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Correlation between bone density and calcium intake in overweight and obese adolescents

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Abstract

As the correlation between overweight and obesity on bone density in adolescence has not been fully understood, this study aimed to identify the correlation between calcium intake, bone density, and overweight/obesity status in adolescents. Conducted in two urban areas, Gorontalo City and Manado City, this research employed a cross-sectional study design. The research sample was obtained by using the minimum sample size formula for a cross-sectional study. The total sample encompassed 90 samples (45 adolescents in Gorontalo City and 45 adolescents in Manado City). The collected data comprised anthropometric data, bodyweight classification, bone density data, and calcium intake data. The data analysis was carried out by univariate analysis and Pearson correlation analysis. The results of the Pearson correlation test show that body weight is significantly correlated with bone density and calcium intake, each with p-values of 0.000 and 0.001, respectively. Thus, it was concluded that body weight correlates with bone density and calcium intake.

1. Introduction

Obesity has recently become a major global health concern. The World Health Organization (WHO) stated that in 2016, more than 18% of children and teenagers aged 5-19 years old worldwide were overweight and obese (WHO, 2020). Such is not only a problem for developed countries. In developing countries, obesity has also emerged as one of the main health concerns that require immediate treatment.

The 2018 Baseline Health Survey reported that the prevalence of overweight and obesity in the 13-15 years old age group was 16%, while in the 16-18 years old age group, the prevalence of the diseases was 13.5% (Badan Penelitian dan Pengembangan Kesehatan, 2019). Meanwhile, the prevalence of overweight and obesity in the 16-18 age group in Gorontalo Province was recorded at 12.4% (Badan Penelitian dan Pengembangan Kesehatan, 2019). North Sulawesi Province, the closest province with a similar diet pattern to Gorontalo, has a higher prevalence of overweight and obesity of 11.4% and 5%, respectively (Badan Penelitian dan Pengembangan Kesehatan, 2019). The high prevalence demands immediate countermeasures to prevent the situation from worsening.

Overweight and obesity caused by the uncontrolled accumulation of fat body can lead to more severe health problems (WHO, 2019). These might include the increased risk of Non-Communicable Diseases (NCDs), such as heart and cardiovascular diseases, type-2 diabetes, gastrointestinal and reproductive cancers, and inflammatory diseases of the joints and bones (Darweish, 2012; WHO, 2019). For teenagers and young adults, such diseases might be detrimental to their growth.

Growth in adolescence is supported by several very important macro and micronutrients, one of which is calcium. As a micro-nutrient, calcium is the most abundant mineral in the body. Calcium is mostly found in bones and teeth, as well as in nerve cells, blood, and body fluids. Calcium plays a role in optimal bone and tooth growth, blood clotting, the process of sending and receiving signals in nerve cells, muscle contraction and relaxation, and maintaining a normal heart rate (Wax, 2019). Henceforth, adequate calcium intake is central to the growth of children and adolescents alike.

Inadequate calcium intake can cause osteoporosis in the bones. Osteoporosis is a condition of decreased bone density and destruction of bone tissue (Gracia-Marco *et al*., 2012). The state of optimal bone density during

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childhood and adolescence is an important determinant of bone health in adulthood (Gracia-Marco *et al*., 2012). The risk of fractures due to osteoporosis can be prevented by as much as 50% by increasing bone density during growth (Gracia-Marco *et al*., 2012).

The correlation between overweight and obesity on bone density in adolescence has not been fully understood. Some studies argue that bone density is not affected by the accumulation of fat mass in male adolescents, but it is different in female adolescents (Gracia-Marco *et al*., 2012). Therefore, research on the correlation between overweight and obesity on calcium intake and bone density in adolescents is essential to be conducted

The research was conducted in two urban areas, Gorontalo City and Manado City. The prevalence of overweight problems is higher in urban areas than in rural areas (Badan Penelitian dan Pengembangan Kesehatan, 2019). This can be caused by various factors such as a lack of physical activity and high consumption of fast food and high-calorie snacks (Nurwanti *et al*., 2019). With the specific variable to assess calcium intake in adolescents with weight problems, as well as the state of bone mass, this study offers a novelty of study that contributes to the development of science, particularly in the field of nutrition sciences. The present study aimed to identify the correlation between calcium intake, bone density, and overweight/obesity status in adolescents.

2. Materials and methods

2.1 Research design

This research employed a cross-sectional study design. The research sample was obtained by using the minimum sample size formula for a cross-sectional study (Lemeshow and David, 1997).

$$n = \frac{Z^2 1-\propto/2 \ P\ (1-P)}{d^2}$$

Where n = number of samples, Z1 – α/2 = standard normal distribution at α = 0.05 (1.96), p = proportion of obesity in adolescents based on the 2018 Baseline Health Survey (13.5%) and d = degree of accuracy (10%)

Based on the sample size formula, the total sample for this study encompassed 90 samples. The sample consisted of 45 adolescents in Gorontalo City and 45 adolescents in Manado City, with inclusion and exclusion criteria as follows.

Inclusion Criteria:

a. Good physical and mental health condition
b. Aged 16-18 years old
c. Active communication
d. Domiciled in Gorontalo City
e. Willing to participate as the research sample
f. Not currently having NCDs, CVDs, and complications

Exclusion criteria:

a. Not being present at the site of data collection
b. Withdraw from the data collection phase

2.2 Data collection

2.2.1 Anthropometric data

The data of bodyweight were extracted by digital weight scale with an accuracy of 0.1 kg. Meanwhile, the body height data of the samples were measured using a stadiometer with an accuracy of 0.1 cm. Data regarding the age of the samples were obtained from the records on the sample's Family Card. Body Mass Index data were obtained using the following formula.

$$\text{Body Mass Index} = \frac{BW\ (kg)}{BH^2\ (m)}$$

2.2.2 Bodyweight classification

The classification of body weight is grouped into three categories based on the obtained BMI calculation value. The nutritional status categories of the sample are as follows (Nishida, 2004).

Thin, if BMI value = < 18.5 kg/m^2

Normal, if BMI value = 18.5 – 23 kg/m^2

Overweight, if BMI value = >23 – 27.5 kg/m^2

Obese, if BMI value = >27.5 kg/m^2

2.2.3 Bone density data

The data of the samples' bone density were retrieved using a bone mass detector.

2.2.4 Calcium intake data

Data on calcium intake were obtained using multiple 24-hour food recalls and semi-quantitative food frequency questionnaire methods.

2.3 Data analysis

The data analysis was carried out by univariate analysis using the mean and frequency for the variables of nutritional status, bone density, and intake. The results are presented in the form of a frequency distribution table. Meanwhile, to see the correlation between each of these variables, a Pearson correlation analysis was conducted.

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3. Results

3.1 Sample characteristics

The characteristics of the sample consisting of gender, age, height, weight, bone density status, and weight classification are presented in Table 1.

Table 1. Sample characteristics

Characteristics	Category	Frequency	
		n	%
Sex	Male	16	17.8
	Female	74	82.2
Bone density status	Low	66	73.3
	Normal	24	26.7
Bodyweight	Thin	13	14.4
	Normal	33	36.7
	Overweight	14	15.6
	Obese	30	33.3

The findings in Table 1 suggest that the majority of the sample comprises female adolescents with low bone density status. In terms of bodyweight, the distribution among the samples is relatively balanced, with a significant portion classified as normal weight, and smaller percentages classified as thin, overweight, or obese. The data on age, body height, and body weight are presented in Table 2.

Table 2. Distribution of frequency of anthropometric data and 24-hour food recalls results.

Variable	Minimum value	Mean value	Maximum value
Age	17	17.57	18
Body height	138	153.57	173
Bodyweight	33.4	56.58	108.7
Calcium intake	256	670.94	1.152

Table 2 displays the information about the central tendency and range of values for each variable in the samples. It consists of adolescents within a narrow age range (17-18 years) with a mean age of 17.57 years. The sample includes individuals with a range of body heights (138-173 cm) and bodyweights (33.4-108.70 kg), indicating variability in these characteristics. Similarly, calcium intake varies among the sample, with a mean intake of 670.94 mg and a range of 256-1152 mg.

3.2. Correlation between calcium intake, total calorie intake, bone density, and bodyweight

The correlation between calcium intake, total calorie intake, bone density, and body weight was analyzed by the Pearson correlation test (Table 3).

The results of the Pearson correlation test show that body weight is significantly correlated with bone density and calcium intake, each with p-value of 0.000 and 0.001, respectively. In conclusion, there are significant relationships between bodyweight, bone density status, and calcium intake in the sample population, in which higher bodyweight and bone density status are associated with higher calcium intake.

4. Discussion

The research sample consisted of male and female adolescents with an age range of 16-18 years. This age range is the puberty phase which is the peak of long bone growth (growth spurt) (Chang *et al.,* 2021). About 80% of bone growth occurs in childhood and adolescence (Kelley *et al*., 2017; Chang *et al*., 2021). During adolescence, maximum bone mass growth is 90%; for girls, the rate of bone mass formation peaks at about age 13, and after this age, bone density increases very little. During this stage, major changes in bone structure occurred, i.e., rapid osteogenesis and bone remodeling (Kim *et al*., 2017). This is the basis for achieving maximum bone mass during adolescence; however, because bone mass decreases with age, if the maximum bone mass is low at a young age, the risk of fracture or osteoporosis at a young age and later years can increase.

Various factors, including aging, family history, impaired calcium absorption, underweight, and insufficient calcium intake, influence the incidence of osteoporosis, but the most important factor is not being

Table 3. Correlation analysis between calcium intake, total calorie intake, bone density, and bodyweight.

		Bodyweight	Bone density status	Calcium intake
Bodyweight	Pearson Correlation	1	0.454**	0.343**
	Sig. (2-tailed)		0	0.001
	N	90	90	90
Bone density status	Pearson Correlation	0.454**	1	0.333**
	Sig. (2-tailed)	0		0.001
	N	90	90	90
Calcium intake	Pearson Correlation	0.343**	0.333**	1
	Sig. (2-tailed)	0.001	0.001	
	N	90	90	90

** Correlation is significant at the 0.01 level (2-tailed).

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

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able to achieve maximum bone density in childhood and adolescence stage (Kim *et al*., 2017). Osteoporosis in adulthood is associated with a lack of osteogenesis and bone density that is built up in the early years of life (Ma and Gordon, 2012). The factors that are associated with bone mineral density include genetic factor, balanced diet, regular physical activity, body mass index, and body weight (Liu *et al*., 2012; Diogenes *et al*., 2013; Duckham *et al*., 2014; Lu *et al*., 2016; Kim *et al*., 2017).

Genetic factors play a significant role in determining bone density and the risk of osteoporosis. Studies have shown that there is a strong genetic component to bone mineral density, with genetic factors accounting for up to 60-80% of the variance in bone density (Guo *et al*., 2010; Estrada *et al*., 2012; Kemp *et al*., 2017). Genetic factors can influence bone density through various mechanisms, including bone turnover, bone remodeling, and calcium metabolism (Karasik *et al*., 2016). Understanding the genetic factors that influence bone density can help identify individuals at higher risk for osteoporosis and develop targeted interventions to improve bone health.

Furthermore, nutrition plays a crucial role in achieving optimal bone density during childhood and adolescence. Adequate intake of essential nutrients, such as calcium, vitamin D, protein, potassium, and phosphorus, is necessary for proper bone formation and maintenance (Weaver *et al*., 2016). Calcium is a critical component of bone mass, and vitamin D helps in the absorption of calcium from the gut. Protein is essential for bone growth and repair, while potassium and phosphorus contribute to bone mineralization. A balanced diet that includes these nutrients in adequate amounts is crucial for building and maintaining strong bones during childhood and adolescence.

Besides, regular physical activity and weight-bearing exercises during childhood and adolescence are crucial for optimal bone development. Physical activity stimulates bone formation and increases bone density through mechanical loading on bones, which helps in strengthening bones (Carter and Hinton, 2014; Safouane *et al*., 2022). Weight-bearing exercises, such as walking, running, jumping, and resistance training, are particularly beneficial for bone health as they increase bone mineral density and improve bone strength. Encouraging regular physical activity in children and adolescents can have long-term benefits for bone health and reduce the risk of osteoporosis in adulthood.

Moreover, body mass index (BMI) and body weight: Body weight and BMI play a significant role in bone health during childhood and adolescence. Adequate body weight and BMI within the normal range are important for achieving optimal bone density. Studies have shown that being underweight or overweight/obese during childhood and adolescence can negatively impact bone health (Goulding *et al*., 2005). Underweight individuals may have lower bone mineral density due to inadequate nutrient intake and hormonal changes, while overweight/obese individuals may have reduced bone density due to excess fat distribution, impaired calcium metabolism, and decreased physical activity. Maintaining a healthy body weight and BMI through a balanced diet and regular physical activity is crucial for optimal bone health during childhood and adolescence.

Last but not least, adequate calcium intake is essential for building and maintaining strong bones during childhood and adolescence. Calcium is a critical component of bone mineralization, and low calcium intake can lead to decreased bone mass and an increased risk of osteoporosis in adulthood (Weaver *et al*., 2016). Studies have shown that adolescents with high BMI or overweight/obese conditions tend to have low calcium levels (Velásquez-Rodríguez *et al*., 2014; Calcaterra *et al*., 2023). Furthermore, excess body weight and fat distribution can inhibit calcium metabolism and vitamin D bioavailability, which can further impact bone health (Pourshahidi, 2015). Ensuring adequate calcium intake through calcium-rich foods, such as milk and dairy products, can significantly contribute to optimal bone density during childhood and adolescence and reduce the risk of osteoporosis in adulthood.

In particular, body weight was the strongest and most positive predictor of exerting physical stress on bones that could trigger osteogenesis and increased bone density (Kim *et al*., 2020). On the other hand, weight loss can lead to bone loss. Weight gain can also increase the secretion of the hormone estrogen by adipose tissue; thus, preventing osteoclast osteolysis (Kim *et al*., 2020). In addition, when it comes to fat mass, bone density in adolescent males decreases significantly as body fat mass increases, but no significant difference was found for females (Park *et al*., 2012).

These results are in line with reports in female children, young women, and young adults who state that body fat is negatively correlated with bone density (Kim *et al*., 2020). Body fat mass, lean mass, and bone density are negatively correlated in adolescent girls with obesity (El Khayat *et al*., 2013). Weight gain due to obesity affects mineral content in bone, secondary hormonal changes, and decreased physical movement so that it can inhibit the formation of minerals in bone (Kim *et al*., 2020).

Body fat and body mass index (BMI) act as protective factors for osteoporosis and fractures (El

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Khayat *et al*., 2013); however, when the BMI reaches more than 30 kg/m^2, it has a negative correlation with bone density (Greco *et al*., 2010). Reflecting on that, one can conclude that proper weight management in adolescence is very beneficial for bone health and density.

The relationship between calcium intake and bone density is a factor that has been widely discussed in academia; higher calcium intake is associated with increased bone density in children as well as higher bone mass, reduced risk of osteoporosis, and lower risk of fractures in adults and the elderly (Ko *et al*., 2012). The relationship is very complex, and some studies emphasize the role of other factors, such as environmental factors. At the same time, apart from gender and age, body mass is an important element influencing the risk of osteoporosis associated with calcium intake (Ko *et al*., 2012).

In adolescents with high BMI or with an overweight/ obese condition, calcium levels tend to be low (Al-Musharaf *et al*., 2012). Moreover, young women with high body mass index and body fat levels tend to have low blood calcium levels (Al-Musharaf *et al*., 2012). This is caused by an excess fat distribution which inhibits calcium metabolism and vitamin D bioavailability (Al-Musharaf *et al*., 2012). In this regard, excess fat, body weight, and low calcium intake are regarded to worsen bone density in adolescents.

The decrease in Body Mass Index in adolescents is closely related to calcium intake >800 mg/day and vitamin D intake; a study reports that levels of vitamin D and calcium affect obesity in an adolescent group. Another study involving a vitamin D plus calcium intervention showed a weight loss effect compared to a placebo (Al-Musharaf *et al*., 2012). Thus, adequate intake of calcium supported by vitamin D has been shown to play an important role in weight loss.

Adequate calcium intake can be achieved through the consumption of calcium sources such as milk. The time required to build adequate bone calcium reserves is relatively short. Calcium is an important component of bone mass and reduces the risk of fractures, especially those caused by osteoporosis (Habibzadeh, 2010). Dairy products contain many important nutrients; milk and dairy products are the main sources of calcium in the diet and provide other important bone-building compounds including vitamin D, protein, potassium and phosphorus (Habibzadeh, 2010).

Calcium deficiency can increase the risk of osteoporosis in adults due to demineralization, which is a state of the body that lacks calcium that will take the calcium deposits in the bones and teeth. During growth, calcium deficiency causes a reduction in the mass and hardness of bones that are being formed (Mulyani, 2009). Therefore, adequate calcium intake during the growth period (children and adolescents) should be properly fulfilled, so that it can reduce the risk of osteoporosis in adulthood and the elderly stage.

5. Conclusion

This study identifies the correlation between calcium intake, bone density, and overweight/obesity status in adolescents. This study could be beneficial for the additional literature as the correlation between overweight and obesity on bone density in adolescence has not been fully understood. Nevertheless, further study is important to be conducted to investigate other contributing factors to overweight/obesity status in adolescents.

This study contributes to the understanding of various factors that influence bone health in adolescents, including body weight, body mass index, body fat, and calcium intake. The findings highlight the critical period of adolescence for achieving maximum bone mass and underscore the importance of promoting optimal bone health during this period to prevent bone-related issues in adulthood. The study also provides valuable insights into the complex relationship between calcium intake and bone health and the role of other factors in influencing this relationship. The findings of this study can guide future research, clinical practice, and public health initiatives aimed at improving bone health in adolescents and reducing the risk of osteoporosis and fractures later in life.

Conflict of interest

The authors declare no conflict of interest.

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