Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 9s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Impact of Daily Habits on Bone Mass Density: A Study on Protein Intake, Physical Activity, and Caffeine Consumption in Indonesian Society

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Cite this paper as: Thomas Erwin Christian Junus Huwae, Istan Irmansyah Irsan, Syaifullah Asmiragani, Panji Sananta, Krisna Yuarno Phatama, Muhammad Garis Herwanto, Revanda Annisa Cahyani, Teresa Almadita, (2025) Impact of Daily Habits on Bone Mass Density: A Study on Protein Intake, Physical Activity, and Caffeine Consumption in Indonesian Society. *Journal of Neonatal Surgery*, 14 (9s), 601-608.

ABSTRACT

Introduction: Bone mass density is the total weight of bone tissue in the human body. Osteopenia, a decrease in bone mass density, is globally affected. Lifestyle and daily habits play a crucial role in bone health. This study aims to determine the relationship between daily habits in physical activity, protein intake, caffeine consumption, and bone mass density.

Method: This study is an analytical-observational cross-sectional study conducted from May to July 2024 in Kendalpayak Village involving 42 participants aged 30-70 who underwent a bone mass density examination using Quantitative Ultrasound. Data was collected through questionnaire-based interviews. Data analysis was conducted using chi-square, and the results were considered significant if p-value < 0.05.

Results: Type (0.014), intensity (0.037), and duration (0.001) of physical activity related to bone mass density (p-value < 0.05). While protein intake, frequency of physical activity, and caffeine consumption are not.

Discussion: The study found no significant relationship between protein intake and bone mass density despite factors like calcium, vitamin D, phosphorus intake, hormonal factors, heredity, and race not being studied. Physical activity, such as weight training and high-intensity exercise, is related to bone mass density, with variation and intensity playing a more significant role. Coffee consumption did not significantly impact bone mass density, as the polyphenol content in the tea or coffee cannot be determined.

Conclusion: Type, intensity, and duration of physical activity were related to bone mass density, while protein intake, frequency, and caffeine consumption were not.

Keywords: *bone density, caffeine, habit, physical activity, protein intake.*

1. INTRODUCTION

Bone mass density is the total weight of bone tissue consisting of matrix, minerals, and bone cells in the human body. This composition is maintained in balance through the deposition and resorption of bone cells.[1] Bone mass will accumulate and peak in the third decade, then decrease by 0.3% - 0.5% each year.[2] The decrease in bone mass density, Osteopenia, globally reaches 48.14% in women and 42.20% in men.[3] Low bone mass density has become one of the global issues. Every three seconds, one fracture occurs due to osteoporosis, and it is estimated that at least 437,884 deaths and 16.6 million Disability Adjusted Life Years (DALYs) are caused by low bone mass density.[4,5] Studies state that at least one in three women and one in five men worldwide have osteoporosis, with the highest prevalence of osteoporosis found on the Asian continent.[4,6] In Indonesia, at least two out of five Indonesians are at risk of developing osteoporosis, with women being twice as likely to be affected by osteoporosis.[4] Bone mass density can be measured using dual-energy x-ray absorptiometry (DEXA), which assesses the risk of fragility and fractures. In addition to DEXA, a Quantitative Ultrasound-based bone densitometer (QUS)

can measure bone mass density.[7] The result of measuring bone mass density is called the T-score and is divided into three levels: normal, decreased bone mass, and osteoporosis. A low T-score indicates a decrease in bone mass density, which can reduce bone strength and increase the risk of fractures.[8]

Various factors influence bone mass density, such as age, gender, family history, physical activity, smoking habits, caffeine consumption, and protein, calcium, and vitamin D intake.[9] Physical activity plays an important role in bone health. Physical activity involves various body movements that require energy and engage muscles. Physical activity can positively affect bone health by stimulating mechanical bone stimulation, promoting the formation of new bone, and enhancing bone strength and health at all ages. When engaging in physical activity, bones are exposed to mechanical forces generated by muscle contractions and gravitational loads. Bone cells (osteocytes) detect mechanical forces such as cell deformation, changes in extracellular fluid tension, pressure gradients, and electric fields at the cellular level. Osteocytes regulate bone formation and resorption by communicating with osteoblasts and osteoclasts, ultimately altering bone geometry and material properties.[10]

Protein intake is essential for bone health because one-third of bone mass consists of protein and is constantly remodeling. During remodeling, many collagen fragments are released through proteolysis and cannot be reused to form a new bone matrix. Therefore, humans need a daily intake of protein. Protein deficiency is associated with bone growth deficits or accelerated bone resorption processes.[11] In addition to protein intake, paying attention to caffeine consumption is also crucial for bone health. A study mentions that caffeine can disrupt bone metabolism by inhibiting osteoblast differentiation and increasing osteoclast activity through caffeine's antagonistic activity against adenosine receptors, thereby increasing urinary calcium excretion. This can decrease bone mass density.[12,13] Among these various factors, it can be concluded that lifestyle and daily habits play an essential role in bone health. Therefore, this study aims to determine the relationship between daily habits in physical activity, protein intake, caffeine consumption, and bone mass density.

2. METHOD

Study Design & Sampling Method

This research is an analytical-observational study with a cross-sectional approach conducted from May to July 2024. The population in this study is the community of Kendalpayak Village, Malang Regency. The Lemeshow formula approach was used to determine the minimum sample size required for this study.

$$\mathbf{n} = \frac{Z^2_{1-\alpha/2} \times P(1-P)}{d^2}$$

n: sample size

Z: Z-score at 95% confidence = 1.96

P: Estimation of the proportion in the population was 41,7% = 0.417

The estimated proportion of 41.7% was obtained based on a study of the prevalence of osteopenia in Indonesia conducted by the Indonesian Ministry of Health Data & Information Center.[4]

d: Tolerable absolute error 15% = 0.15

$$\mathbf{n} = \frac{(1,96)^2\ 0,147(1\ -\ 0,147)}{0,15^2}$$

$$\mathbf{n} = \frac{(1,96)^2\ 0,147\ 0,583}{0,15^2}$$

$$\mathbf{n = 41,50823189333 = 42}$$

Based on the Lemeshow formula calculation, a sample size of 42 participants was obtained. The inclusion criteria in this study are: (1) individuals aged 30-70 years and (2) willing to participate in the study and undergo bone mass density examination using Quantitative Ultrasound (QUS). The exclusion criteria are: (1) long-term steroid use, (2) having certain diseases such as diabetes mellitus, kidney failure, or hormonal disorders that significantly affect bone density like Cushing's disease and hyperthyroidism, (3) having a history of fractures, (4) smoking, and (5) consuming alcohol. The sampling technique used is total sampling.

Research Procedure

Primary data was collected through interviews based on three questionnaires and bone mass density examinations using quantitative ultrasound (QUS) on each respondent. The three questionnaires used are the Global Physical Activity Questionnaire (GPAQ), composed of 6 questions to observe each individual's physical activity habits; the semi-quantitative Food Frequency Questionnaire, to determine daily protein intake; and a self-developed questionnaire to assess participants' caffeine consumption. The questionnaire has undergone validity and reliability testing.

Data Analysis

Descriptive analysis determines the percentage of each characteristic and research variable. Bivariate analysis tests were conducted using chi-square. The research results are significant if the p-value < 0.05. Data analysis was performed using SPSS version 27.

3. RESULT

This study's results indicate that most respondents were male (85.7%), aged over 60 (57.1%), and half worked as factory laborers. Daily protein consumption is below the recommendation (69%), with more plant-based than animal-based protein. The majority of the community in Kendalpayak Village engages in one type of physical activity: Cardiovascular, Resistance, or Flexibility Exercise (50%), with a frequency of 1-2 days/week (42.8%), light intensity, and a duration of >120 minutes. Detailed information regarding the characteristics can be found in Table 1.

Table 1. Research Data Characteristics

Characteristic	Frequency	Percentage (%)
Gender		
Male	36	85,7%
Female	6	14,3%
Age		
41 – 50 years	8	19,1%
51 – 60 years	10	23,8%
>60 years	24	57,1%
Occupation		
Trader	17	40,5%
Factory Worker	21	50%
Farmer	4	9,5%
Bone Mass Density		
Normal	11	26,2%
Osteopenia	23	54,8%
Osteoporosis	8	19%
Daily Protein Intake		
Daily Average Amount		
Less than Recommendation	29	69%
As per Recommendation	1	2,4%
More than Recommendation	12	28,6%
Daily Average Type		
More Animal-based Protein	9	21,4%
More Plant-based Protein	33	78,6%
Physical Activity		
Types		
Sedentary	2	4,7%

Crafting or Arts	3	7,1%
One among Cardiovascular, Resistance, or Flexibility Exercise	21	50%
Two among Cardiovascular, Resistance or Flexibility Exercise	11	26,2%
All Cardiovascular, Resistance, and Flexibility Exercise	5	12%
Frequency		
Sometimes	7	16,7%
1-2 days/weeks	18	42,8%
3 days/weeks	10	23,8%
4-5 days/weeks	5	12%
Every day	2	4,7%
Intensity		
Sangat Ringan	9	21,4%
Ringan	12	28,6%
Sedang	8	19%
Berat	8	19%
Sangat Berat	5	12%
Duration		
<30 minutes	4	9,5%
30-60 minutes	7	16,7%
60-90 minutes	9	21,4%
90-120 minutes	10	23,8%
>120 minutes	12	28,6%
Caffeine Consumption		
Low (<150 mg)	18	43%
Medium (150-300 mg)	12	28,5%
High (>300 mg)	12	28,5%
Total	42	100%

A bivariate analysis of protein intake, physical activity, and caffeine consumption with bone mass density is shown in Table 2.

Table 2. Chi-square Analysis

Variables	p-value
Protein Intake	
Daily Protein Amount	0.484
Daily Protein Type	0.936
Physical Activity	
Types	0.014*
Frequency	0.069
Intensity	0.037*
Duration	0.001*
Caffeine Consumption	0.328

Based on Table 2, it can be concluded that there is a relationship between the type, intensity, and duration of physical activity and bone mass density (p-value < 0.05).

4. DISCUSSION

Protein Intake and Bone Mass Density

The results of this study indicate that there is no relationship between protein intake and bone mass density. The results of this study are consistent with previous research conducted by Noprisanti (2018)[11] and Khotimah (2021)[14]. The absence of a relationship between daily protein intake and bone mass density occurs due to other factors not studied in this research, such as calcium, vitamin D, phosphorus intake, hormonal factors, heredity, race, etc. Bone mass density depends on protein intake and involves interactions with other nutrients such as calcium, phosphorus, vitamin D, and other minerals.[15] The other study mentioned that adequate protein and sufficient calcium intake positively impact bone health.[16] This study emphasizes that protein is vital in maintaining muscle mass, contributing to bone stability and strengthening, and reducing the risk of fractures in the older. However, excessive protein intake also risks causing abnormal Bone Mineral Density. This occurs due to the calcium effect and the acid-base metabolism it induces, where each increase of 1 gram of protein intake can result in the loss of 1 mg of calcium from the bones excreted in urine.[17] Excessive animal-based protein consumption causes the body's blood to become more acidic (low pH). Animal-based protein contains the amino acids cysteine and methionine, which contain sulfur, so basic calcium bicarbonate is needed to neutralize it. If the amount of calcium in the blood is insufficient, the body will take calcium reserves from the bones. If this continues for a long time, bone density will decrease.[18]

Physical Activity and Bone Mass Density

In this study, the type, intensity, and duration of physical activity are related to bone mass density, whereas frequency is not. The results of this study are consistent with previous research, which states that variation and intensity of exercise play a more significant role in increasing bone density than just frequency.[19] Other studies show that weight training and high-intensity physical activity are more effective in increasing bone mass than high-frequency training without sufficient variation and intensity.[20,21] High-intensity exercises have proven effective in stimulating bone remodeling and increasing bone mineral density.[22] In their research, Chang et al. (2022) also confirmed that the mechanical stress generated from high-intensity exercise is a key factor in stimulating biochemical processes in bone remodeling to help prevent osteoporosis.[23] In addition to variation and intensity, longer durations of physical activity are also beneficial for bone health because they can improve bone structure due to prolonged mechanical stress.[24] In general, physical activity plays an important role in maintaining bone health. Physical activities that involve weight-bearing, such as walking, running, and weight training, can increase bone density by stimulating osteoblasts (bone-forming cells) and strengthening bone structure. Regular physical exercise can prevent a decrease in bone density, especially in the older population.[25]

Caffeine Consumption and Bone Mass Density

Data analysis of the research shows that there is no significant relationship between the amount of caffeine consumption and bone mass density. The results of this study are consistent with previous research conducted by Dai (2018)[26], Verinda (2020)[27], and Cui (2023)[28]. The caffeine content calculated in this analysis is the average amount in coffee and tea, which does not reflect the actual types and quantities of consumption in society. Moreover, the sample size in this study is relatively

small, which does not represent the population intended for thorough research, and the analysis results are insignificant. In addition to caffeine, coffee and tea contain active compounds such as polyphenols that protect bones. Polyphenols increase osteoblasts, inhibit osteoclasts, function as antioxidants, and protect bones from pro-inflammatory enzymes.[29] One of them is epigallocatechin-3-gallate (EGCG). EGCG has a function in collagen crosslinking that supports the collagen biosynthesis process and inhibits collagen degradation in bones. The stronger the crosslink bonds formed, the more resilient the collagen can withstand the proteolytic properties of enzymes.[30] However, the polyphenol content in the tea or coffee consumed by the people of Kendalpayak Village cannot be determined with certainty.

5. CONCLUSION

This study investigates the relationship between daily habits in physical activity, protein intake, caffeine consumption, and bone mass density. It found that type, intensity, and duration of physical activity were related to bone mass density, while protein intake, frequency, and caffeine consumption were not despite factors like calcium, vitamin D, phosphorus intake, hormonal factors, heredity, and race not being studied. High-intensity and regular physical exercises stimulate bone remodeling and increase bone mineral density.

ETHICAL APPROVAL

Health Research Ethics Commission General Hospital Saiful Anwar provided ethical approval for this study with a number (400/378/K.3/102.7/2024).

CONFLICT OF INTEREST

We declare that no competing financial interests or personal relationships could have appeared to influence the work reported in this manuscript.

FUNDING

This study received no specific grant from funding agencies, commercial or not-for-profit sectors.

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