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Correlation between Macronutrient Intakes (Carbohydrate, Protein, Lipid) and Bone Mineral Density in the Elderly

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ABSTRACT: Osteoporosis is a systemic disease that occurs in bone and is characterized by reduced bone mass and simultaneous damage to bone structure. Osteoporosis commonly occurs in the elderly because of the hormonal mechanism that plays a huge role in bone density. Micronutrients such as calcium and vitamin D have long been recognized as important in maintaining bone structure. Meanwhile, the effect of macronutrient intake on bone density remains unclear. Only a few studies have analyzed the correlation between macronutrient intakes and bone mineral density (BMD) in the elderly. Moreover, the primary data regarding the correlation has not been found in Indonesia. This study analyzed the correlation between macronutrient intakes (carbohydrate, protein, and lipid) and BMD in the elderly. This research is an observational analytical study with a cross-sectional design. Thirty-eight elderly women who met the inclusion criteria underwent an interview with 3 x 24-hour food recall, SQ-FFQ, and examination of bone density using the DXA method. Bivariate analysis using Pearson and Spearman tests was then carried out. Carbohydrate intakes and BMD have a significant negative correlation (p= 0.008), while the correlations of both lipid and protein intake with BMD are insignificant (p> 0.05). There is a significant correlation between carbohydrate intake and BMD in the elderly. On the other hand, there is no significant correlation between protein and lipid intake with BMD in the elderly.

KEYWORDS: Osteoporosis, macronutrient intake, bone mineral density, elderly

I. INTRODUCTION

Osteoporosis is a systemic bone disease characterized by decreased bone strength due to declining bone mass and bone damage simultaneously. Consequently, the bone becomes more fragile, thus increasing the risk of bone fracture.(1) *The* World Health Organization (WHO) defined osteoporosis as a condition in which bone mineral density (BMD) has a t-score of less than -2.5.(2)

The elderly, according to *Undang-Undang Republik Indonesia Nomor 13 Tahun 1998,* are people who have reached 60 years old and pose one of the risk factors for osteoporosis. This has become a concern since the total of elderly in Indonesia by 2012 reached 7.59%.(3) Furthermore, the Ministry of Health of the Republic of Indonesia had stated that by 2011, the cases of hip fracture in the elderly aged 60-99 years old had reached a total of 7.188.(4) According to the data from the National Health and Nutrition Examination Survey III (NHANES III), it has been reported that approximately 10 million American residents aged 50 years old and above suffer from osteoporosis while the other 33 million have low bone mass.(5)

Elderlies are more likely to suffer from osteoporosis because hormonal mechanisms significantly affect bone density.(6) Aside from age, the etiologies of osteoporosis are multifactorial. A study showed that macronutrient and micronutrient intakes were among the factors that could affect the occurrence of osteoporosis.(7)

Micronutrients such as calcium and vitamin D have long been recognized as important in maintaining bone structure. Around 100 mg of calcium daily is used for bone formation in the first 5-6 years of life and more than 400 mg in adolescence. In adulthood, calcium absorption decreases to 150 mg daily, reducing bone mass. A randomized controlled trial on 29 samples showed that calcium and vitamin D supplementations lowered the risk of bone fracture by 24%.(7,8)

Meanwhile, the effect of macronutrient intake on bone density remains unclear. A study stated that high-protein diet-induced bone damage results from excessive amino acid metabolism. The kidneys, especially in the elderly, cannot neutralize

the excess acid level in the blood; therefore, the calcium from bone is excreted as a buffer.(9) Conversely, a recent study discovered a significant positive correlation between protein intake and bone density, particularly for preventing hip fractures in post-menopause women.(10) A 4-year cohort study also stated that the group with the lowest protein intake had the most vulnerable bones.(11)

A study assessing the correlation between polyunsaturated fatty acid (PUFA) and bone health in post-menopausal women stated that PUFA possessed a considerable advantage over long-chain n-3 PUFA within fish and seafood.(12) Whereas it was proven in another study on men and women aged 24-64 that low-fat consumption had no significant effect on bone health, so did low-carbohydrate consumption.(13) A distinct study also supported the theory by which the level of energy sufficiency was not considered an inhibition factor for osteoporosis.(14)

Only a few studies have analyzed the correlation between macronutrient intakes and bone mineral density (BMD) in the elderly. Moreover, the primary data regarding the correlation has not been found in Indonesia. Some of the studies also showed controversial results. Those matters encouraged this study to be done, aiming to analyze the correlation between macronutrient intakes and BMD in the elderly, particularly in the Semarang region.

II. METHOD

This research was an analytical observational study with a cross-sectional design, in which the correlation between dependent and independent variables was measured momentarily. The targeted population was elders enrolled in the Semarang region's Elders Health Care, particularly Tegalsari, Mahoni, and Dewi Sartika. The inclusion criteria were: (1) Elderly women ≥ 60 years of age; (2) Able to communicate; (3) Willing to be enrolled in the study. The subjects were excluded if they: (1) Had received or are currently receiving long-term corticosteroid therapy; (2) Was a permanent recipient of calcium supplementation; and (3) Suffered from diabetes mellitus (DM). Those who met the eligibility criteria were then provided with informed consent.

Subjects were consecutively sampled, meaning the eligible subjects within the population were enrolled as study participants. Independent variables in this study were carbohydrate, protein, and lipid intakes. The dependent variable was bone mineral density (BMD), measured with DXA in g/cm^2 unit and ratio scale. Carbohydrate intake refers to the percentage of carbohydrate adequate intake (carbohydrate AI) measured with 3 x 24-h food recalls and SQ-FFQ with % unit and ratio scale. This definition also applies to protein and lipid intake.

The retrieved data were processed with univariate analysis to determine the general characteristics of research subjects and bivariate analysis to examine the correlation between each macronutrient intake (carbohydrate, protein, and lipid) and bone mineral density (BMD) in the elderly. The data from both variables were numeric and less than 50 samples; therefore, the Shapiro-Wilk test was conducted to examine the normality. The data were considered normally distributed when a p-value >0.05 was obtained. Pearson's test was performed on normally distributed data, while Spearman's test was performed on non-normally distributed data. Both variables were significantly associated if the obtained p-value < 0.05.

III. RESULTS

A total of 38 subjects were recruited for the study with distribution and descriptive analysis, as shown in Table 1. Most research subjects are 60-65 years old (39.5%). The mean age of the research subjects is 67.42 ±5.9 years old.

Table 1. Subject characteristics based on age

Age (years)	N	Percentage (%)
60-65	15	39.5
66-70	14	36.9
71-75	4	10.5
76-80	4	10.5
81-85	1	2.6
Total	**38**	**100**
Mean 67.42 ± 5.9		

Table 2 shows that most research subjects have normal BMI (18.5-25 kg/m^2) (55.3%). The average BMI of the subjects is 25.21±4.6 kg/m^2. According to Table 3, the BMD Lumbar variable has a mean value of 0.89±0.1 g/cm^2 while the carbohydrate, protein, and lipid intake has a mean value of 60.33±24.4 %, 69.22±29.7 %, and 99.06±47.3 % respectively.

Table 2. Subject characteristics based on Body Mass Index (BMI)

Body Mass Index/BMI (kg/m²)	N	Percentage (%)
< 17	0	0
17 – 18.4	1	2.6
18.5 – 25	21	55.3
25.1 – 27	7	18.4
>27	9	23.6
Total	**38**	**100**
Mean 25.21 ± 4.6		

Table 3. Descriptive analysis results from BMD Lumbar variable, carbohydrate intake, protein intake, and lipid intake

	N	Min value	Max value	Mean± SD
BMD Lumbar (g/cm²)	38	0.63	1.25	0.89± 0.1
Carbohydrate intake (%)	38	23.94	111.83	60.33± 24.4
Protein intake (%)	38	23.52	142.84	69.22± 29.7
Lipid intake (%)	38	22.33	212.40	99.06± 47.3

Table 4. The correlation between age, BMI, protein intake, carbohydrate intake, and lipid intake with BMD Lumbar

	Correlation Coefficient	p-value
Age	-0.317[a]	0.052
BMI	0.465[a]	0.003*
Protein intake	-0.298[a]	0.069
Carbohydrate intake	-0.422[b]	0.008*
Lipid intake	-0.062[b]	0.712

*significant correlation applies if p < 0,05

[a] Spearman correlation test

[b] Pearson correlation test

The correlation between age, BMI, and protein intake with BMD Lumbar was analyzed with the Spearman correlation test as the data were not normally distributed. In contrast, the correlation between carbohydrate and lipid intake with BMD Lumbar was analyzed with the Pearson correlation test.

It can be concluded from Table 4 that the correlation between age, protein intake, and lipid intake with BMD Lumbar is not statistically significant (p-value 0.052, 0.069, and 0.712, respectively). Nevertheless, a strong correlation between BMI and the Lumbar variable (p-value=0.003) is found. Moreover, a statistically significant negative correlation exists between carbohydrate intake and BMD Lumbar (p-value=0.008), meaning that higher carbohydrate intake leads to lower BMD value.

IV. DISCUSSION

Thirty-eight women with an average of 67.42±5.9 years of age were recruited for the study. Based on the results, there is no significant correlation between age and BMD. Nevertheless, the result showed that the average BMD of the subjects (0.89±0,1 g/cm²) was clinically classified as osteoporosis. The correlative coefficient between the two groups is negative, meaning that older ages tend to have lower BMD values. A study by Prihatini et al. (2010) showed that by age 55, the risk of osteoporosis among women multiplied up to five times.(15) This was also supported by the survey conducted by the Indonesia Department of Health, stating that the BMD value dropped to its lowest point at 65-75 years old.(4)

According to existing theory, one factor contributing to bone strength reduction was micro-damage/micro-crack, which increases in value along with age. The rise of osteocalcin in the elderly increases the occurrence of bone turnover. Moreover, elderlies are vulnerable to persistent secondary hyperparathyroidism due to calcium malabsorption in the intestines and diminished calcium reabsorption in the kidneys. These conditions also result in increased bone resorption and loss of bone mass. Decreased secretion of estrogen, GH, and IGF-1, along with physical inactivity, increase the vulnerability of the elderly to suffer from osteoporosis.(16)

The study indicates a significant correlation between BMI and BMD (p=0,003). The positive correlation coefficient means subjects with higher BMI will also have higher BMD values. This result was consistent with a study by Limbong et al. (2014) about the effect of body mass index on osteoporosis. It was stated that women with a BMI<18.5 were 2.99 times at greater risk than those with a BMI≥18.5.(17) Another study by Larijani et al. (2015) in Iran also provided significant evidence regarding the

correlation between BMMI and BMD in women aged 10-75.(18)A theory suggests that a decrease in body mass can also indicate a decrease in bone mass. Body mass is composed of bone mass, muscle mass, and fat mass. The latter is considered a bone mass predictor due to the capability of fat tissue to stimulate bone formation (osteogenesis) by producing estrogen. Therefore, more fat tissue will enhance osteogenesis, subsequently lowering osteoporosis risk.(19)

This study also found that carbohydrate intake and BMD values are significantly correlated. The negative correlation coefficient means lower carbohydrate intake signifies a higher BMD value. This result aligned with Bazzano's study (2016) on women with low-carbohydrate diet intervention for 12 months, increasing BMD maintenance.(20) Another study by Bielohuby et al. (2015) indicated that a low-carbohydrate diet would stimulate the pituitary gland to secrete growth hormone (GH). Higher GH levels will promote osteoblast function, resulting in favorable bone remodeling.(21)A theory suggests that bone quality will decline alongside an increase in glucose levels. This is due to glucose's capability to accumulate fat tissue in the bone marrow and hamper osteoblast function. In its metabolism pathway, glucose molecules are phosphorylated, resulting in glucose-6-phosphate (G6P) molecules, which are later metabolized by the liver as fatty acid, glycogen, and ATP. Glycogen is a readily mobilized storage form of glucose in a limited amount, with only 100 g in the liver and 500 g in the muscle. Excessive carbohydrate consumption will be converted and reserved as fat tissue. Fat tissue possesses pro-inflammation cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which induce osteoclast function and increase bone resorption.(22)The study result, however, was not in line with the initial hypothesis, which predicted a positive correlation between carbohydrate intake and BMD. This was because a study by Coleman et al. (2004) posed as the basis of the hypothesis, compared two groups of intervened subjects, one with a low-carbohydrate and high-protein diet and the other with a high-carbohydrate and low-fat diet. In contrast, this study solely analyzed the correlation between each macronutrient intake and BMD. The SQ-FFQ data showed that the average frequency of carbohydrate consumption among research subjects was 3.48 times a day, yet it covered only 60.33 % of the recommended daily intake. This result indicated that the research subjects did not yet fulfill the recommended daily intake, even if they consumed carbohydrates more than three times daily. Furthermore, subjects with 1.53 times daily carbohydrate consumption had a notable BMD value of 1.18 g/cm². On the other hand, subjects with 6.07 times daily carbohydrate consumption had a lower BMD value, which was 0.809 g/cm².Another finding in this study was the absence of a correlation between protein intake and BMD ($p>0.005$). This was concordant with a study by Marjan et al. (2013) on elderly women aged 57-88 years old, which showed no significant correlation between protein adequacy and osteoporosis.(14) A study on adult women by Fauziah et al. (2015), in which the correlation between protein and bone density was insignificant, also supported this finding.(23) However, this result did not satisfy the initial hypothesis, which predicted the positive correlation between protein intake and BMD. This was because a study by Hanan et al. (2000), which posed as the basis of the hypothesis, was a 4-year cohort study with a total of 616 subjects. There was a striking difference in terms of duration and number of subjects.(11)A theory suggests that low protein intake will subsequently decrease the calcium absorption in the intestine and increase calcium resorption of the bone.(16) Another study stated that a high protein diet-induced bone damage results from excessive amino acid metabolism. The kidneys, especially in the elderly, cannot neutralize the excess acid level in the blood; therefore, the calcium from bone is excreted as a buffer.(9) The effect of protein intake on BMD was highly influenced by calcium level. However, this study did not consider the calcium level, so the mechanism could not be explained thoroughly.The last finding in this study was the insignificant correlation between lipid intake and BMD ($p>0.005$). This result corresponded with another study by Brinkworth et al. (2016) on obese men and women aged 24-64, which provided evidence that low-fat and low-carb diets are not significantly correlated with bone health.(13)

The average lipid adequacy intake among the subjects was 99.06 ± 47.344 %. A theory suggests that high lipid intake will result in bone marrow adipose (BMA) expansion, a form of fat tissue in the bone. Fat tissue possesses pro-inflammation cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which induce osteoclast function and increase bone resorption. Moreover, the adipocytes in fat tissue are lipotoxic to osteoblasts.(22)This finding also dissatisfied the initial hypothesis, which predicted a positive correlation between lipid intake and BMD. This was because a study by Longo et al. (2016) posed the basis of the hypothesis specified on the correlation between the intake of polyunsaturated fatty acid (PUFA) and bone health in post-menopausal women. In contrast, this study employed lipid intake in general.(12) Moreover, the level of pro-inflammation cytokines was ignored in this study; therefore, the lipotoxic effect of high lipid intake on bone could not be examined clearly.

V. CONCLUSIONS

Based on this study, it can be concluded that there was a significant correlation ($p=0.008$) between carbohydrate intake and BMD in the elderly. The correlation coefficient was negative, meaning lower carbohydrate intake signified a higher BMD value. It was also found that there was no significant correlation ($p>0.005$) between protein and lipid intake with BMD in the elderly. For future research, the micronutrient intakes must also be measured to acquire more thorough data on the correlation between

nutrient intake and BMD in the elderly. Furthermore, the recall bias can be minimized by providing daily meal notes before the interview.

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