The Effects of Milk Consumption on Blood Calcium Concentration and Bone Density of Adolescents Boys

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Abstract— Milk consumption during adolescence is considered an early means of preventing osteoporosis in adults. Osteoporosis is a systemic skeletal disease characterised by low bone density and microarchitectural deterioration of bone tissues, with a consequent increase in bone fragility and suspectibility to fracture. Augmenting bone mass during adolescence has been suggested as a strategy to prevent osteoporosis, because adolescents may represent the final opportunity for substantially increasing bone mass before skeletal consolidation. The purpose of this study was to determine effects of fresh and high calcium milk on blood calcium concentration and bone density. Variables measured in this study were blood calcium concentration, bone density of spine and bone density of whole body.
The study using 55 adolescent boys that had 17 to 19 years old. The design of this study is nested randomized design with two factors are kind of mil (fresh milk, high calcium milk) and volume of each kind of milk (250 ml, 500 ml, 750 ml). Results of the study indicated that fresh and high calcium milk in this research not significant effects (P>0.05) on blood calcium concentration and bone density of whole body. But, high calcium milk consumption was able to increase bone density. It was found that high calcium consumption showed very highly significant effect (P<0.01) on bone density of spine with 1.79% contributions. Based on general linear model equation, bone density of trunk can be estimated by high calcium milk consumption.

Keywords : milk consumption, adolescence, blood calcium concentration, bone density

I. INTRODUCTION

Consumption of milk during adolescence is intended to strengthen bones so that bones are denser, not brittle and are not susceptible to the risk of osteoporosis in old age. Research related to bone density is mostly focused on women and the elderly, while research on bone density in men, especially adolescent boys, is still lacking.

Adolescence is an important period in human survival. This period is a transition period from childhood to adulthood marked by rapid growth and development both physically and mentally, increasing activity and often accompanied by changes in food consumption patterns. According to WHO [1], adolescents are those aged between 10 to 24 years.

Adolescence is a period of peak activity. At this time, teenagers are usually very busy with various activities. Conditions like this, of course, require high nutritional intake and quality, especially those related to efforts to improve or maintain nutritional status.

In addition, adolescence can be considered as the last period of optimal nutrition improvement, because after this period, nutrition improvement is mostly only useful for maintaining body fitness. During adolescence, bone tissue is formed. Total bone tissue mass in the body is 45% formed during adolescence and peak adult bone density is reached in late adolescence. The period of bone growth is in dire need of calcium, which can mainly be obtained from milk as the main source of calcium [2]. If this cannot be fulfilled, the bones become brittle and will quickly suffer from osteoporosis in old age.

Osteoporosis is a disease characterized by loss of bone mass, which is associated with micro-architectural damage to bone tissue which causes an increased risk of fracture (fracture) [3]. Although the risk of osteoporosis in men is only one third compared to women, the prevalence of vertebral fractures is higher in men. For example, the incidence of vertebral fractures in the UK in men is 12%, while in women it is only 10% [4]. This incident generally starts from a lack of calcium which is needed by the body for bone health.

Milk is the main source of calcium for people in Western countries. For developing countries such as Indonesia, milk is still considered an expensive food ingredient, so it can only be reached by the middle to upper economic class. One of the consequences of this condition, people (especially teenagers) are more likely to choose other types of drinks that are easier and cheaper to obtain when compared to milk.

During adolescence, changes in food and drink consumption patterns often occur. According to [5], there has been a change in drink consumption patterns in American adolescents. It was found that more than half of American teens consume milk

drinks less than once a day, while the recommended amount is three times a day. In Indonesia, the average consumption of milk is only about 0.5 glasses per week per person [6].

The results of a study conducted by [7] with breastfeeding for 12 weeks in adolescent boys, showed that breastfeeding significantly had a positive effect on bone density. In adolescent girls, studied by [8], showed that the provision of milk drinks can also significantly increase bone density. [9], reported that of 57 studies on the effect of milk consumption on bone density, 53% showed no significant effect, 42% showed a positive effect and 5% showed a negative effect.

This study will analyze the effect of the type of milk (fresh milk and high calcium milk) on blood calcium levels and bone density in adolescent boys. From the results of the study, it is hoped that further information about bone density of adolescents boys can be found, especially its relationship with milk consumption.

II. MATERIAL AND METHODS

A. Material

The experimental material in this study was commercial UHT (*Ultra High Temperature*) liquid milk in two types, namely fresh milk and high calcium milk. Each type of milk is given in three groups of portions (volume). The experimental unit in this study was adolescent boys (19-20 years old).

The main nutritional content of treated milk is as shown in the following table.

Table 1. Main nutrient content of treated milk

Nutrient	Nutrient Content / 250 ml	
	Fresh milk	High Ca Milk
Energy (kkal)	150.00	110,00
Protein (g)	7.50	8,30
Ca (mg)	270.00	327,50
P (mg)	216.25	222,50
Vit. D (IU)	106.25	107,50
Vit. C (mg)	9.00	8,56
Fe (mg)	0.50	0,51

B. Research Implementation

Prior to conducting the research, a medical examination and adaptation of the experimental unit were carried out. Medical examination is intended so that the experimental unit used is in good health or does not suffer from a health problem that can interfere with the research. The adaptation of the experimental unit is intended so that during the research, the experimental unit is familiar with milk consumption and is familiar with the pattern of milk feeding that is carried out

Milk feeding

Milking is done every day for 16 weeks (4 months). Each experimental unit obtained the type and portion of milk according to the results of randomization. The milk provided consisted of 2 types, namely fresh milk and high calcium milk in 3 volume levels (for each type of milk), namely 250 ml, 500 ml and 750 ml.

Variable Measurement

- Response variable:

The variables measured were blood calcium levels, lumbar bone density and whole body bone density. Blood calcium levels were measured by the endpoint method and bone density was measured using a bone densitometer (DXA , Prodigy ; Lunar Corp.).

- Confounding variable (confounding factor)

In this study, in addition to measuring the main variable, namely the provision of fresh milk (P) and the provision of high calcium milk (L) as the main factor, measurements were also carried out on the confounding variable (X) which was estimated to affect the value of the response variable. The confounding variables measured were the initial condition of the response variables (initial blood calcium levels and initial bone density), exercise activity and the level of nutrient consumption. Sports activities and levels of nutrient consumption were collected through the 1 X 24 hour recall method.

Experiment Design and Data Analysis

- Experimental Design

The experimental design used was a randomized nested design consisting of 2 factors, namely the type of milk (fresh milk, high calcium milk) and the volume of milk (250 ml, 500 ml, 750 ml). In this design, the volume of milk is nested in the type of milk.

From the combination of factors such as type of milk and milk volume, 6 treatments were obtained, namely:

(1) Giving 250 ml of fresh milk (P1)
(2) Giving 500 ml of fresh milk (P2)
(3) Giving 750 ml of fresh milk (P3)
(4) Giving 250 ml high calcium milk (L1)
(5) Giving 500 ml high calcium milk (L2)
(6) Giving 750 ml high calcium milk (L3)

The number of replications (n) for each treatment group was 8 experimental units. The number of experimental units for 2 types of milk with 3 levels of milk supply was 48 people (8 X 2 X 3) with 7 experimental units without treatment (TP).

Data analysis

To determine the effect of independent variables (P, L. and X) with the dependent variable (Y), and to determine the contribution of treatment and influential confounding variables, the data were analyzed using a linear model approach with the following general equation:

$$Y = \beta_0 + \beta_1 P + \beta_2 P^2 + \beta_3 P^3 + \beta_4 X_1 + \beta_5 X_{12} + \beta_6 X_{13} + ... + \beta_{47} X_{54} + \text{\euro}$$
$$Y = \beta_0 + \beta_1 L + \beta_2 L^2 + \beta_3 L^3 + \beta_4 X_1 + \beta_5 X_{12} + \beta_6 X_{13} + ... + \beta_{47} X_{54} + \text{\euro}$$

Information :
Y = Measured response variable (BMI, spine density)
P = Fresh milk (P)
L = High calcium milk (L)
X = The measured confounding variable (X1, X2, …, X54)
€ = Galat

III. RESULT AND DISCUSSION

Blood Calcium Level
Calcium is needed by the body for normal growth and formation of the skeleton [10]. Results from intervention studies and cross-sectional studies report a positive effect of calcium on bone density in children and adolescents [11].

Table 2. Average blood calcium levels at the beginning and at the end of the study (mg/dl)

Treatment	Pre	Post	Delta
P1	9,26	9,59	0,33
P2	9,52	9,58	0,05
P3	9,64	9,79	0,16
L1	9,18	9,74	0,56
L2	9,39	9,87	0,47
L3	9,84	9,92	0,09
Control	9,75	9,74	-0,01

The average blood calcium levels of each treatment ranged from 9.18 mg/dl to 9.92 mg/dl (Table 2). This concentration is still within the normal range of blood calcium levels. Normal blood calcium levels are in the range of 9.50 mg/dl to 10.4 mg/dl. Calcium deficiency (hypocalcemia) if blood calcium levels are <8.5 mg/dl and excess calcium (hypercalcemia) if levels are >10.5 mg/dl [12].

From the results of the linear model analysis in both the high calcium milk group and the fresh milk group, it did not show a significant relationship (P>0.05) between treated milk and other independent variables on blood calcium levels. These results indicate that in this study there were no factors that had a prominent effect on blood calcium levels in the experimental unit.

Blood calcium levels under normal conditions are always maintained by various factors so that they remain in the amount needed by the body, this is so that the body does not experience calcium deficiency (hypocalcemia) or excess calcium (hypercalcemia). According to [12], serum calcium levels are tightly controlled by various factors including the nutritional intake received by the body and maintained within narrow limits. Control is carried out by various factors which include 1,25-dihydroxychocalciferol, parathyroid hormone, calcitonin, phosphorus, protein and estrogen. Factors that play a role in regulating calcium in the blood include vitamin D and parathyroid hormone. The most important vitamin D is vitamin D3, which is cholecalciferol. Most of this material is formed in the skin as a result of UV radiation from the sun on 7-dehydrocholesterol. Vitamin D3 is then converted to 25-hydroxycholecalciferol through processes in the liver. If the intake of vitamin D3 is excessive, then 25-hydroxycholecalciferol will have an inhibitory effect on the liver. Furthermore, 25-hydroxycholecalciferol through a process in the kidney to form 1,25-dihydroxycholecalciferol which is assisted by activation of parathyroid hormone. 1,25-dihydroxycholecalciferol has the effect of increasing the absorption of calcium from the intestine through the intestinal epithelium which is transferred to the blood plasma. If the concentration of calcium in plasma is excessive, it will cause an inhibitory effect on parathyroid hormone in activating the kidneys in the formation of 1,25-dihydroxycholecalciferol. This process continues so that under normal conditions blood calcium levels will remain stable.

Bone Density
Normal bone density is > 0.833 g/cm2, osteopenia sufferers have a bone density between 0.833 – 0.648 g/cm2 and is called osteoporosis if the bone density is <0.648 g/cm2 [13]. Based on these criteria, there is no bone disease (osteopenia, osteoporosis) in the experimental unit in this study (Table 3 and Table 4).

Lumbar Bone Density
Giving treatment milk can increase the bone density of the lumbar. The increase in lumbar bone density with 750 ml of high calcium milk (L3) was higher than the other treatment groups (Table 3). This is consistent with the results of research that found that giving milk or its processed products can increase the density of the lumbar bone (14;15;16; 17).

Table 3. Lumbar and whole body bone density pre and post of research

Treatment	Lumbar bone density (g/cm²)			Whole body bone density (g/cm²)		
	Pre	Post	Delta	Pre	Post	Delta
P1	0,94	0,95	0,01	0,98	1,00	0,02
P2	0,95	0,97	0,02	0,98	0,99	0,01
P3	1,01	1,02	0,02	1,00	1,01	0,02
L1	0,98	0,99	0,01	1,03	1,03	0,01
L2	0,92	0,93	0,01	1,00	1,01	0,01
L3	0,99	1,02	0,03	1,00	1,02	0,02
Control	0,.93	0,94	0,01	0,96	0,97	0,01

The increase in lumbar bone density from this study was not much different from the results of a study conducted by Volek et al. [7]. Research Volek et al. [7] conducted on teenage boys who were attending sports training for 12 weeks (3 months) who obtained a lumbar bone density of about 0.023 g/cm2 of the milk-fed group.

The results of the linear model analysis showed that there was a very significant positive effect (P<0.01) between consumption of high calcium milk and final bone density with a contribution of 1.79%. Initial lumbar bone density also had a very significant effect (P<0.01) with a contribution of 94.33% (Table 4).

Table 4. Linear model of lumbar bone density with high calcium milk

Variable	Model Coefficient	R^2 Partial	R^2 Model	Probability > F
Intercept	0,03806251			0,5730
X_1	0,96239399	0,9433	0,9433	0,0001**
L^3	0,07398782	0,0179	0,9612	0,0012**

Information :

X_1 = Lumbar bone density pre research
L^3 = High calcium milk
** = Very significant effect (P<0,01)

Linear model equation :

$Y = 0,03806251 + 0,96239399\ X_1 + 0,07398782\ L^3$

The linear relationship between high calcium milk consumption and lumbar bone density can be seen in Figure 1. From the figure, it can be seen that the higher the consumption of high calcium milk, the higher the lumbar bone density.
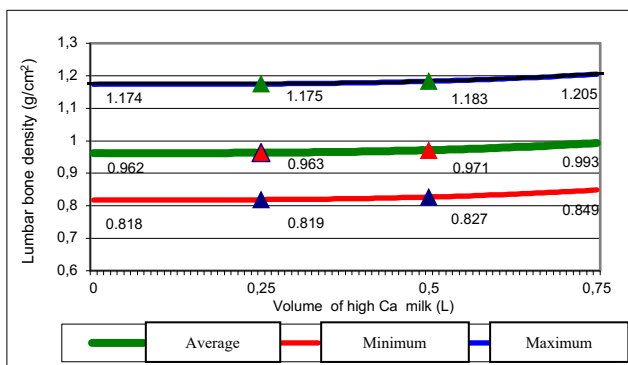

Fig. 1 Relationship of high calcium milk volume linear model with lumbar bone density

Equation of the linear model at the time X average :
$Y = 1,069461645 + 0,10291255\ H^3$
Equation of the linear model at the time X minimum :
$Y = 0,926074377 + 0,10291255\ H^3$
Equation of the linear model at the time X maximum :
$Y = 1,279762972 + 0,10291255\ H^3$

Fresh milk treatment has not shown a significant effect (P> 0.05) on the density of the lumbar bone. The lumbar bone density during the study was more influenced by the initial lumbar bone density (P<0.01) with a contribution of 95.96% (Table 5).

Table 5. Linear model of lumbar bone density with fresh milk

Variable	Model Coefficient	R^2 Partial	R^2 Model	Probability > F
Intercept	-0,00637277			0,8661
X_1	1,01970226	0,9596	0,9596	0,0001**

Information :

X_1 = Lumbar bone density pre research
** = Very significant effect (P<0,01)

Linear model equation :

$Y = -0,00637277 + 1,01970226\ X_1$

Whole Body Bone Density

The increase in whole body bone density in this study was an average of 0.015 g/cm2. This result is lower when compared to the results of research by Volek et al. [7] who obtained a whole body bone density with an average of 0.028 g/cm2. Differences occur partly because of differences in genetics, type of milk and treatment given.

The treatment with high calcium milk (L) did not show a significant effect on whole body bone density (P>0.05). Whole body bone density was significantly influenced by initial whole body bone density (P<0.01) and by phosphorus adequacy level (P<0.05) with contributions of 94.27% and 0.89%, respectively.

Table 6. Linear model of whole body bone density with high calcium milk

Variable	Model Coefficient	R^2 Partial	R^2 Model	Probability > F
Intercept	0,00339987			0,5730
X_2	0,98803994	0,9427	0,9427	0,0001**
X_{23}	0,00010547	0,0089	0,9516	0,0310*

Information :

X_2 = Whole body bone density
X_{23} = Total final phosphorus adequacy level
* = Significant effect (P<0,05)
** = Very significant effect (P<0,01)

Linier model equation :

$Y = 0,00339987 + 0,98803994\ X_2 + 0,00010547\ X_{23}$

As with high calcium milk, fresh milk also did not significantly affect the final whole body bone density (P>0.05). The final whole body bone density was influenced by the initial whole body bone density and the delta level of calcium adequacy not from treatment milk (P < 0.01) with a contribution of 88.81% and 2.99%, respectively.

Table 7. Linear model of whole body bone density with fresh milk

Variable	Model Coefficient	R^2 Partial	R^2 Model	Probability > F
Intercept	0,08303220			0,5730
X_2	0,92536792	0,8881	0,8881	0,0001**
X_{39}	0,00012214	0,0299	0,9180	0,0034**

Information :

X_2 = Whole body bone density pre research
X_{39} = Increased level of non-dairy calcium adequacy
** = Very significant effect (P<0,01)

Linear model equation:

$Y = 0,08303220 + 0,92536792\ X_2 + 0,00012214\ X_{39}$

Associated with bone formation, phosphorus in the form of phospho-peptide acts as a trigger for calcium absorption (Cashman, 2002). Thus, the better the absorption of calcium, the better the contribution of calcium in bone formation.

IV. CONCLUSION

Giving high calcium milk has an effect on increasing lumbar bone density with a contribution of 1.79%. The higher the volume of high calcium milk consumed, thehigher the bone density of the lumbar. Giving fresh milk or high calcium milk has no significant effect on blood calcium levels and bone density throughout the body.

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REFERENCES

[1] C. Wall. Food and Nutrition Guidelines for Healthy Adolescents. Ministry of Health. Wellington, New Zealand. 1998.

[2] V. Matkovic et al. Timing of peak bone mass in Caucasian females and its implication for the prevention of osteoporosis. J Clin Invest. 1994, 93,799–808.

[3] J.W. Nieves. Osteoporosis : the role of micronutrients. Am J Clin Nutr. 2005. 81: 1232S-1239S.

[4] E.M.C. Lau. Osteoporosis in men. JMHG. 2004. Vol. 1 (1) : 68 – 70.

[5] Weaver CM. The growing years and prevention of osteoporosis in later life. Proceed Nutr So. 2000, 59, 303-306.

[6] A. Khomsan. Peranan Pangan dan Gizi untuk Kualitas Hidup. Gramedia Widiasarana Indonesia, Jakarta. 2004.

[7] J.S. Volek et al. Increasing fluid milk favorably affects bone mineral density responses to resistance training in adolescent boys. J Am Diet Assoc. 2003, 103:1353-1356.

[8] J. Cadogan, R. Eastell, N. Jones, M.E.Barker. Milk intake and bone mineral acquisition in adolescent girls : randomized, controlled intervention trial. British Med J ; 1997, 315 : 1255.

[9] R.L. Weinsier, C.L. Krumdieck. Dairy foods and bone health: examination of the evidence. Am J Clin Nutr 2000 Sep;72(3):681-9

[10] B.E. Nordin. Calcium in health and disease. Food Nutr Agri; 1997. 20 : 13-26.

[11] B. Dawson-Hughes. Calcium insufficiency and fracture risk. Osteo Int, 1996, 3 ; S37-S41.

[12] H.E. Sauberlich. Laboaratory Tests for the Assessment of Nutritional Status. Second Ed. CRC Press, Washington.1999.

[13] Anonim. Osteoporosis and Bone Physiology. 2003. http://courses.washington.edu/bonephy/opop/opop.html

[14] C-K Shaw. 1993. An epidemiologic study of osteoporosis in Taiwan. Ann Epidemiol. 1993, 3 : 264 – 271.

[15] R. Prince R et al. The effects of calcium supplementation (milk powder or tablets) and exercise on bone density in postmenopausal wome. J Bone Miner Res; 1995, 10 : 1068 – 1075.

[16] J.W. Davis, R. Novotny, R.D.Ross, Wasnich. Anthropometric, lifestyle and menstrual factors influencing size-adjusted bone mineral content in multietnic population of premenopausal women. J Nutr.1996, 126: 2968–2976.

[17] D. Teegarden D, R.M. Lyle, W.R. Proulx, C.C. Johnston, C.M. Weave. Previous milk consumption in associated with greater bone density in young women. Am J Clin Nutr. 1999, 69 : 1014 – 1017.

[18] K.D. Cashman. Calcium intake, calcium bioavailability and bone health. British J Nutr, 87, Suppl. 2002, S169-S177.

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