Analysis of The Association Between Nutrient Intake and Bone Mineral Density in College Students

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ABSTRACT

Background: *Osteoporosis is a condition characterized by brittle bone prone to fracture. The risk increases significantly with age, particularly among women. An effective approach for understanding and preventing the progression of osteoporosis is by examining bone mineral density (BMD), with diet playing an essential role. Therefore, this study aimed to analyze the association between nutrient intake and BMD in female students at the University of Lampung.*
Method: *This analytical observational study adopted a cross-sectional design. A total of 150 female students at the University of Lampung, were selected as samples using a multistage random sampling technique. The study variables were BMD and nutrient intake, specifically calcium, phosphorus, magnesium, vitamin C, vitamin D, and protein. BMD was assessed based on examination using an ultrasound bone densitometer, while nutrient intake was measured through 2x24h food recall. In the process, data analysis was conducted using the chi-square test.*
Result: *The results showed that female students had BMD in the osteopenia category of 52.7% and osteoporosis of 10%. Calcium and phosphorus intake were associated with BMD in Lampung University female students ($p<0.01$; $p=0.11$), while intake of magnesium, vitamin C, vitamin D, and protein did not correlate ($p=0.751$; $p=0.382$; $p=0.41$; $p=0.694$). Therefore, meeting calcium and phosphorus needs from an early age is essential to prevent osteoporosis.*

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INTRODUCTION

Osteoporosis is a condition characterized by brittle bones that are prone to fracture due to diminished strength. Its prevalence among women in Indonesia is 23 and 53% in the 50-80 and 70-80 years age groups, respectively. According to the International Osteoporosis Foundation (IOF), 20% of individuals with fractures caused by osteoporosis may die within a year, while many survivors experience severe mobility dependence or dependence on assistance.(1) This condition significantly diminishes quality of life and imposes a substantial economic burden.(2)

Women are four times more prone to develop osteoporosis than men.(1) The condition occurs more often in older women, particularly after menopause. This is attributed to bone resorption beyond remodeling due to reduced levels of the hormone estrogen.(3) Bone remodeling is a process of continuous absorption/destruction and formation. At approximately 30-40 years of age, the process of absorption/destruction and formation are in balance, thereby determining bone mineral density (BMD).(4)

BMD reflects the mineral content in bone tissue and serves as a key indicator of mineralization associated with osteoporosis. The World Health Organization (WHO) created criteria for bone density levels based on T-scores derived from BMD measurements. In this context, values ≥ -1 SD, between -1 SD and -2.5 SD, as well as ≤ -2.5 SD, represent normal density, osteopenia, and osteoporosis, respectively.(5) BMD increases during growth phase, peaks between the ages of 20 to 30, and diminishes with age.(6)

Adolescents and early adulthood are crucial for achieving optimal BMD, playing a significant role in mitigating the risk of osteoporosis in the future. Women are particularly vulnerable due to the protective role of estrogen during reproductive age, which diminishes postmenopause. Maintaining bone density during reproductive age (15–49 years) is critical for reducing the tendency of osteoporosis in later life.(7)

Bone density is influenced by both unmodifiable, such as genetics, age, and gender, and modifiable factors, including nutritional intake, physical activity, and smoking habits.(8) Proper nutrition is

essential for bone health, with protein, calcium, phosphorus, and vitamin D being key contributors to maintaining BMD. Protein supports bone turnover,(9) while calcium and vitamin D are particularly vital during the growth phase. Insufficient vitamin D disrupts calcium homeostasis and impairs bone mineralization.(10)

Adequate exposure to sunlight, a natural source of vitamin D, is vital. In Indonesia, exposure during early morning or late afternoon for 10–15 minutes, three times weekly, is considered sufficient.(11) Additionally, consuming dairy and animal products helps enhance calcium, vitamin D, and phosphorus intake, particularly during growth periods.(12)

Maintaining a balanced diet, specifically dairy products, alongside a healthy lifestyle, is essential for bone health.(13) Excessive food intake can lead to weight gain, affecting bone density and increasing the risk of osteoporosis. This is due to metabolic changes such as insulin resistance and excessive production of androgen and estrogen hormones, which reduces osteoblast activity. Furthermore, elevated adipokines or leptin levels associated with high fat intake can enhance intestinal calcium absorption.(14)

Early assessment and prevention of low bone density should begin at a young age. A study assessing BMD among individuals aged 19-25 years stated that 56.8 had normal density, while 22.1, and 21.1% were categorized as having, osteoporosis, and osteopenia, respectively. Female students, being in both early adulthood and childbearing age, need adequate calcium intake and good bone density to support pregnancy and prevent excessive loss of bone mineral, reducing the future risk of osteoporosis. This study aimed to examine the relationship between food intake and BMD in female students at the University of Lampung. As most students are at the age when peak bone mass is reached, understanding mineralization levels can facilitate early detection of osteoporosis risk and strategies to optimize bone density into adulthood.(15) The results served as a basis for health promotion initiatives to improve eating behavior and prevent osteoporosis.

METHOD

This study was conducted from February to March 2023 at the University of Lampung and the method used was a cross-sectional survey design. The target population included all women of childbearing age at the University, specifically female students within childbearing age.

The study sample comprised University of Lampung students aged 18-25 years. Exclusion criteria included pregnancy, a history of pregnancy or childbirth, and hormone disorders, such as menstrual irregularities or symptoms indicative of estrogen imbalance. The sample size, calculated using a formula for unpaired categorical analysis, total of 150 participants.

Participants were selected through a multistage random sampling technique. Initially, 4 out of 8 faculties at the University of Lampung were chosen using simple random sampling. From each selected faculty, a study program was further identified. Subsequently, samples were drawn from each program using disproportional stratified random sampling.

The independent variables included nutrient intake, specifically calcium, phosphorus, magnesium, vitamin D, vitamin C, and protein, while the dependent variable was BMD. Nutrient intake was assessed through interviews and a 2x24 hours food recall questionnaire, covering a weekday (Monday to Friday) and a weekend (Saturday and Sunday). BMD was measured using a Furuno CM 200 Ultrasound Bone Densitometer, targeting the inorganic material content in the right heel area.

Data processing included editing, coding, entry, cleaning, and storage stages. Univariate analysis was conducted to determine the frequency distribution of each variable, while bivariate analysis was performed using the chi-square test. Ethical approval for the study was obtained from the Medical and Health Research Ethics Committee, Faculty of Medicine, University of Lampung with number 276/UN26.18/PP.05.02.00/2023.

RESULT AND DISCUSSION

The results showed that the majority of the participants had abnormal BMD. Specifically, 79 (52.7%) participants were classified in the osteopenia category, 15 (10%) in the osteoporosis category, and only 56 (39.3%) fell into the normal category. The average calcium intake of the participants was 591 mg, falling below the recommended nutritional adequacy of 981 mg. Phosphorus intake averaged 683 mg, also lower than the recommended 747 mg. Similarly, magnesium intake averaged 218 mg, below the recommended adequacy of 299 mg. Vitamin C intake had an average of 14 mg, significantly lower than the recommended 71 mg. The average vitamin D intake was 4 mcg, compared to the recommended adequacy of 14 mcg. Lastly, protein intake averaged 50 g, which did not meet the recommended level of 58 g.

Table 1. Description of study variables

Variable	n	%	Average
Bone Mineral Density			
Abnormal Osteopenia	79	52.7	
Abnormal Osteoporosis	15	10	
Normal	56	39.3	
Calcium Intake (mg)			
Not enough	108	72	981
Enough	42	28	
Phosphorus Intake (mg)			
Not enough	74	49.3	747
Enough	76	50.7	
Magnesium Intake (mg)			
Not enough	93	62	299
Enough	57	38	
Vitamin C Intake (mg)			
Not enough	145	96.7	71
Enough	5	3.3	
Vitamin D Intake (mcg)			
Not enough	138	92	14
Enough	12	8	
Protein Intake (g)			
Not enough	93	62	58
Enough	28	18.7	
More	29	19.3	

The results showed that 108 (72%) and 42 (28%) were in the insufficient and adequate calcium intake categories, respectively. A total of 76 (50.7%) had sufficient phosphorus intake, while 74 (49.3%) were in the insufficient category. Approximately 57 (38%) and 93 (62%) participants had sufficient and insufficient magnesium intake, respectively. A total of 5 (3.3%) had sufficient vitamin C intake, while 145 (96.7%) fell in the insufficient category. Furthermore, 12 (8%) and 138 (92%) participants had sufficient and insufficient vitamin D intake, respectively. A total of 29 (19.3%), 28 (18.7%), and 93 people (62) had excessive, sufficient, and insufficient protein intake.

The results showed that participants who had insufficient and sufficient calcium intake with abnormal BMD were 78 (71.6%) and 13 (31.7%). According to chi-square analysis, calcium intake was associated with the dependent variable (p=0.000). The insufficiency was observed to be a risk factor with a value of OR=5.4 (CI: 2 .48-11.80). This implied that participants with less calcium intake had a 5.4 times higher risk of experiencing abnormal BMD.

Participants who had insufficient and sufficient phosphorus intake with abnormal BMD were 53 (71.6%) and 38 (50%), respectively. The results of the chi-square analysis showed that phosphorus intake was associated with the dependent variable (p=0.011). The insufficiency was observed to be a risk factor with a value of OR=2.5 (CI: 1 .28-4.96). This implied that participants with less intake had a 2.5 times higher risk of experiencing abnormal BMD.

The results showed that participants who had insufficient and sufficient magnesium intake with abnormal BMD were 55 (59.1%) and 36 (63.1%), respectively. Based on the chi-square analysis, intake was not associated with BMD in female students at the University of Lampung (p=0.751).

Participants who had insufficient and sufficient vitamin C intake with abnormal BMD were 89 (61.4%) and 2 (40%), respectively. The results of the chi-square analysis showed that the intake was not associated with the dependent variable (p=0.382).

The results showed that participants who had insufficient and sufficient vitamin D intake with abnormal BMD were 85 (62%) and 6 (46.1%), respectively. Based on the chi-square analysis, vitamin D intake was not associated with the dependent variable (p=0.410).

Participants who had insufficient and sufficient protein intake with abnormal BMD were 56 (58.9%) and 35 (63.6%). %), respectively. The results of the chi-square analysis showed that sufficient intake was not associated with the dependent variable (p=0.694).

Nutritional intake, both macronutrients and micronutrients is essential for improving health status. In this context, mineral calcium is an important mineral and the main constituent of bone structure. Results showed that the calcium intake of 108 (72%) female students remained insufficient. The average value was 591 mg, while the recommended daily intake was 981 mg. This implied that

the average intake met only 57% of the RDA. The results are in line with the study conducted to assess the calcium intake of adolescent girls where the value was below the recommended levels.(16)

Poor diet plays a role in the development of osteoporosis. Nutritional factors or intake, can be optimized in an effort to achieve good bone density. Calcium and vitamin D are the main micronutrients that play a role in the formation of bone mass.(17) Bone and plasma calcium were in balance at a concentration of 2.25-2.60 mmol/l (9-10.4 mg/100 ml). Dairy products, specifically cow's milk, are major sources of calcium, providing approximately 120 mg of the nutrient per 100g of the product. Additionally, non-dairy products such as fish, shrimp, eggs, green vegetables, tofu, and soybeans contribute to intake.(9)

The results of bivariate analysis with the chi-square statistical test showed that there was a significant relationship between calcium intake and BMD as signified by a p-value of 0.000 ($p < 0.05$). Insufficient intake is a risk factor with OR value = 5.419 (CI: 2.488-11.803). This implied that participants with less calcium intake had a 5.4 times higher risk of experiencing abnormal BMD compared to adequate calcium intake.

The results were in line with reports that calcium intake was significantly related to BMD in adolescent girls (p-value = 0.000).(6) According to other studies, intake was positively correlated with total BMD in adolescents.(18,19) After reaching peak bone mass in early adulthood, a decrease occurs with age, specifically among women who are susceptible to bone loss due to pregnancy and menopause.(20) Bone mass decreased specifically at the age of 50 years in men and women, but the speed of reduction in women was higher due to the hormone estrogen. The potential for calcium absorption was higher during the growth period and decreased with age. Factors that enhance calcium absorption in the intestine, include vitamin D and protein.(21)

Calcium is a micronutrient needed to form bone and regulate the physiological and biochemical processes. At normal levels in the blood, it signifies a balance of bone mineralization and demineralization. When calcium levels decrease, parathyroid hormone (PTH) is released, prompting the body to collect nutrients from other areas, such as the bone.(22)

Fish consumed with bones, such as dried anchovies, seluang fish, and anchovies, are excellent sources of calcium. Dried anchovies contain 1200 mg of calcium per 100 grams, which is significantly greater compared to catfish (23.8 mg), fish (23.6 mg), goldfish (299 mg), and tuna (321 mg). Results showed that dried shrimp provide 1209 mg of this nutrient. Additionally, foods such as milk flour (904 mg) and cheese (777 mg) are rich in calcium.(23)

Table 2. Association of food intake with BMD

Variable	BMD				OR (CI 95%)	p-value
	Abnormal		Normal			
	n	%	n	%		
Calcium Intake					5.4 (2.48-11.80)	0,000
Not enough	78	71.6	31	28.4		
Enough	13	31.7	28	68.3		
Phosphorus Intake					2.5 (1.28-4.96)	0.011
Not enough	53	71.6	21	28.4		
Enough	38	50	38	50		
Magnesium Intake					NA	0.751
Not enough	55	59.1	38	40.9		
Enough	36	63.1	21	36.9		
Vitamin C Intake					NA	0.382
Not enough	89	61.4	56	38.6		
Enough	2	40	3	60		
Vitamin D Intake					NA	0.410
Less	85	62	52	38		
Simply	6	46.1	7	53.9		
Protein Intake					NA	0.694
Less	56	58.9	39	41.1		
Enough-More	35	63.6	20	36.4		

The study identified that 78 out of 150 female students had insufficient calcium intake and abnormal BMD. Based on the results of the consumption assessment, the most common calcium sources among Unila students include chicken, eggs, and catfish. The content per 100 grams of chicken and eggs was 11 mg and 14 mg, respectively. These foods are low in calcium compared to other potential sources.

Based on the results of interviews, 54 (59.3%) female students with insufficient calcium intake and abnormal BMD lived in boarding houses, where foods are independently managed and selected based on preference. Furthermore, some students did not consume milk and fish, which are the main sources of calcium. The types of fish consumed include catfish, tuna, anchovies, salty fish, and tilapia.

Calcium intake has been proven to be a factor that influences the bone density of Lampung University students. Therefore, adequate intake from food sources containing high calcium should begin early to optimize bone density. Students were encouraged to consume milk or fish which are the main sources of this nutrient. Anchovy is a fish that contains more calcium than catfish and is easy to obtain, hence, it is highly recommended for Unila students.

In addition to calcium, another mineral that makes up bone matrix is phosphorus. The results of this study show the phosphorus intake of 150 Lampung University students. Approximately 76 (50.7%) and 74 (49.3%) students had sufficient and insufficient intake, respectively. The average value of phosphorus intake was 683 mg, compared to the recommended 747 mg. Food sources rich in minerals include cow's milk, fish, eggs, wheat, cheese, chocolate, mushrooms, and nuts.9 However, students' diets lacked sufficient milk and fish, which are sources of phosphorus.

The results of this study showed that 53 (58.2%) female students with insufficient phosphorus intake had abnormal BMD, while 21 (35.3%) had normal BMD. Bivariate analysis using the chi-square statistical test presented a significant relationship between phosphorus intake and BMD, with a p-value of 0.011 ($p < 0.05$). Insufficient intake was observed to be a risk factor with OR value = 2.524 (CI: 1.283-4.964). This implied that participants with less consumption of phosphorus had a 2.5 times higher risk of experiencing BMD.

A study stated that phosphorus intake is positively related to bone density in female adolescents (p-value = 0.010).(16) It is also positively correlated with BMD and bone mineral content in young women. In addition to calcium, phosphorus is a mineral contained in bone matrix.(24) Its intake plays an important role in bone formation during growth. Low levels of phosphate in serum can limit the bone mineralization process. Furthermore, maintaining extracellular phosphorus homeostasis is critical for bone health. Chronic phosphorus deficiency can cause bone demineralization and loss through resorption.(9) Despite being an important mineral for bone, excessive consumption is not good. A high ratio of phosphorus to calcium in food leads to decreased calcium absorption due to the formation of water-insoluble calcium oxalate. The recommended ratio is 1:1, and a shift towards phosphorus signifies low calcium intake. It is important to acknowledge that high phosphorus intake but low calcium intake can increase parathyroid hormone levels and cause increased bone resorption.25 Phosphorus intake is a factor that influences the bone density of Lampung University students. Therefore, maintaining an adequate and balanced consumption of both minerals is necessary.

Another mineral that is important for bone is magnesium. The results showed that 93 (62%) female students at the University of Lampung had insufficient magnesium intake. The average value of intake was 218 mg, while the phosphorus adequacy was 299 mg. Food sources of mineral magnesium include fish, spinach, almonds, cashews, and pumpkin.(9) The diet of Lampung University students still lacked consumption of fish and vegetables which are sources of mineral magnesium.

Among female students with insufficient magnesium intake, 55 (60.4%) and 36 had abnormal and abnormal BMD, respectively. Bivariate analysis with the chi-square statistical test showed that there was no significant relationship between magnesium intake and BMD as signified by a p-value of 0.751 ($p > 0.05$). The results are not in line with the study that magnesium intake is positively related to bone density in female adolescents (p-value = 0.041).(16) Additionally, the meta-analysis of four studies showed a positive relationship between intake and hip bone BMD.(26)

In the body, magnesium is discovered in bone (53%), muscle (27%), soft tissue (19%), and less than 1% in serum. It functions as a coenzyme, in the conversion of vitamin D which plays a role in calcium metabolism and a supporting role in the normal function of the parathyroid glands. Magnesium deficiency can lead to increased release of proinflammatory cytokines that promote osteoclast activity, as well as decreased levels of Parathyroid Hormone (PTH) and 25-hydroxyvitamin D [25(OH)D]. Intake of this mineral has not been proven to be a factor influencing the bone density of Unila students. There is a mechanism for how magnesium affects bone health and an increased risk of osteoporosis due to magnesium deficiency. Therefore, adequate magnesium

intake in female students is highly recommended to prevent osteoporosis.(9)

The results of this study showed that the vitamin C intake of 145 (96.7%) female students at the University of Lampung was insufficient. The average value of vitamin C intake and adequacy for female students is 14 mg and 71 mg, respectively. Therefore, the average % RDA for this mineral is 20%. Vegetables and fruit are the best sources of vitamin C and the consumption of both is still lacking in diet.(9)

Analysis showed that among female students with insufficient vitamin C intake, 89 (97.8%) and 56 (94.9%) had abnormal and normal BMD. Based on the bivariate statistical test, there was no significant relationship between vitamin C intake and BMD as signified by a p-value of 0.382 ($p > 0.05$). A study showed that no significant relationship exists between nutrient intake and BMD.(27) However, a positive relationship was observed between vitamin C intake and BMD in the hip bone and femoral neck.(28)

Vitamin C supports calcium absorption by promoting the growth of osteoblasts. Adequate intake of this nutrient improves bone health and helps prevent osteopenia, osteoporosis, and fractures.(9) The metabolic effects of vitamin C can stimulate procollagen which increases collagen synthesis and activates the activity of phosphatase, a marker for osteoblast formation.28 Its intake has not been proven to be a factor that influences the bone density of Lampung University students. A study showed the potential for vitamin C to prevent a decrease in bone mass. Therefore, sufficient intake is recommended for female students to optimize bone density.(29)

Vitamin D and calcium are essential nutrients for bone health. Approximately 13 (92%) participants had insufficient intake, averaging 4 mcg compared to the recommended 14 mcg, thereby meeting only 30% of RDA. Animal-based foods, such as fatty fish (salmon, tuna, mackerel) and fish liver oil are the best sources of vitamin D. Egg yolks, liver, and cheese contain small amounts of mineral.(9) Vitamin D is also obtained from exposure to sunlight, which compensates for low dietary intake.(30)

This study showed that among female students with insufficient vitamin D intake, 85 (93.4%) and 52 (88.1%) participants had abnormal and normal BMD, respectively. Bivariate analysis with the chi-square statistical test presented no significant relationship between vitamin D intake and the dependent variable with a p-value of 0.410 ($p > 0.05$). These results differ from previous studies that discovered a significant association between serum 25(OH) D concentrations and BMD in young adults aged 19-24.(31)

Vitamin D plays an important role in bone health, regulating calcium and phosphorus during bone formation. Lack of vitamin D in the active form can inhibit calcium absorption, while the adequacy enhances intestinal absorption, thereby meeting bone needs. The most important factor influencing serum 25(OH)D levels is exposure to sunlight, as very few foods naturally provide sufficient vitamin D.(9) The intake of this nutrient did not affect BMD in Unila students, but maintaining adequate levels from both diet and sunlight is crucial for calcium and phosphorus balance. Therefore, female students should ensure adequate vitamin D intake.32 Protein, as a macronutrient, supports the formation of bone mass. This study showed that 93 (62%) had a deficit intake of this nutrient. The average value of the intake was 50 g compared to an adequacy value of 85 g, hence, the average % of female students' RDA was 89%. Adequate protein intake is crucial for overall health, including maintaining bone health and preventing muscle loss.(9)

Among students with deficit protein intake, 56 (61.5%) and 39 had abnormal and normal BMD. Bivariate analysis using a chi-square statistical test showed no correlation between protein intake and the dependent variable at a p-value of 0.694 ($p > 0.05$). it is in line with a study reporting no significant relationship between protein intake and BMD in adolescent girls.16 An investigation stated that higher total protein intake, particularly from animal sources, is associated with increased bone density.(26)

Increasing protein intake beyond the recommended 0.8-0.9 g/kg/day, particularly in conditions such as old age, is beneficial for bone health by enhancing BMD and bone turnover, reducing the risk of fracture. A minimum intake of 1 g/kgBW is essential for maintaining adequate BMD and muscle mass strength. Therefore, a diet should include both animal and vegetable protein to prevent decreased bone density and muscle loss.(9) This study showed no evidence that protein intake influenced the bone density of Lampung University students. However, protein remains a critical macronutrient for overall body health and bone support. Students should ensure their diet provides the nutrients in sufficient form to meet individual needs.(33) A limitation of this study is that the assessment of dietary intake such as calcium, phosphorus, and magnesium, was based solely on a consumption survey, rather than objective blood biochemical tests.

CONCLUSION

In conclusion, the prevalence of abnormal BMD among Lampung University students was relatively high, with 52.7% and 10% classified as osteopenia and osteoporosis, respectively. Calcium and phosphorus intakes were identified as factors influencing BMD. It was important to acknowledge that the majority of

participants had insufficient calcium intake. The University of Lampung was recommended to organize regular health promotion programs emphasizing balanced nutrition and the importance of meeting nutrient adequacy, particularly for nutrients critical to bone health. Additionally, implementing policies to ensure canteen managers provide balanced, nutritious food could help address the nutritional needs of students. Female students of childbearing age were encouraged to adopt healthier eating behavior, specifically by ensuring adequate nutrient intake, to reduce the risk of osteoporosis and related health conditions.

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