data showed only half of the WU subjects (55.3 %) represented a normal BMI (BMI mean = 20.5 ± 1.2 kg/m^2) being similar in both genders (52.7 % males and 56.2 % females). Overall data of BMI also showed similar numbers of subjects with low BMI (underweight) and high BMI (pre-obesity and obesity), 22.1 and 22.6 %. However, when compared the percentage of subjects in groups of low BMI and high BMI between males and females, showed that the numbers of males with high BMI (29.1 %) were higher than that with low BMI (18.2 %), whereas in females, the numbers of low BMI subjects (23.5 %) were higher than that of high BMI subjects (20.4 %). These data indicated most obese students were usually found in males (10.9 %), but less in females (6.8 %). When considering the BMI means of both genders, we found that they represented similar data in each group, although those of males were a little higher. However, an average BMI mean of all subjects was 21.2 ± 3.4 kg/m^2. In obese groups, means of the BMI were 30.1 ± 2.0 kg/m^2 in males and 29.6 ± 1.2 kg/m^2 in females.

Using the WC assessment, data in **Table 1** demonstrate that 80.7 % WU students represented normal WC with an average mean of 71.4 ± 6.2 cm. Numbers of normal WC males (78.2 %) were a little lower than females (81.5 %). Average WC means of males in normal and abnormal groups (normal = 75.8 ± 7.7 cm; abnormal = 96.1 ± 6.5 cm) were higher than those of females (normal = 70.0 ± 4.9 cm; abnormal = 86.6 ± 6.1 cm). The numbers of students with higher than normal WC were found to be greater in males (21.8 %) than females (18.5 %), and these values were higher than those assessed by the BMI.

Table 1 Anthropometric data: body mass index (BMI, kg/m^2) and waist circumference (WC, cm) and BMD status of 217 students, Walailak University, Nakhon Si Thammarat, Thailand.

Anthropometric data and BMD status	**Number of subjects (%, mean, s.d.)**		
	Male (n = 55)	**Female (n = 162)**	**Total**
1. Body mass index; BMI (kg/m^2)			
- Underweight (< 18.5)	10 (18.2, 17.8, 0.4)	38 (23.5, 17.5, 0.8)	48 (22.1, 17.6, 0.8)
- Normal weight (18.5 - < 23)	29 (52.7, 20.8, 1.3)	91 (56.2, 20.4, 1.2)	120 (55.3, 20.5, 1.2)
- Pre-obesity (23 - < 27.5)	10 (18.2, 24.8, 1.0)	22 (13.6, 24.1, 0.9)	32 (14.8, 24.3, 1.0)
- Obesity (≥ 27.5)	6 (10.9, 30.1, 2.0)	11 (6.8, 29.6, 1.2)	17 (7.8, 29.8, 1.5)
Total	**55 (100, 22.0, 3.8)**	**162 (100, 21.0, 3.2)**	**217 (100, 21.2, 3.4)**
2. Waist circumference; WC (cm)			
Normal WC: - WC ≤ 90 cm - WC ≤ 80 cm	43 (78.2, 75.8, 7.7)	132 (81.5, 70.0, 4.9)	175 (80.7, 71.4, 6.2)
Over WC: - WC > 90 cm - WC > 80 cm	12 (21.8, 96.1, 6.5)	30 (18.5, 86.6, 6.1)	42 (19.3, 89.3, 7.5)
Total	**55 (100, 80.2, 11.2)**	**162 (100, 73.1, 8.2)**	**217 (100, 74.9, 9.6)**
3. BMD status (Z score)			
1. High (> 1.00)	7 (12.7, 1.5, 0.1)	35 (21.6, 1.6, 0.4)	42 (19.4, 1.6, 0.4)
2. Normal [-0.45 to 1.00]	26 (47.3, 0.2, 0.4)	82 (50.6, 0.3, 0.4)	108 (49.8, 0.2, 0.4)
3. Risk [-0.99 to -0.45]	16 (29.1, -0.7, 0.2)	19 (11.8, -0.7, 0.1)	35 (16.1, -0.7, 0.1)
Total (Normal BMD)	**89.1 %**	**84 %**	**85.3 %**
4. Osteopenia [-1.99 to -0.99]	6 (10.9, -1.4, 0.3)	20 (12.3,-1.5, 0.3)	26 (12.0, -1.5, 0.3)
5. Osteoporosis [< -1.99]	0 (0.00)	6 (3.7, -2.5, 0.5)	6 (2.8, -2.5, 0.5)
Total (Low BMD)	**10.9 %**	**16 %**	**14.7 %**
Total	**55 (100, -0.1, 0.9)**	**162 (100, 0.5, 1.1)**	**217 (100, 0.0, 1.1)**

As shown in **Table 1**, 5 groups of the BMD status at the distal-third radius and the mid-shaft tibia were classified using age-sex-matched Z-score. Although our subjects were at an age of an expected peak bone mass, we found that only 85.3 % of both genders represented normal BMD, and the rest 14.7 % (10.9 % males and 16 % females) demonstrated low BMD (osteopenia and osteoporosis). In these results, 29.1 % males and 11.8 % females were classified in the risk groups. The percentage of females with a high BMD (21.6 %) was higher than that of males (12.7 %). However, no data of male subjects indicated osteoporosis at both the radius and tibia sites, whilst 3.7 % females were defined.

Lifestyle characteristics

The data of lifestyle behaviors of WU students are shown in **Table 2**. We found that proportion of the subjects who consumed milk less (low) or more (normal) than 3 packs per week were not much different between males (low = 52.7 % and normal = 47.3 %) and females (low = 55.6 % and normal = 44.4 %). Only a few subjects preferred to consume coffee or tea daily (5.4 % males and 2.5 % females). Likewise, only 6 % of both genders (7.3 % males and 5.6 % females) preferred drinking carbonated beverages equal or more than 3 cups per week. However, our data indicate most WU students (87.1 %) enjoyed consuming high cholesterol foods (> 3 days per week). This behavior was similar in both genders (85.5 % males and 87.7 % females). For data of high protein intake, they could not be clarified.

Data for exercise behaviors of WU students (**Table 2**) showed that 76 % of both genders did exercise less than 3 times per week (low), and most of them were females (80.3 %). The numbers of males (36.4 %), who preferred exercise equal or more than 3 times per week (normal), were higher than females (19.7 %). In addition, smoking was recorded in the students. Data show 7.3 % males and 0.6 % females smoked.

The analysis of crude association between BMI, WC, lifestyle characteristics and BMD status of 217 WU students is shown in **Table 3**. They indicated no association of all factors to the BMD status (*p-value* > 0.05). However, we found that BMI status, WC range and milk intake are potential determinants of BMD as the *p-value* less than 0.1.

Table 2 Lifestyle characteristics of 217 students of Walailak University, Nakhon Si Thammarat, Thailand.

Lifestyle characteristics	Number of subjects (%)		
	Male (55)	**Female (162)**	**Total (217)**
Milk intake			
Low (< 3 packs/week)	29 (52.7)	90 (55.6)	**119 (54.8)**
Normal (≥ 3 packs/week)	26 (47.3)	72 (44.4)	**98 (45.2)**
Coffee/Tea intake			
Normal (≤ 7 cups/week)	52 (94.6)	158 (97.5)	**210 (96.8)**
High (> 7 cups/week)	3 (5.4)	4 (2.5)	**7 (3.2)**
Soft drink intake			
Normal (< 3 cups/week)	51 (92.7)	153 (94.4)	**204 (94.0)**
High (≥ 3 cups/week)	4 (7.3)	9 (5.6)	**13 (6.0)**
High-cholesterol food intake			
Low (< 3 days/week)	8 (14.5)	20 (12.3)	**28 (12.9)**
High (≥ 3 days/week)	47 (85.5)	142 (87.7)	**189 (87.1)**
Smoking status			
No	51 (92.7)	161 (99.4)	**212 (97.7)**
Yes	4 (7.3)	1 (0.6)	**5 (2.3)**
Exercise			
Low (< 3 times/week)	35 (63.6)	130 (80.3)	**165 (76.0)**
Normal (≥ 3 times/week)	20 (36.4)	32 (19.7)	**52 (24.0)**

Table 3 Crude analysis of association between body mass index, waist circumference, lifestyle characteristics and the BMD status of 217 students, Walailak University, Nakhon Si Thammarat, Thailand.

Determinants	Number of subjects (%) at the BMD status					*p-value*
	1	2	3	4	5	
1. Caffeine						
Normal (≤ 7 cups/week)	41 (19.5)	104 (49.5)	35 (16.7)	24 (11.4)	6 (2.9)	0.53
High (> 7 cups/week)	1 (14.3)	4 (57.1)	0 (0.0)	2 (28.6)	0 (0.0)	
2. Soft drink						
Normal (≤ 3 cups/week)	38 (18.6)	103 (50.5)	34 (16.7)	23 (11.3)	6 (3.0)	0.44
High (> 3 cups/week)	4 (30.8)	5 (38.5)	1 (7.7)	3 (23.1)	0 (0.0)	
3. Milk intake						
Low (< 3 packs/week)	27 (22.7)	58 (48.7)	17 (14.3)	17 (14.3)	0 (0.0)	0.03
Normal to high (≥ 3 packs/week)	15 (15.3)	50 (51.0)	18 (18.4)	9 (9.2)	6 (6.1)	
4. Exercise						
Low (< 3 times/week)	33 (20.0)	80 (48.5	27 (16.4)	21 (12.7)	4 (2.4)	0.9
Normal to high (≥ 3 times/week)	9 (17.3)	28 (53.9)	8 (15.4)	5 (9.6)	2 (3.9)	
5. Body mass index						
Under weight	9 (18.8)	19 (39.6)	10 (20.8)	10 (20.8)	0 (0.0)	0.06
Normal	29 (19.1)	85 (56.0)	20 (13.2)	13 (8.6)	5 (3.3)	
Obese	4 (23.5)	4 (23.5)	5 (29.4)	3 (17.7)	1 (5.9)	
6. Waist circumference						
Normal	28 (16.0)	93 (53.1)	29 (16.6)	21 (12.0)	4 (2.3)	0.09
Abnormal	14 (33.3)	15 (35.7)	6 (14.3)	5 (11.9)	2 (4.8)	

+ BMD status; 1 = High (z-score > 1.00), 2 = Normal (−0.45 <= z-score <= 1.00), 3 = Risk (−0.99 <= z-score < −0.45), 4 = Osteopenia (−1.99 <= z-score < −0.99), 5 = Osteoporosis (z-score < −1.99)
++ Level of significance is 0.05.

Final analysis of the potential determinants

The final analysis of the potential determinants (BMI status, WC range and milk intake) and the BMD status was examined using Multinomial Logistic Regression analysis with gender adjustment. When a normal BMD group was set as the reference group, the analysis model demonstrated that the relative risk ratio (RRR) of the WC range is 4.38 for being in a high BMD group compared with a normal BMD group (RRR = 4.38, *p-value < 0.01*). In other words, we found that the students with the expected normal WC range in high BMD group were greater than in the normal BMD group. Moreover, the RRR of gender is 0.37 for being in the risk BMD group compared with the normal BMD group (RRR = 0.37, *p-value < 0.05*). After controlling for gender with male data as a reference group, the analysis showed that the expected risk staying in a risk BMD group is lower for the female students. However, there is no association in the other BMD groups (**Table 4**).

Table 4 Association between gender, WC range, BMI range, milk intake, and the BMD status of 217 students, Walailak University, Nakhon Si Thammarat, Thailand.

BMD status	RRR	P-value	95 % CI	
High BMD				
Gender	1.6	0.32	0.63	4.19
WC range	4.38	0.00	1.59	12.07
BMI range	0.64	0.27	0.29	1.42
Milk intake	0.68	0.32	0.32	1.46
Risk				
Gender	0.37	0.02	0.17	0.84
WC range	1.4	0.59	0.41	4.72
BMI range	0.76	0.55	0.31	1.86
Milk intake	1.25	0.59	0.56	2.76
Osteopenia				
Gender	1.02	0.97	0.37	2.84
WC range	2.43	0.18	0.67	8.83
BMI range	0.49	0.13	0.2	1.24
Milk intake	0.68	0.41	0.27	1.69
Osteoporosis				
Gender	1.33e+08	1.0	0	.
WC range	1.88	0.62	0.15	23.5
BMI range	2.79	0.41	0.24	32.39
Milk intake	6.08e+08	1.0	0	.

+ Normal BMD is a reference group and the model is adjusted by gender.
++ Level of significance is 0.05.

Discussion

This study aimed to assess the BMD status of healthy students studying at Walailak University, evaluating lifestyle behaviors and obese status which affected their BMD status. Our subjects were 217 volunteer undergraduate students (55 males and 162 females) aged between 17 - 23 years (mean age = 19 years) without chronic and bone diseases. We measured the BMD at the distal-third radius of the non-dominant arm and confirmed the results of low BMD by re-measurement at the left mid-shaft tibia using Quantitative Ultrasound (QUS). The QUS technique has been developed to assess bone mineral status in some peripheral skeletal sites including the radius and tibia. It is safe, easy to use, radiation-free, and devices are portable. Although QUS is not a gold standard instrument for diagnosis of osteoporosis, evidence has been reported that QUS techniques have emerged, and are able to discriminate between osteoporotic and healthy patients, and to provide a good prediction of bone mechanical properties [20,21]. Moreover, QUS was significantly correlated with BMD in site-specific measurements, and the Omnisense provided an opportunity to assess bone status at different anatomical sites [22]. In addition, Muller *et al*. [21] demonstrated that BMD status at the distal radius was able to predict bone mechanical properties related to trauma because it was the location for Colles' fractures, common in osteoporosis.

We assessed BMD status of WU students using a Z-score (**Table 1**). Although our subjects were at an age during PBM, data showed that only 85.3 % of both genders represented normal BMD of the radius. Low BMD (osteopenia and osteoporosis) at both radius and tibia was found to be 14.7 % of both genders. It is widely known that PBM is considered a key determinant of the lifetime risk of osteoporosis [1]. It is attained between the age of 20 - 25 and levels remain relatively static until the age of 45, because the processes of bone formation and bone resorption are in balance [23]. Therefore, this age is a particularly crucial period of life that osteoporosis prevention should begin by optimizing gains in bone mineral. Recently, it was found that there were several factors affecting PBM. In addition to genetic factors which influence skeletal growth and the amount of bone mass attained in early adulthood [24], changes in lifestyle behaviors among children and adolescents, such as increased beverage intake, decreased calcium consumption and diminished physical activity, can modify bone accrual [25]. Moreover, in the present study, these behaviors may develop obesity, and consequently affect bone mass. Therefore, our study recorded BMI and WC to assess obese status, and collected lifestyle characteristics of the subjects in order to relate them to their BMD status.

We demonstrated the results for BMI and WC in **Table 1**. As described above, BMI is widely used as an anthropometric assessment of general adiposity, whereas WC indicates the abdominal obesity that is more strongly associated with obesity-related health problems than is adiposity measured by BMI [26]. In our study, we assessed the obesity status according to the Asian reference database. As using BMI criteria, our data showed that those who were obese (BMI $\geq$ 27.5 kg/m^2) were greater in males (10.9 %) than in females (6.8 %). An average BMI mean of the obese males (30.1 $\pm$ 2.0 kg/m^2) was a little higher than that of females (29.6 $\pm$ 1.2 kg/m^2). These results may be consistent with a recent report [27] which explained that when compared with women, BMI overestimated adiposity in men, whose excess weight was largely attributable to muscular body builds and greater bone mass. They concluded that BMI did not account for differences in body composition, and gender- and age-specific thresholds should be considered when the BMI is used to indicate adiposity. However, when using WC criteria, we found that 19.3 % WU students displayed abdominal obesity. This number was higher than that assessed by the BMI. Similar to data of BMI above, obese males (21.8 %) had greater numbers than females (18.5 %), and their average WC mean was also quite high (96.1 $\pm$ 6.5 cm). However, both average BMI mean and WC mean of these obese groups are close to critical cut-off points (BMI $\geq$ 30 kg/m^2; WC $\geq$ 100 cm) for obesity defined by WHO criteria [4,28] that indicates the risk of metabolic syndrome, and consequently risk to osteoporotic fracture [29]. Moreover, a threshold value of WC also corresponds to critical amounts of visceral adipose tissue.

As mentioned above, body weight is one of the strongest predictors of BMD in adolescents, but previous results were still controversial whether excess fat has a detrimental or protective effect on skeletal health in children and adults. Recently, there has been a growing concern that obesity may negatively affect bone development and is linked to lower bone mass [30], whereas some studies report that overweight and obesity are associated with high bone mineral content (BMC), but low bone mineral apparent density [31]. However, the association between BMI, WC and BMD status of WU students will be discussed later (**Table 3** and **4**).

Lifestyle characteristics of WU students are presented in **Table 2**. We found that only 45.2 % WU students had a milk intake of more than 3 packs per week. At the same time, they did not drink high coffee/tea or carbonated beverages. Whiting *et al*. [5] mentioned that the trend in food consumption in adolescents is currently moving towards a reduced milk intake, and a coinciding increased consumption of low nutrient dense beverages such as carbonated drinks. It is widely known that milk is recommended as an excellent Calcium source for bone health, and active components in milk including milk whey protein can suppress osteoclast-mediated bone resorption and osteoclastic cell formation that protects bone loss [32]. Previous studies revealed that on average 300 ml milk intake a day or 2 glasses of milk 3 days per week (for 2 months) had greater increases of BMD and BMC [33-35], and women with low milk intake (< 1 serving of milk/day) during childhood and adolescence have less bone mass in adulthood and greater risk of fracture [36]. Therefore, to promote PBM, a campaign of adequate milk intake at least 1 serving daily should be of concern for WU students.

In addition, although high beverage intake of carbonated or caffeine beverages were not a lifestyle characteristic of most WU students, these behaviors should be avoided because there is evidence of negative effects on bone mass. Ma and Jones [37] found that cola drinks caused an increased risk of wrist and forearm fracture in children aged 9 - 16 years independent of other factors. For caffeine beverages, in fact, caffeine (1,3,7-methylxanthine) affects bone metabolism through a mild diuretic effect that increases urinary Ca and Na excretion. Evidence shows that consumption of at least 2 - 3 cups of coffee or 5 - 8 cups of tea induce acute diuresis [38], whereas caffeine intake in the range (99.9 mg/day) was not an important risk factor for low BMD of young adult women [39]. However, the effects of coffee on bone metabolism remain controversial because they are associated with nutrition, exercise and lifestyle factors as well as the amount of caffeine contained in the coffee.

For food consumption and exercise habit, we found that most WU students (87.1 %) preferred high cholesterol diets by intake more than 3 days per week, at the same time they did exercise less than 3 times per week (76.0 %). Both behaviors may be possible causes of developing obesity that we will discuss in relation to the BMD status later. When considered effects of exercise, there is increasing evidence that regular weight bearing physical activity (or resistance exercise) has beneficial effects on bone mineralization and development in children and adolescents, particularly during periods of rapid bone growth [40]. Moreover, it has been reported that the effective effects of exercise on a given peak BMD depend on the optimal intensity, frequency and duration of such exercise and the location of bone accrual [41,42]. Recently, Shenoy *et al*. [43] found that dynamic impact loading exercises (DILE) for 3 months showed significant improvement at both distal radius and mid-shaft tibia of young university women, and Ca supplement also potentiated this effect. Therefore, in order to increase PBM during young adults and prevent osteoporosis in later life, both regular weight bearing exercise and adequate milk consumption should be promoted in university students.

We analyzed the association between BMI, WC, lifestyle characteristics, and BMD status of WU students. We found no association of these factors to their BMD status, however our crude analysis indicated BMI status, WC range and milk intake are potential determinants of the BMD (**Table 3**). When using Multinomial Logistic Regression analysis with gender adjustment, we found the relative risk ratio (RRR) of WC range is 4.38 in the high BMD group as compared with the normal BMD group ($p\text{-value} < 0.01$). This analysis indicated WU students with normal WC possibly have higher BMD than the obese students. Our results did not show WC associating with low BMD that may be due to WC mean of both genders being only 89.3 ± 7.5 cm. Although no previous report explained our data, evidence suggests that WC is a surrogate measure of visceral adipose tissue [44], and the WC value over 100 cm indicates critical amounts of visceral adipose tissue that are associated with low BMD [28,29]. In our study, an average WC mean of the obese males was close to 100 cm. This result may support another finding in **Table 4** that indicated the association of gender and BMD status, males being at higher risk to low BMD than females. This association will be discussed later. However, the effects of obesity, particularly abdominal obesity, are still controversial. In the past, it was believed that women with android-like obesity were protected from osteoporosis because higher body weight increased mechanical loading on the skeleton, particularly the cortical elements [45]. Whereas recent studies reported the abdominal obesity or high fat mass affecting reduced BMD that resulted from 2 mechanisms: (1) obesity may decrease osteoblast differentiation and bone formation, or (2) obesity may promote osteoclast activity and bone resorption through increased circulation and tissue proinflammatory cytokines in chronic inflammation [46].

In addition, our analysis in **Table 4** also indicated the RRR of gender in a risk BMD group is 0.37 as compared with a normal group ($p\text{-value} < 0.05$). This means that females are at lower risk to low BMD than males. This result may be described by 2 reasons; the numbers of obese males are higher than females, and the average WC mean of males (96.08 ± 6.50 cm) is closer to the threshold value of waist girth (100 cm) that corresponds to critical amounts of visceral adipose tissue when compared to that of females (86.58 ± 6.14 cm). Therefore, it is possible that males are at higher risk of low BMD than females. However, when considered to other lifestyle factors, we found that there was not much different between males and females.

Conclusions

Approximately 15 % of WU students were found to have low BMD at both the radius and tibia in spite of being at the age of PBM. About half students had milk intake ≥ 3 packs per day, whereas most students did not favor caffeine or carbonated beverages. WU students preferred consumption of high cholesterol diets, at the same time they exercised less than 3 times per week. Consequently, we found a large number of the abdominal obese subjects, particularly males who had a higher risk of low BMD than females. Moreover, our finding indicates that WU students with normal WC trend to have high BMD. However, to promote healthy lifestyle practices during PBM for the prevention of osteoporosis in later life, we suggest regular exercise and consumption of high Ca diets. In addition, care must be taken concerning obesity of young adults because, besides the risk of chronic diseases and increased mortality, obesity also increases osteoporotic risk.

Acknowledgements

This research has been financially supported by the Institute of Research and Development, Walailak University under the contact WU 53108. We would like to sincerely thank all participant students of Walailak University for their cooperation, and also deeply thank the dean and all staff of school of medicine for the support and encouragement.

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