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Research Article

Bone Health Status and its Association with Body Composition, Physical Activity, and Calcium Intake Among Malaysian University Students in Bangi, Selangor, Malaysia

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ABSTRACT

External and internal factors, including body composition, active participation in physical activities, and adequate calcium intake (CI), have been suggested as important measures to optimize bone health, particularly among young adults, as peak bone mass accumulates during this stage of life. This cross-sectional study was conducted to investigate the relationship between body composition, physical activity levels (PAL), and CI with bone mineral density (BMD) in Malaysian university students. A total of 216 students from Universiti Kebangsaan Malaysia (72 each from Malay, Chinese, and Indian ethnicities) with a mean age of 22.1 ± 2.2 years were recruited. The assessment included body mass index (BMI), waist circumference (WC), body fat (BF), lean mass (LM), BMD, PAL, and CI. These were measured using a measuring tape, digital scale, quantitative ultrasound, the international physical activity questionnaire, and a 24-hr dietary recall alongside a food frequency questionnaire, respectively. The results showed that BMI, WC, BF, LM, BMD, PAL, and CI levels were 22.7 ± 4.5 kgm-2, 79.8 ± 12.3 cm, 23.2 ± 8.6%, 46.9 ± 11.4 kg, 0.29 ± 1.2, 2106.0 ± 1381.0 MET-min/week, and 335.4 ± 211.0 mg/day and 449.4 ± 284.6 mg/day, respectively. This means that the subjects had normal body composition, normal BMD levels, and moderate PAL. However, their calcium intake was generally low. The BMD mean of overweight subjects was significantly higher (f= 2.792, p=0.041) compared to the BMD of underweight subjects. A trend toward a significant increase of BMD (p=0.058) was also shown when PAL was increased. All parameters, except for body fats (r=-0.013, p=0.847) had a significantly weak correlation with BMD (*r values*: 0.143 to 0.198, p<0.05). The results of this study highlight the importance of maintaining body composition, living an active lifestyle, and optimizing CI levels for strong bones to prevent osteoporosis in old age.

Key words: Body composition, bone mineral density, calcium intake, physical activity, young adults

INTRODUCTION

Osteoporosis is a serious health condition characterized by a reduction in bone density or tinning of the bone, which can eventually lead to severe bone fractures (National Institutes of Health (NIH), 2001). Generally, there are no early signs and symptoms of osteoporosis, as it is usually diagnosed and detected only after a bone fracture occurs. Bone fractures can lead to mobility issues and reduced self-reliance, consequently diminishing the quality of life (Alexiou *et al*., 2018; Stanghelle *et al*., 2019). The prevalence of osteoporosis is commonly reported in individuals aged 50 years and above (Salari *et al*., 2021). Since there are no safe and effective ways to rebuild the osteoporotic skeleton, preventive measures, including maximizing peak bone mass during skeletal growth and development, are crucial (Weaver *et al*., 2016). Approximately 50% of adult peak bone mass is accumulated during adolescence (Lewis *et al*., 2018) and continues to grow to its maximum or peak level around the late 20s (Lu *et al*., 2016; Xue *et al*., 2020). This age range is therefore critical for bone growth. Individuals who are unable to achieve an optimum amount of bone mass during their late teens may have fewer reserves to support normal bone loss later in life, particularly during old age (Rosengren *et al*., 2022).

Although 50-85% of the variance in peak bone mass is determined by genetic factors (Boudin *et al*., 2016), other factors including diet and physical activity also play a crucial role in the acquisition of bone mineral density (BMD) particularly during adolescence and early adulthood (Zhu & Zheng, 2021). A positive association between bone mineral status and regular participation in high-impact physical activity has also been reported (Elhakeem *et al*., 2020). Recent evidence among Malaysian adolescents supports the idea that physical activity, amongst other factors, impacts bone health (Zulfarina *et al*., 2018). However, studies on the bone health status of young adults in Malaysia are relatively scarce. To our knowledge, only Yahya *et al*. (2018) have studied the matter among Malays, and Yahya *et al*. (2021) linked it to lactose intolerance. Additionally, Jamil *et al*. (2020) also did the investigation but conducted a study on young men with intellectual disabilities. Other investigations have focused on children (Sien, 2014; Chang *et al*., 2021; Koo *et al*., 2021), adolescents (Zulfarina *et al*., 2018), middle-aged individuals (Chin *et*

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al., 2015; Chin *et al*., 2017; Chan *et al*., 2020), postmenopausal women (Nurumal *et al*., 2019) and older adults (Chin *et al*., 2016; Chin *et al*., 2017; Abdulameer *et al*., 2018; Lim *et al*., 2022). Therefore, it is necessary to conduct a study among the young adult population, particularly to explore possible differences between young adults of the 3 major races in Malaysia. This study aimed to determine bone health status and investigate the association of physical activity and dietary calcium intake with BMD among Malay, Chinese, and Indian young adults. By identifying factors associated with BMD, more preventive measures could be taken to reduce the risks of bone diseases, particularly osteoporosis, during adulthood.

MATERIALS AND METHODS

Subject selection and ethical approval

This cross-sectional study was conducted at Universiti Kebangsaan Malaysia, involving 216 students. Initially, the intended sample size was 100 subjects per race, based on Yahya *et al*. (2018) study, which included 100 Malay subjects. However, due to challenges in recruiting Indian subjects (a minority group) and time constraints during the study period, a total of 72 subjects were recruited for each race. Despite these limitations, the total number of subjects in this study met the sample size estimation as outlined by Daniel and Cross (2013), which used a prevalence of 91% (Yahya *et al*., 2021). Subjects were selected through convenient sampling and were recruited via posters, flyers, and referrals among undergraduate and postgraduate students. The study excluded subjects who were athletes, smokers, pregnant and lactating mothers, had chronic diseases, or were taking calcium or vitamin D supplements or medications known to interfere with bone metabolism and development. Additionally, individuals diagnosed with any disease or clinical signs of bone disease that could potentially limit physical activity were also excluded. All subjects provided written informed consent before participation. The ethical approval for this study was obtained from The Secretariat for Medical Research and Innovation of Universiti Kebangsaan Malaysia (UKM) (Project code: UKM 1.5.3.5/244/FST-2015-003).

Data collection

This study was conducted from January to December 2015. Before its commencement, a screening session was carried out. Subjects who expressed interest in participating were provided with a comprehensive explanation of the study's objectives and the procedures involved. Those who agreed to participate were then required to sign an informed consent form and complete a screening questionnaire to determine their eligibility based on the predefined inclusion and exclusion criteria. Eligible subjects were scheduled for a study session. They were instructed to fast overnight for 10–12 hr before the session, during which only water consumption was permitted. The study was conducted in the morning before breakfast to minimize potential variability in body composition measurements. During the session, subjects underwent anthropometric, body composition, and BMD assessments. Physical activity and calcium intake were also evaluated using questionnaires described below. Clear instructions were provided to ensure accurate and reliable responses. All assessments were completed in a single session, after which subjects were permitted to leave.

Anthropometric and body composition assessments

Body weight and height were measured without shoes to the nearest 0.1 kg and 0.1 cm, respectively, using a digital weight and height scale (SECA 220, Birmingham, United Kingdom). Body mass index (BMI) was calculated by dividing body weight (kg) by the square of body height (m^2). The values obtained were classified into 4 groups according to WHO Asian BMI classifications (WHO, 2004): underweight (< 18.5 kg/m^2), normal weight (18.5 to 22.9 kg/m^2), overweight (23 to 27.4 kg/m^2) and obese (> 27.5 kg/m^2). Waist circumference was measured at the midpoint between the lowest lateral border of the ribs and the uppermost lateral iliac crest while subjects were standing. Subjects were grouped into normal (men: ≤ 90 cm, women: ≤ 80 cm), increased (Men = 94 - 101.9 cm, Women = 80 - 87.9 cm), and substantially increased (men: ≥ 102 cm, women: ≥ 88 cm) circumferences using WHO (2011) classification. Fat percentage and lean mass (kg) were determined using the Bodystat ©1500 analyzer (Bodystat Ltd, Douglas, Isle of Man), which employs bioelectrical impedance analysis (BIA). Lean mass was estimated by subtracting fat mass (kg) from the lean mass, which also includes muscles, water, and bone. Each subject was instructed to remove the left sock and shoe and lie supine with arms and legs away from the body. Alcohol was used to clean the skin on the left hand and foot where the electrode would be placed. The BIA measurements were conducted according to the manufacturer's protocol (Kyle *et al*., 2004).

Bone mineral density assessment

Bone health was assessed by measuring the broadband ultrasound attenuation (BUA) using quantitative ultrasound (QUS) of the left calcaneus with a QUS-2 ultrasound densitometer (Quidel Corporation, CA, USA). All measurements were performed by the same trained staff following the manufacturer's standard guidelines. Quality control and calibration of the machine were conducted regularly, particularly before data collection. Two measurements were taken for each subject, and the average value of the readings was calculated. The readings were interpreted as T-scores and categorized based on Chin *et al*. (2013), as the WHO Criteria of Osteopenia and Osteoporosis were deemed unsuitable for this assessment due to the different apparatus used (Yahya *et al*., 2021). Additionally, since the main purpose of this study was to screen the bone health status of young adults rather than to diagnose osteoporosis, the readings were referred to as the relative risk of individuals developing osteoporosis. The classifications were divided into 3 categories: ≥ -1.12 SD as low risk, a score between -1.12 and -1.80 as moderate risk, and ≤ 1.80 SD as high risk. According to WHO criteria, these classifications correspond to normal, osteopenia, and osteoporosis, respectively.

Physical activity assessment

Physical activity levels were measured using the long form of the international physical activity questionnaire in Malay (Chu

& Moy, 2015). The total energy expenditure (MET-min/week) was calculated by multiplying the duration (in min) and frequency (days) of walking by a factor of 3.3, 4, and 8 for low, moderate, and vigorous-intensity activities, respectively. Total energy expenditure was then categorized into low (≤ 600 MET-min/week), moderate (600 - 2999 MET-min/week), and high (≥ 3000 MET-min/week) physical activity levels.

Calcium intake assessment

Dietary data were collected using 24-hr dietary recalls (24HDR) and a food frequency questionnaire (FFQ). The 24HDR was used to assess calcium intake by asking subjects to recall foods consumed over the past 24 hr (1 day) using local household measurements such as bowls, cups, glasses, teaspoons, and tablespoons on a weekday. The average calcium intake was then analyzed using Nutritionist Pro™ software (Axxya Systems LLC, United States). Additionally, the frequency of consumption of calcium-rich foods in the 1 to 2 months before the study was assessed using a validated semi-quantitative FFQ, developed by Chee *et al*. (2002). The quantification of calcium intake (grams) was performed based on methods described by Yahya *et al*. (2021). Combining 24HDR and FFQ in a single study is a common practice and has been used in other nutrition studies (Okada *et al*., 2023). The results from both assessments were compared with the Malaysian Recommended Nutrient Intake (RNI, 2017), which recommends that young adults aged 20 to 39 years consume 1000 mg of calcium per day.

Statistical analysis

Data are presented descriptively as mean ± standard deviation and analyses were performed according to gender and race. The distribution of the data was checked using the Shapiro-Wilk test before the analyses. Data were normally distributed. One-way analysis of variance (ANOVA) was performed to determine significant differences between means. Pearson's correlation coefficient was used to test correlations between continuous variables. All analyses were set at $p<0.05$ and $p<0.001$ for the level of significance (two-tailed). Data analysis was performed using Statistical Package for Social Sciences (SPSS) software version 21.0 (SPSS Incorporation, Chicago, IL, USA).

RESULTS

The general characteristics of the subjects are presented in Table 1. The mean age was 22.1 ± 2.2 years, with a significant difference between races (f= 3.251, p=0.041), but no significant difference between the genders (p>0.05). A significant difference between genders was observed for BMI (p=0.002). Overall, 39% of the subjects had a normal BMI, 16% were underweight, 31% were overweight and 14% were obese. Although most of the subjects had a normal waist circumference (< 90 cm for males & < 80 cm for females) (WHO, 2011), males had a significantly higher waist circumference (84.3 ± 12.4 cm) compared to females (75.4 ± 10.6 cm, p<0.001). Significant differences in body fat were also observed both between gender (p<0.001) and races (f= 3.784, p=0.024), with Indian subjects showing significantly higher body fat compared to Chinese subjects. The lean mass assessment revealed that females had significantly lower lean mass than males (p<0.001). BMD analysis indicated significant differences among genders (p=0.006) and races (f=3.159, p=0.044). Among males, Chinese had significantly lower BMD scores (T-score: -0.2 ± 0.9, f=11.392, p<0.001) compared to Malays (1.0 ± 1.5) and Indians (T-score: 0.7 ± 1.1). Conversely, Malay female subjects showed a trend toward significantly higher T-scores (0.4 ± 0.8, p=0.073) compared to other groups (Chinese = -0.1 ± 0.9, Indians = -0.1 ± 1.1). In general, 86% of the subjects had normal BMD, and 31% were at moderate risk of fractures. No subjects were reported to have a high risk of fractures.

The mean MET score for physical activity was significantly difference among the races (f=4.908, p=0.008), with an average of 2106 ± 1381 MET-min/week, which falls under the moderate level category. In general, males had a more active lifestyle than their female counterparts. When comparing across genders, Indian males recorded the highest MET score at 2735.4 ± 1413.9 MET-min/week but no significant difference (p>0.05) with other groups. No significant differences were also found among the females (f=0.702, p>0.05). Among males, 45% were classified as having high physical activity levels, 42% as moderately active, and 13% as having low physical activity levels. Conversely, 18% of females were classified as having high physical activity levels, 61% as moderately active, and 21% as having low physical activity levels. Dietary intake assessments using both 24HDR and FFQ revealed that subjects had low mean calcium intakes of 335.4 ± 211.0 mg/day and 449.4 ± 284.6 mg/day, respectively, achieving only 42 to 45% of the RNI 2017 recommendations. Indian subjects had significantly higher CI (p=0.002), compared to other groups. However, both males and females did not consume sufficient calcium, with mean intakes of 361.4 ± 212.3 mg/day and 309.3 ± 207.6 mg/day, respectively.

Table 2 presents the mean BMD in relation to body composition, physical activity levels, and calcium intake. A significant difference in BMD was observed only across BMI categories (f=2.792, p=0.041). No significant differences were found in other parameters (p>0.05). There was a trend of increasing mean T-scores with higher BMI. However, obese subjects appeared to have lower BMD levels compared to overweight subjects. Although subjects with higher lean mass tended to have higher BMD, this difference was not statistically significant (p>0.05). BMD scores showed an increasing trend with higher physical activity levels, approaching statistical significance (f=2.092, p=0.058), indicating a potential but not definitive effect on BMD. Subjects with low physical activity levels had lower BMD scores (T-score: -0.05 ± 1.00), compared to those with moderate (T-score: 0.30 ± 1.12) and high (T-score: 0.48 ± 1.26) physical activity levels. Among those with high physical activity, Indian subjects had the highest BMD scores (T-score: 0.76 ± 1.54), followed by Malay (T-score: 0.33 ± 0.79) and Chinese subjects (T-score: 0.20 ± 1.23). Subjects with low calcium intake tended to have lower BMD (0.24 ± 1.12 mg/day) compared to those with moderate intake (0.57 ± 1.36 mg/day). Interestingly, the high calcium intake group also had lower BMD than the moderate group, possibly due to the small sample size in this category (n=6), which may have lacked the statistical power to detect differences in BMD levels.

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Table 1. General characteristics of subjects

Characteristics	Gender								Race (*n*=216)			
	Male (*n*=108)				Female (*n*=108)							
	Malay (*n*=36)	Chinese (*n*=36)	Indian (*n*=36)	*P-value*	Malay (*n*=36)	Chinese (*n*=36)	Indian (*n*=36)	*P-value*	Malays (*n*=72)	Chinese (*n*=72)	Indian (*n*=72)	*P-value*
Age (years)												
Individual	22.2 ± 2.1	21.9 ± 2.3	22.6 ± 3.1	0.567	23.2 ± 4.0	21.7 ± 1.4	21.6 ± 3.4	0.061	22.2 ± 2.5^{ab}	22.8 ± 3.3^{a}	21.6 ± 2.7^{b}	0.041*
Total		22.3 ± 2.5				22.2 ± 3.2		0.795		22.1 ± 2.2		
BMI (kg/m^2)												
Individual	23.5 ± 4.0	24.6 ± 4.5	22.9 ± 4.2	0.266	22.2 ± 4.1	21.2 ± 3.7	22.1 ± 5.0	0.552	23.4 ± 4.9	21.8 ± 3.9	22.9 ± 4.5	0.089
Total		23.7 ± 4.3				21.9 ± 4.3		0.002*		22.7 ± 4.5		
Waist circumference (cm)												
Individual	86.8 ± 13.0	82.1 ± 11.9	83.9 ± 12.2	0.280	74.2 ± 10.6	74.2 ± 6.6	77.7 ± 13.4	0.288	80.8 ± 13.4	78.3 ± 10.6	80.4 ± 12.9	0.434
Total		84.3 ± 12.4				75.4 ± 10.6		<0.001**		79.8 ± 12.3		
Body fat percentage (%)												
Individual	17.2 ± 6.3	19.2 ± 7.1	18.5 ± 8.3	0.506	27.8 ± 4.3^{b}	25.2 ± 5.7^{b}	31.4 ± 8.2^{a}	< 0.001**	15.2 ± 8.0^{ab}	12.8 ± 5.9^{b}	16.2 ± 8.6^{a}	0.024*
Total		18.3 ± 7.3				28.1 ± 6.7		< 0.001**		23.2 ± 8.6		
Lean mass (kg)												
Individual	56.1 ± 10.0	55.9 ± 8.0	55.5 ± 8.0	0.957	38.3 ± 5.9	37.8 ± 4.3	38.1 ± 5.4	0.909	47.3 ± 12.2	47.0 ± 9.8	46.7 ± 12.2	0.962
Total		42.5 ± 8.8				22.1 ± 5.63		< 0.001**		32.3 ± 12.6		
BMD (T-score)												
Individual	1.0 ± 1.5^{a}	-0.2 ± 0.9^{b}	0.7 ± 1.1^{a}	<0.001*	0.4 ± 0.8	-0.1 ± 0.9	-0.1 ± 1.1	0.073	0.3 ± 0.9^{ab}	0.1 ± 1.0^{b}	0.5 ± 1.4^{a}	0.044*
Total		0.5 ± 1.3				0.1 ± 0.9		0.006*		0.3 ± 1.2		

Note: Data are expressed as mean ± standard deviations, *n*=216. Significant difference at *$p < 0.05$ and **$p < 0.001$, in each gender and between races, tested using analysis of variance whilst between genders, tested using t-test. BMD = bone mineral density, BMI = Body mass index, CI = Calcium intake, FFQ = food frequency questionnaires, IPAQ = International physical activity questionnaires, MET = Metabolic equivalent of task, 24HDR = 24-hr dietary records.

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Table 1 (Continued). General characteristics of subjects

IPAQ (MET- min/ week)												
Individual	2638.3 ± 1398.4^{ab}	2214.9 ± 1412.8^{b}	2735.4± 1413.9^{a}	0.253	1794.1 ± 1356.1	1487.6 ± 1142.6	1768.1 ± 1140.3	0.498	2242.6 ± 1495.6^{a}	1704.3 ± 1289.3^{b}	2372.3 ± 309.7^{a}	0.008*
Total		2529.5 ± 1413.5				1683.25 ± 1213.8		<0.001**		2106.0 ± 1381.0		
CI (24HDR) (mg)												
Individual	400.2 ± 181.6	360.5 ± 264.4	323.6 ± 178.3	0.312	330.3 ± 195.2^{ab}	368.9 ± 229.2^{a}	228. 6 ± 174.1^{b}	0.011*	328.7 ± 212.5	353.7 ± 206.8	323.7 ± 215.5	0.662
Total		361.4 ± 212.2				309.3 ± 207.6		0.069		335.4 ± 211.0		
FFQ												
Individual	439.5 ± 294.4	396.9 ± 187.4	543.9 ± 346.1	0.082	404.2 ± 294.8^{ab}	371.9 ± 256.0^{b}	539.9 ± 273.3^{a}	0.026*	421.8 ± 293.1^{b}	384.4 ± 223.1^{bc}	541.9 ± 309.7^{a}	0.002*
Total		460.1 ± 287.9				438.7 ± 282.2		0.581		449.4 ± 284.6		

Note: Data are expressed as mean ± standard deviations, *n*=216. Significant difference at *$p < 0.05$ and **$p < 0.001$, in each gender and between races, tested using analysis of variance whilst between genders, tested using t-test.

BMD = bone mineral density, BMI = Body mass index, CI = Calcium intake, FFQ = food frequency questionnaires, IPAQ = International physical activity questionnaires, MET = Metabolic equivalent of task, 24HDR = 24-hr dietary records.

Table 2. Means of bone mineral density according to body composition, calcium intake, and physical activity level

Variable	Bone Mineral Density (T- score), mean ± SD, (*n*)				*P*-value
	Malay (*n*=72)	Chinese (*n*=72)	India (*n*=72)	Total subjects (*n*=216)	
Body mass index (kgm^{-2})					
Underweight (< 18.5)	0.41 ± 1.33 (*n*=9)	-0.10 ± 1.18 (*n*=14)	-0.14 ± 1.11 (*n*=12)	0.01 ± 1.18[b] (*n*= 35)	0.041*
Normal (18.5-22.9)	0.21 ± 0.77 (*n*=28)	-0.05 ± 0.79 (*n*=32)	0.26 ± 1.16 (*n*=24)	0.13 ± 0.90[ab] (*n*= 84)	
Overweight (23.0-27.4)	0.43 ± 0.86 (*n*=23)	0.2 ± 1.23 (*n*=18)	0.96 ± 1.65 (*n*=25)	0.57 ± 1.32[a] (*n*= 66)	
Obese (>27.5)	1.01 ±1.14 (*n*=12)	0.51 ± 1.02 (*n*=8)	0.95 ± 1.41 (*n*=11)	0.47 ± 1.25[ab] (*n*= 31)	
Waist circumference (cm)					
Normal (M < 94, W<80)	0.26 ± 0.89 (*n*=52)	0.01 ± 1.0 (*n*=62)	0.60 ± 1.48 (*n*=51)	0.27 ± 1.16 (*n*=165)	0.137
Increased (M= 94-101.9, W=80-87.9)	0.36 ± 0.69 (*n*=9)	0.02 ± 1.15 (*n*=6)	-0.14 ± 0.87 (*n*=12)	0.07 ± 0.88 (*n*=27)	
Substantially increased (M ≥ 102, W ≥ 88)	0.28 ± 1.34 (*n*=11)	0.90 ± 0.95 (*n*=4)	1.11 ± 1.44 (*n*=9)	0.69 ± 1.33 (*n*=24)	
Body fat (%)					
Low (< 22)	0.10 ± 0.73 (*n*=24)	0.05 ± 1.06 (*n*=41)	0.70 ± 1.46 (*n*=33)	0.28 ± 1.18 (*n*=98)	0.426
Normal (22 – 30)	0.17 ± 1.11 (*n*=29)	-0.01 ± 0.95 (*n*=23)	0.47 ± 1.54 (*n*=17)	0.18 ± 1.18 (*n*=69)	
High (> 30)	0.64 ± 0.83 (*n*=19)	0.36 ± 1.01 (*n*=8)	0.36 ± 1.29 (*n*=22)	0.46 ± 1.07 (*n*=49)	
Lean mass (kg)					
Low (< 36)	0.38 ± 0.85 (*n*=42)	-0.08 ± 1.00 (*n*=41)	0.20 ± 1.25 (*n*=45)	0.17 ± 1.06 (*n*=128)	0.126
Normal (36-40)	0.02 ± 0.98 (*n*=7)	0.18 ± 1.17 (*n*=6)	0.74 ± 1.24 (*n*=5)	0.27 ± 1.09 (*n*=18)	
High (> 40)	0.16 ± 1.09 (*n*=23)	0.26 ± 1.01 (*n*=25)	1.19 ± 1.60 (*n*=22)	0.52 ± 1.31 (*n*=70)	
Physical Activity (MET-min/week)					
Low (<600)	0.28 ± 1.00 (*n*=14)	-0.11 ± 0.97 (*n*= 22)	-0.59 ± 0.98 (*n*= 16)	-0.05 ± 1.00 (*n*=52)	0.058
Moderate (600 - 2999)	0.23 ± 1.03 (*n*=34)	0.12 ± 0.96 (*n*=36)	0.55 ± 1.31 (*n*=37)	0.30 ± 1.12 (*n*=107)	
High (> 3000)	0.33 ± 0.79 (*n*=24)	0.20 ± 1.23 (*n*=14)	0.76 ± 1.54 (*n*=29)	0.48 ± 1.26 (*n*=67)	
Calcium intake (mg/day)					
Low (<500)	0.29 ± 0.92 (*n*=61)	-0.01 ± 1.01 (*n*=57)	0.46 ± 1.33 (*n*=60)	0.24 ± 1.12 (*n*= 178)	0.328
Moderate (500 - 900)	0.32 ± 1.16 (*n*=9)	0.27 ± 0.98 (*n*=13)	1.21 ± 1.8 (*n*=10)	0.57 ± 1.36 (*n*=32)	
High (> 900)	0.35 ± 0.16 (*n*=2)	0.94 ± 0.76 (*n*=2)	-0.59 ± 0.86 (*n*=2)	0.23 ± 0.86 (*n*=6)	

Note: Data are expressed as mean ± standard deviations. *n*=216. MET = Metabolic equivalent of task. Significant difference at *$p<0.05$, between races, tested using analysis of variance.

The correlation analysis shows the relationship between body composition, physical activity level, and calcium intake with BMD, as presented in Table 3. The results indicated that all parameters, except body fat, had a significant correlation with BMD ($p<0.05$). However, these correlations were categorized as weak, with *r-values* ranging only from 0.1 to 0.29.

Table 3. Correlation of body composition, physical activity, and calcium intake with bone mineral density

	Bone Mineral Density (T- score)	
	r-value	*p-value*
Body mass index (kgm^{-2})	0.167	0.014*
Waist circumference (cm)	0.155	0.023*
Body fat (%)	-0.013	0.847
Lean mass (kg)	0.198	0.003*
Physical activity levels: IPAQ (MET-min/week)	0.158	0.020*
Calcium intake: 24-hr diet recall	0.143	0.036*

Significant difference at *p<0.05, n=216. Correlation strengths (weak: 0.1 – 0.29, moderate: 0.3 – 0.49, strong: 0.5 – 1.00). IPAQ= International physical activity questionnaires, MET = Metabolic equivalent of task.

DISCUSSION

The study of BMD and its influencing factors among Malaysian young adults is still limited. Assessing these parameters within this age group is crucial, as it can serve as a preventative measure and early screening for bone health before reaching the peak age for maximum calcium deposition, which is around 30 years old (Baxter-Jones *et al*., 2011). Moreover, bone loss tends to accelerate after the age of 50, particularly among women (Tuzun *et al*., 2012). Therefore, this study accessed the BMD status of Universiti Kebangsaan Malaysia students and examined the physical parameters that could potentially affect BMD.

The results indicated that the subjects' BMD was within the normal range, reflecting good bone health. When BMD was compared across BMI groups, it was observed that BMD generally increased with higher BMI values. This finding aligns with previous studies suggesting that an increased BMI is associated with higher BMD and offers protection against lower BMD. This aligns with existing literature suggesting that higher body weight provides mechanical loading on bones, which can stimulate bone formation and increase BMD. Potentially serving as a protective factor against osteoporosis (Lloyd *et al*., 2014). However, BMD appeared to peak in the overweight category before declining in the obese group. This pattern may be related to a saturation point between BMI and BMD, around a BMI of 26 kg/m2 (overweight category) (Ma *et al*., 2021). Ma *et al*. (2021) also suggested that individuals with a BMI near this value might experience fewer adverse effects while achieving optimal BMD. Consistent with Ma *et al*. (2021), the group with the highest mean BMD had a mean BMI of 24.7 ± 1.27 kg/m2, which falls within the overweight category. Furthermore, the results of this study showed a significant association between BMI and BMD (r=0.167, p=0.014). Similar findings have been demonstrated in other populations and across different age ranges (Bierhals *et al*., 2019; Song *et al*., 2020; Tajaldeen *et al*., 2022; Chiu *et al*., 2024), indicating that this relationship is not limited to young adults alone.

Our findings also showed that the majority of the subjects (76.3%) had a normal waist circumference, while only 11.1% had a high waist circumference. Nevertheless, the group with high waist circumference had the highest t-score values. The correlation between waist circumference and BMD was also found to be weak, although it was significant (r=0.155, p=0.023). These results contrast with other studies that demonstrated a negative association between waist circumference and BMD (Guo *et al*., 2023; Zhao *et al*., 2023; Ma *et al*., 2024). The lack of a strong effect in this study may be due to the smaller sample size (n=216) compared to the large sample sizes in other studies, which to our knowledge at least had a minimum of 772 subjects (Zhao *et al*., 2023) to 10372 subjects (Guo *et al*., 2023). Based on these studies, it has been suggested that waist circumference could be used as a potential predictor of osteoporosis. While waist circumference may not be as strong a predictor of osteoporosis as BMI, it should still be monitored as part of efforts to prevent bone loss. Additionally, it is an important factor in metabolic health.

Regarding body fat results, 22.7% of subjects had a high percentage of body fat, but at the same time, they also had the highest levels of BMD. However, it was not significant (p>0.05) compared to other groups. Consistent with our findings, studies by Mathieu *et al*. (2021) and El Miedany *et al*. (2024) also showed that high-fat mass is associated with high BMD. Conversely, research by Kim *et al*. (2019) and Gandham *et al*. (2023) reported a negative correlation between these parameters. This suggests that the relationship between body fat and BMD remains unclear and requires further investigation. Nevertheless, for the benefit of metabolic health and disease prevention, it is still advisable for individuals to maintain body fats within normal levels. This is because individuals with a normal BMI, but high body fat are still likely to have lower BMD compared to those with normal BMI and body fats (Yoon *et al*. 2023). Therefore, managing a healthy body composition, rather than focusing solely on just BMI, is crucial in preventing decreased BMD.

Additionally, this study found that BMD generally increased with higher levels of lean mass, and the correlation between these parameters was positively significant (p=0.003). This relationship is well-established and has been reported in numerous studies (Nguyen *et al*., 2020; Perna *et al*., 2023; Zhu *et al*., 2023). Lean mass, which includes muscle mass, can be maintained or increased through physical activity, particularly high-intensity or resistance training. During physical activities, muscles exert mechanical forces on bones, thus stimulating bone formation. The greater the muscle mass, the stronger the forces applied to the bones, leading to increased BMD. This also explains why physical activity is associated with higher BMD.

In this study, individuals who engaged in high levels of physical activity exhibited the highest BMD levels, with a positive correlation observed. These levels of physical activity, particularly weight-bearing exercises and resistant training, are known to stimulate bone growth and improve bone density, as reflected in the higher BMD values across all age groups (Hong & Kim 2018; Simoes *et al*., 2021; Massini *et al*., 2022; Oliveira *et al*., 2023). Interestingly, aside from high-intensity activities, low-impact sports and recreational activities also appear to have a positive effect on BMD (Multani *et al*., 2011; Patel *et al*., 2020; Clemente *et al*., 2021). These findings confirm that physical activity is essential for bone development and maintenance throughout adulthood. Furthermore, exercise may reduce the rate of bone loss and increase bone mass in the postmenopausal skeleton through the process of resorption and remodeling (Li *et al*., 2014).

Subjects with higher calcium intake in this study were found to have higher BMD. A study demonstrated that female adults who experienced bone fractures had a significantly lower calcium intake (390.5 mg/day) compared to non-fractured women (438.1 mg/day) (Wlodarek *et al*., 2014). Tai *et al*. (2015), in a systematic and meta-analysis, reported that high intake of calcium increased BMD by 0.6 to 1.0% (total hip and body) in the first year and by 0.7 to 1.8% (in similar sites, including lumbar spine & femoral neck) during the second year. These results suggest that a high intake of calcium, particularly from dairy products, may contribute significantly to higher BMD.

This study has several limitations. Firstly, BMD results were obtained using QUS instead of dual-energy X-ray absorptiometry (DXA), which is a gold standard method for determining bone density. However, due to the non-portability of DXA, along with financial constraints and logistic challenges, QUS was the best available option for this study. Secondly, this study is preliminary, involving only 261 subjects. Although the sample size meets the population estimation, the trend toward significant or non-significant results may reflect the relatively small sample size, leading to insufficient power to detect subtle differences between groups. This limitation is particularly notable when compared to other BMD studies, which are typically large-scale and involve thousands of subjects. Despite this, the study highlighted trends in the effect of prominent parameters, such as BMI, lean mass, physical activity, and calcium intake on BMD, contributing to our understanding of BMD among young adults. Thirdly, the population in this study was limited to one university, which means the results do not represent the entire population of young adults in Malaysia. Due to financial and time constraints, recruiting a larger and more diverse sample was not feasible. This should be addressed in future research.

Despite these limitations, this study has filled a gap in the knowledge of BMD and its influencing factors among young adults in Malaysia. Ultimately, it contributes to the body of research on bone health in Malaysia, which is still insufficient.

CONCLUSION

In summary, BMI, waist circumference, lean mass, physical activity, and calcium intake play a role in BMD. Promoting an active lifestyle, combined with proper management of a high-quality diet, may support good bone health and positively impact the overall health and well-being of young adults.

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ETHICAL STATEMENT

This study was approved by the Committee for Medical Research and Innovation, Hospital of Universiti Kebangsaan Malaysia, approval number UKM 1.5.3.5/244/FST-2015-003.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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