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The Association between Energy and Protein Density with Obesity among Adults in Tembokrejo Sub-District, Pasuruan City

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Abstract
Introduction: Adult obesity is a major nutritional concern, with national prevalence rates of 21.8% and 22.4% in East Java Province and 19.9% in Pasuruan City, respectively. Consumption of energy- and protein-dense foods, combined with low physical activity and urban lifestyle patterns, were the main contributing factors. This study aimed to examine the association between energy density, protein density, and obesity among adults in the Tembokrejo Sub-District of Pasuruan City.
Methods: This was an analytical observational study with a cross-sectional design involving 192 adult respondents selected through simple random sampling. The researchers and enumerators visited one of the residents' houses where several respondents were located within the same neighborhood unit. Energy and protein density were assessed using the 2 days of 24-h food recall method, whereas obesity was determined based on Body Mass Index (BMI) calculated from measured height and weight. Data analysis was conducted using the chi-square test.
Results: There were 68.2% female respondents in the study. Approximately one-third were aged 19.29 years, 30-50 years and > 50 years, respectively. Individuals consuming high-energy-dense foods were 14 times more likely to develop obesity (p=0.000), whereas those consuming high-protein-dense foods are 2 times more likely to develop obesity (p=0.001).
Conclusion: Energy- and protein-dense food consumption was associated with obesity among adults in the Tembokrejo Sub-District, Pasuruan City. It is recommended that the community regulates the consumption of high-energy and protein-dense foods as a preventive measure against obesity.

Keywords: Dietary Intake, Energy Density, Protein Density, Obesity, Adults

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Introduction

The longest phase of life is adulthood, which lasts from 19 to 55 years. [1] It represents the peak of an individual's life cycle, marked by the end of puberty and increased need for nutrients. [2] If nutrient intake is below the required level, the individual will experience malnutrition, and vice versa. [3]

Common nutritional problems during adulthood include overnutrition, obesity, and non-communicable diseases such as

heart disease, diabetes mellitus, and other related conditions. [4] Data from the 2018 Basic Health Research (Riskesdas) indicate that Indonesia has a prevalence of overnutrition among adults at 13.6% and an obesity prevalence of 21.8%. The prevalence of obesity among adults has met the national target for obesity reduction in Indonesia by 2024, which was set at 21.8%. [5] In East Java Province, the prevalence of overnutrition among adults was 13.7% and the prevalence of obesity was 22.4%. [6] Based on the latest data from the 2023 Indonesian Health Survey (Survei Kesehatan Indonesia or SKI) for East Java Province, the prevalence of adult obesity was 24.4%, whereas that of overweight was 14.8%. [7] Based on the results of a preliminary study conducted by the Pasuruan City Health Office, the prevalence of obesity among adults in Pasuruan City in 2023 is expected to reach 19.9%. The Sekargadung Public Health Center has the highest percentage of adult obesity, with 10.298 people, almost 49.6%) classified as extremely high. [8]

Overnutrition and obesity during adulthood can lead to various negative effects, including an increased risk of diabetes, insulin resistance, and the growth of coronary heart disease-causing atherosclerotic plaques. Obesity also affects an individual's quality of life due to a decline in physical capabilities. [9]

Two types of factors contribute to adult obesity and overnutrition, direct and indirect. The indirect factors included education, nutritional knowledge, dietary patterns, residential area, and economic status. The direct factors include genetics, hormonal influences, medications, physical activity, and dietary intake. [10] Selective behavior in food choice is essential, especially with advancements that facilitate access to energy-dense, nutrient-poor (EDNP) foods, which are associated with overnutrition and obesity. [11]

The 2018 Riskesdas data for Indonesia showed that the most frequently consumed food types by residents over three years of age in East Java were sweet foods (31.3%), salty foods (28.7%), fatty foods (48.5%), and foods with flavor enhancers (79%). This indicates a tendency to consume high-energy foods. [12] Energy density is the quantity of energy per unit weight of food, measured in kcal per gram. [13] Foods rich in energy density are sources of fats, sugars, and carbohydrates, which are frequently popular, affordable, and delicious. Consuming foods with high energy density can contribute excessively to the total calorie intake. [12] Continuous excessive calorie intake can lead to weight gain and increase the risk of overweight or obesity. [11]

Protein density refers to the ratio of daily protein intake per 1.000 kcal of energy consumed. Protein intake density can be used to characterize an individual's protein adequacy, which affects nutritional status. [12] Excess protein intake results in the body storing it as triglycerides. Amino acids undergo deamination when the protein is excessively consumed, and the remaining carbon bonds are converted into acetyl-CoA, which is subsequently used in lipogenesis to produce triglycerides stored in the body. This process leads to increased body fat, which affects nutritional status, including overweight and obesity. [14]

Based on a preliminary study and information from nutrition experts at the Sekargadung Public Health Center, obesity among adults is related to the center’s urban work area, which serves as an economic growth hub with easy access to various facilities. This convenience results in decreased physical activity, causing energy intake to exceed the energy expenditure. According to the 2018 Pasuruan City Central Statistics Agency, the Tembokrejo Sub-District, located within the Sekargadung Public Health Center working area, has the highest population (7,367 residents). Tembokrejo is a residential area where many residents work, leading to a preference for purchasing fast food outside rather than cooking at home because of the limited time. Furthermore, Pasuruan City is a strategic region rich in fisheries resources, resulting in excessive seafood consumption without an adequate physical activity balance.

Based on this background, researchers are interested in conducting a study determining the association between energy and protein density and obesity

among adults in the Tembokrejo sub-district of Pasuruan City.

Methods

This was an analytical observational study with a cross-sectional design in which the dependent and independent variables were measured at the same point in time. In this study, the dependent variable was obesity, whereas energy and protein density were independent variables. In this study, the obesity variable was categorized as follows: the "obese" category included respondents with an obesity nutritional status, while the "non-obese" category included respondents with underweight, normal, or overweight nutritional status. Respondents in the obese category had a body mass index (BMI) of >27 kg/m², whereas those in the non-obese category had a BMI of <27.0 kg/m². For the energy density variable was calculated by dividing total energy intake (kcal) by the weight of food consumed (g) and subsequently classified high category included male respondents with an energy density value >2.1 kcal/g and female respondents with a value >2.0 kcal/g. The "low-to-moderate" category included male respondents with energy density values ranging from <1.7 to 2.1 kcal/g, and female respondents with values from <1.6 to 2.0 kcal/g [11]. The protein density variable was calculated by dividing protein intake by total energy intake and multiplying the result by 1000 kcal, after which it was categorized as high category, including both male and female respondents with a protein density value >40 g/1000 kcal, while the "low-to-moderate" category included both male and female respondents with a protein density value ranging from <20 to 40 g/1000 kcal. [15]

The Sekargadung Public Health Center's operational area served as the study location. The selection of Tembokrejo Sub-District as the research location was based on specific criteria, one of which is data from the Central Bureau of Statistics (BPS) of Pasuruan City in 2018, indicating that Tembokrejo is the most populous sub-district within the working area of the Sekargadung Health Center, with a total population of 7,367 people. Tembokrejo Sub-District is also located in a residential area, and a significant portion of its residents are employed, leading them to prefer purchasing fast food outside the home rather than cooking at home due to time constraints. Additionally, Pasuruan City is a strategic area with abundant fishery resources that leads the community to consume excessive amounts of seafood without being balanced by sufficient physical activity. Based on the interview findings, many residents of Tembokrejo Sub-District do not make optimal use of their leisure time for physical activities such as exercise. Furthermore, their daily occupations are generally associated with light physical activity, including civil servants, private sector employees, and workers in state-owned enterprises (SOEs) and regionally owned enterprises (ROEs). These factors collectively contribute to the high prevalence of obesity in the Tembokrejo sub-district. The study was conducted in February 2025 with adult subjects residing in the Tembokrejo Sub-District.

This study employed a simple random sampling technique with the inclusion criteria of adults aged 19–55 years [1] were able to communicate effectively. The exclusion criteria included respondents with illnesses requiring medical treatment in a hospital, those undergoing a diet program, those residing outside the city, and those who did not complete the study. The study population consisted of adults in the Tembokrejo Sub-District, totaling 3,957 individuals. The number of subjects in this study was calculated using Lemeshow's formula (1993) as follows:

$$n = \frac{(Z_{1-\alpha/2}\sqrt{2\bar{P}(1-\bar{P})} + Z_{1-\beta}\sqrt{P1(1-P1)+P2(1-P2)})^2}{(P1-P2)^2}$$

Description:

n = number of subjects

$Z_{1-\alpha/2}$ = significance level of 95% (1.96)

$Z_{1-\beta}$ = power of 80% (0.84)

P_1 = proportion of high protein density with obese nutritional status (0.21) [15]

P_2 = proportion of low-to-moderate protein density with obese nutritional status (0.40) (Fauzi, 2014)

$\bar{P}$ = average of P1 and P2 ($\frac{P1+p2}{2}$) (0.30) [15]

Consequently, 192 people served as study subjects.

The primary data collected in this study included general respondent information consisting of respondent identity (name, date of birth, age, gender, and address), nutritional status data obtained through body weight measurements using a digital scale with 0.1 kg accuracy and height measurements using a microtoise with 0.1 cm accuracy, and dietary intake data used to calculate energy and protein density, which were obtained through 2x24-hour food recall interviews conducted on both weekdays and weekends. Secondary data in this study were obtained from the prevalence of obesity recorded at the Sekargadung Public Health Center and from data on adults living in the Tembokrejo subdistrict. SPSS version 24.0 for Windows was used to conduct univariate and bivariate data analyses. The chi-square test was used for bivariate analysis, and a significance threshold of 0.05 was applied. There was a significant correlation between the independent and dependent variables when the p-value was less than 0.05. There was no significant correlation between the independent and dependent variables when the p-value ≥0.05.

Results

Tables 1-3 present the demographic characteristics and dietary patterns of respondents in terms of energy and protein intake. The majority of respondents were female and aged between 19 and 50. Most participants were classified as non-obese and tended to consume foods with low to moderate energy and protein densities.

The primary focus of this study was on the results shown in Table 4, which show a strong correlation between the incidence of obesity and energy and protein density. Respondents who consumed high-energy dense foods were 14 times more likely to be obese than those who consumed foods with low to moderate energy densities (p = 0.000). Furthermore, those who consumed high-protein dense foods were 2 times more likely to be obese as those who consumed foods with low to moderate protein density (p = 0.001). According to this study, adult residents of the Tembokrejo Sub-District are at a heightened risk of obesity due in large part to the quality of their food, especially with regard to calorie and protein content.

Table 1. Frequency Distribution of Respondents Demographic Characteristics

Variable	Frequency (n)	Percentage (%)
Gender		
Man	61	31.8
Woman	131	68.2
TOTAL	**192**	**100**
Respondents Age		
19-29 Years	66	34.38
30-50 Years	66	34.38
>50 Years	60	31.3
TOTAL	**192**	**100**

Table 2. Frequency Distribution of Respondents Based on Obesity Status

Variable	Frequency (n)	Percentage (%)
Obese		
Obese	56	29.2
Non-Obese	136	70.8
TOTAL	**192**	**100**

Table 3. Frequency Distribution of Respondents Based on Energy Density and Protein Density

Variable	Frequency (n)	Percentage (%)
Energy Density		
High	52	27.1
Low-Moderate	140	72.9
TOTAL	**192**	**100**
Protein Density		
High	34	17.7
Low-Adequate	158	82.3
TOTAL	**192**	**100**

Table 4. The Association Between Energy Density and Obesity

Variable	Obese		Non-Obese		Total		Prevalence Ratio	P Value
	n	%	n	%	n	%	(95% CI)	
Energy Density								
High	47	90.4	5	9.6	52	100	14.06	0.000
Low-Moderate	9	6.4	131	93.6	140	100	(7.43 – 26.62)	
Protein Density								
High	18	52.9	16	47.1	34	100	2.201	0.001
Low-Adequate	38	24.1	120	75.9	158	100	(1.445 – 3.353)	

Discussion

Characteristics of Dietary Patterns According to Respondents Demographic Profiles

Based on the analysis of the 2 × 24-h food recall data, male respondents tended to prefer foods high in fat, carbohydrates, protein, and sugar (such as sweet tea and sweetened coffee), whereas female respondents were more likely to prefer vegetables, fruits, high-fat foods, and consume sweet tea and coffee. Respondents aged 19–29 years commonly consumed foods with high energy density, such as meatballs, spicy street food (seblak), snacks, fried foods, and packaged beverages, more frequently than those aged 30–50 years and over 50 years. Respondents aged 30–50 years occasionally consumed high-energy dense foods such as fried snacks, wafers, crackers, meatballs, and fried peanuts. However, some respondents in this age group preferred to consume fruit, vegetables, and steamed foods such as bananas. Most respondents aged over 50 years frequently consumed fruits and steamed foods such as steamed bananas, cassava, sweet potatoes, and similar items. This age group tended to be more mindful of their dietary intake, as some were affected by degenerative diseases such as hypertension, diabetes mellitus, and coronary heart disease.

Characteristics of Respondents with Obesity

The majority of respondents who were classified as obese were female. This may be attributed to the influence of metabolism on differences in obesity prevalence between men and women. Hormonal factors contribute to a lower metabolic rate in women than that in men. In addition, the

metabolism in women declines significantly after menopause. [16] Obesity is a condition in which the amount of body fat exceeds the normal level relative to total body weight. It can be identified by an increase in the Body Mass Index (BMI) above the normal threshold. Obesity results from an imbalance between the energy obtained from dietary intake and energy expended by the body. [17] This imbalance is characterized by the accumulation of fat in adipose tissue. [18]

The prevalence of obesity in the Tembokrejo Sub-District has not yet met Indonesia's national obesity reduction target of 21.8%. The prevalence of obesity among adults in Tembokrejo was higher than that in the East Java Province and Pasuruan City. In East Java Province, the adult obesity prevalence was 21.8%, whereas in Pasuruan City, it was 19.9%. This high prevalence is largely due to the continued consumption of foods that are high in energy and fat.

Characteristics of Respondents Based on Energy Density

Energy density is the amount of energy concentrated in food consumed by a person. The macronutrient composition and water content of food determine its energy density, with foods with higher fat content tending to have greater energy density than those with high water content. [19] Energy density is the quantity of energy per unit weight of food, measured in kilocalories per gram. [13] It is a component of the Healthy Eating Index and serves as a measure of dietary quality. Energy density can be classified into two types: consumption and food energy density. High energy density can lead to overeating, thereby increasing the prevalence of obesity. Consuming foods with high energy density, characterized by high fat and sugar content and low fiber content, contributes significantly to increased total calorie intake. In contrast, eating low-energy-density meals can lower the overall energy consumption. [20] Based on the 2×24-hour food recall results, respondents with high energy density intake were those who frequently consumed foods with low weight but high energy content, such as chips, rice crackers, crackers, wafers, biscuits, sausages, cakes, fritters, and fried foods. Respondents with low to moderate energy density intake were those who consumed heavier foods with high energy and carbohydrate content, such as rice, potatoes, rice cakes, bananas, cassava, porridge, and similar items. Foods with high water content, including fruits and vegetables, are also classified as low-to moderate-energy-density foods, in addition to heavier meals that are high in calories and carbohydrates.

Characteristics of Respondents Based on Protein Density

Protein density is defined as the concentration of proteins in food. Protein density refers to the amount of protein per 1,000 kilocalories of energy. [21] Foods containing proteins not only consist of amino acids as their building blocks, but also have a high micronutrient-to-energy ratio and are nutrient-dense. [22] Protein intake density can be used to assess an individual's protein adequacy. In addition to protein adequacy, protein intake density can be used to characterize an individual's dietary consumption patterns. [12] Based on the 2×24-hour food recall results, respondents with high protein density frequently consumed protein-rich foods such as all types of meat (beef, goat, pork, skinless chicken, and lamb), chicken liver, eggs, seafood (frigate tuna, crab, squid, shrimp, lobster, and shellfish), and soybean-based products such as tofu, tempeh, oncom, and mendol tempeh. Respondents with low to moderate protein density were those who consumed green vegetables (spinach, broccoli, water spinach, cassava leaves, etc.), fruits, potatoes, young jackfruit, mung beans, cow's milk, goat's milk, small amounts of meat, tofu, tempeh, and eggs.

The Association between Energy Density and Obesity

The chi-square test results showed a p-value of 0.000, indicating a significant association between energy density and obesity among adults in the Tembokrejo sub-district. Individuals who consumed high energy density foods were 14 times more likely to be obese than those who

consumed low to moderate energy density foods.

The findings of this study indicate that obese respondents tend to consume foods and beverages such as snacks, chips, rice crackers, fried snacks, sweetened coffee, sweetened tea, ice cream, sweet chocolate drinks, biscuits, wafers, and similar items. These foods and beverages are characterized by high energy densities. On average, obese respondents consumed more than 50 grams of such snacks per day, with a frequency of two to three times daily. In contrast, non-obese respondents tended to consume low to moderate energy density foods such as fruits, vegetables, steamed sweet potatoes, steamed bananas, fruit salads, boiled cassava, bread, and similar items. Non-obese respondents occasionally consumed high energy density foods, but in smaller quantities (less than 50 g), with a frequency of less than twice per day.

Energy is essential for sustaining life, promoting growth and development, and supporting physical activity. [23] Energy density is the quantity of energy in each unit weight of ingested food. Obesity results from an imbalance in calorie intake, in which the number of calories consumed exceeds the number of calories expended for energy. Over time, excess calories are stored as body fat (BF). Obesity, which begins during adolescence, often persists into adulthood and into old age. Weight gain can be caused by the consumption of high-energy foods. [24] Excessive energy intake is stored in the adipose tissue as fat, and obesity may occur when this tissue is enlarged. Insufficient intake of high-fiber foods such as fruits and vegetables, both in terms of quantity and quality, is associated with an increased risk of overnutrition and obesity. [25] The finding in our study is in line with that of Vernarelli et al., which demonstrated an association between energy density and children's body weight, showing that high-energy-density food consumption was linked to increased rates of overweight and obesity in children.[26]

The Association between Protein Density and Obesity

The chi-square test results showed a p-value of 0.001, indicating a significant association between protein density and obesity among adults in the Tembokrejo sub-district. Individuals who consumed foods with high protein density were twice as likely to be obese as those who consumed foods with low to adequate protein density.

According to the study findings, people who eat meals high in protein are more likely to be fat. Respondents with obesity were more likely to consume foods such as various types of meat (beef, goat, chicken, and duck), eggs, shrimp, crab, shellfish, mackerel, squid, and soybean-based products, such as tofu, tempe, and mendol tempe. These foods are classified as having high protein density. [27] Conversely, non-obese respondents consumed green vegetables (spinach, broccoli, water spinach, cassava leaves, etc.), fruits, potatoes, young jackfruits, mung beans, cow milk, goat milk, and smaller quantities of meat, tofu, tempe, and eggs. These foods are considered to have a low to adequate protein density. [28]

Protein density is defined as the concentration of proteins in the food. Proteins are sequences of amino acids linked by peptide bonds that serve as the primary structural components of all cells and play an essential role in maintaining bodily functions. Proteins contribute to the formation of blood cells, hormones, enzymes, and antibodies that protect the body from infections and diseases. [29] Consuming food in quantities exceeding the body's needs is one of the factors contributing to obesity. Protein is a macronutrient that is associated with the risk of obesity. Generally, 60–80% of the protein comes from plants and 20–40% comes from animals. Excessive protein consumption results in the inability of the body to store large amounts of protein; consequently, surplus protein is converted into triglycerides, which increase fat tissue and may lead to overweight or obesity. [28] High-protein foods often contain high levels of fat, which can contribute to obesity. [30] Excessive protein intake leads to the deamination of amino acids. Once nitrogen is excreted, the remaining carbon skeleton is converted into acetyl-CoA, which can be

stored in the body and transformed into triglycerides via lipogenesis. This process increases the fat tissue in the body, potentially resulting in obesity. [28]

This study is consistent with the findings of Ahmad Fauzi (2014), who reported a significant association between protein density and the nutritional status of elementary school students. [14] A higher protein intake density reflects greater consumption of protein-rich foods. Their study demonstrated that both energy and protein intake could influence children's nutritional status.

Limitations of the Study

This study has several limitations that should be considered when interpreting the results. First, the cross-sectional design used in this study established a causal relationship between energy density, protein density, and obesity. Second, dietary intake was assessed using the 2 × 24-h food recall method, which relies on the respondents' memory and may introduce recall bias, potentially failing to fully capture long-term dietary habits. Third, other variables that may influence obesity, such as physical activity level, genetic factors, and intake of other macronutrients (fat and carbohydrates), were not analyzed in detail in this study. Fourth, the study location was limited to a single sub-district within the working area of the Sekargadung Public Health Center; therefore, the findings may not be generalizable to a broader population.

Conclusion

A significant association was observed between energy density and obesity. Individuals who consume foods with high energy density are 14 times more likely to become obese than those who consume foods with low to moderate energy densities. Additionally, there was a significant association between protein density and obesity. Individuals who consume foods with a high protein density are 2 times more likely to become obese as those who consume foods with a low adequate protein density.

It is recommended that the public regulate the intake of foods with high energy and protein densities to prevent obesity. Future studies should include other macronutrient density variables, such as fat and carbohydrate density, which are suspected to be associated with obesity. Future studies should conduct more comprehensive data analyses. It is also recommended that health institutions use these findings as a basis for programs aimed at reducing the prevalence of overnutrition and obesity, through nutrition education campaigns for the public about foods and beverages that are high in energy and protein density, so that individuals can better manage their consumption of such foods.

Ethics approval

This study was approved by the Health Research Ethics Committee of the State Polytechnic of Jember, and was declared to have passed the ethical review (No.16101/PL17.4/PG/2024).

Availability of data and materials

The corresponding author can provide the dataset generated or analyzed during this study; however, the dataset is not publicly available because of a privacy protection agreement between the author and the respondents.

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Author Contribution

LCA analyzed and interpreted all respondent data. MJ, DIA, and ADE were the main contributors to drafting the manuscript and reviewing all analyzed and interpreted data. The final manuscript has been reviewed and approved by all authors.

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