Research Article

Association Between Macronutrient and Dietary Fiber Intake and Fat Mass Index Among Adults with Obesity

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Abstract

Obesity has become a global public health challenge and is recognized as a complex chronic disease associated with numerous non-communicable diseases. Dietary factors, including macronutrient composition and dietary fiber intake, are considered important determinants of adiposity. However, evidence regarding their association with Fat Mass Index (FMI) in adults with obesity remains limited. This study aimed to determine the association between macronutrient intake, including energy, carbohydrate, protein, and fat intake, as well as dietary fiber intake, and Fat Mass Index among adults with obesity. A cross-sectional study was conducted between February and May 2026 among 100 adults with obesity. Dietary intake was assessed using non-consecutive 2-day dietary recalls. Body composition was measured using bioelectrical impedance analysis (BIA), and FMI was calculated as fat mass (kg) divided by height squared (m²). Spearman correlation analysis was used to evaluate unadjusted associations, while multiple linear regression analysis adjusted for age, sex, physical activity, and total energy intake was performed to examine independent associations with FMI. In unadjusted analyses, energy, carbohydrate, protein, fat, and dietary fiber intake were not significantly associated with BMI or FMI (all p > 0.05). However, after adjustment for age, sex, physical activity, and total energy intake, protein intake was positively associated with FMI (B = 0.053; 95% CI: 0.009–0.098; p = 0.020). Carbohydrate, fat, and dietary fiber intake were not significantly associated with FMI. Sex remained a significant predictor of FMI in all regression models (p < 0.001). Macronutrient and dietary fiber intake were not associated with BMI or FMI in the unadjusted analysis. After controlling for potential confounders, protein intake showed a positive association with FMI. These findings suggest that adiposity in adults with obesity is influenced by multiple factors beyond short-term nutrient intake.
Keyword: *macronutrient intake, fiber intake, fat mass index, obese adult.*

Hubungan Asupan Makronutrien dan Serat dengan *Fat Mass Index* pada Dewasa dengan Obesitas

Abstrak

Obesitas merupakan salah satu masalah kesehatan masyarakat global yang terus meningkat dan kini diakui sebagai penyakit kronis kompleks yang berhubungan dengan berbagai penyakit tidak menular. Faktor pola makan, termasuk komposisi makronutrien dan asupan serat, diduga berperan terhadap tingkat adipositas. Namun, bukti mengenai hubungan keduanya dengan Fat Mass Index (FMI) pada dewasa obesitas masih terbatas.Penelitian ini bertujuan menganalisis hubungan asupan makronutrien yang meliputi energi, karbohidrat, protein, dan lemak serta asupan serat dengan FMI. Penelitian observasional analitik dengan desain potong lintang dilakukan pada Februari-Mei 2026 terhadap 100 dewasa obesitas. Data asupan makanan diperoleh menggunakan metode non-consecutive 2-day dietary recall. Komposisi tubuh diukur menggunakan Bioelectrical Impedance Analysis (BIA), dan FMI dihitung sebagai massa lemak (kg) dibagi tinggi badan kuadrat (m²). Analisis bivariat dilakukan menggunakan uji korelasi Spearman, sedangkan analisis multivariat menggunakan regresi linear berganda dengan penyesuaian terhadap usia, jenis kelamin, aktivitas fisik, dan asupan energi total. Analisis bivariat menunjukkan tidak terdapat hubungan yang signifikan antara asupan energi, karbohidrat, protein, lemak, maupun serat dengan BMI dan FMI (seluruh p > 0,05). Namun, setelah dilakukan penyesuaian terhadap usia, jenis kelamin, aktivitas fisik, dan asupan energi total, asupan protein berhubungan positif dengan FMI (B = 0,053; IK95%: 0,009-0,098; p = 0,020). Asupan karbohidrat, lemak, dan serat tidak berhubungan signifikan dengan FMI. Jenis kelamin merupakan prediktor independen yang signifikan pada seluruh model regresi (p < 0,001). Asupan makronutrien dan serat tidak berhubungan dengan BMI maupun FMI pada analisis bivariat. Setelah mengendalikan faktor perancu, asupan protein menunjukkan hubungan positif dengan FMI. Hasil penelitian ini menunjukkan bahwa adipositas pada dewasa obesitas dipengaruhi oleh berbagai faktor selain asupan zat gizi jangka pendek.
Kata kunci: *asupan makronutrien, asupan serat, fat mass index; dewasa obesitas.*

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Introduction

Obesity has become a global epidemic, with the fastest increase occurring in low- and middle-income countries.[1,2] Beyond aesthetic concerns, obesity is now recognized as a complex chronic disease and a major driver of non-communicable diseases (NCDs), including type 2 diabetes, ischemic heart disease, chronic kidney disease, and various malignancies. The health burden attributable to obesity has nearly tripled since 1990.[3] According to the World Health Organization (WHO), nearly 43% of the world's adult population is currently classified as overweight, while almost one billion individuals are living with obesity.[1] In Indonesia, the world's fourth most populous country, the prevalence of obesity increased to 23.4% in 2023.[4] At the same time, mortality attributable to obesity and other major NCD risk factors has continued to rise over recent decades. Cardiovascular diseases (CVDs), for example, are estimated to account for more than 30% of all deaths,[5,6] placing Indonesia among the countries with the highest burden of CVD-related mortality. The increasing prevalence of obesity reflects a broader decline in diet quality. This nutritional imbalance is characterized by excessive consumption of energy-dense macronutrients accompanied by inadequate dietary fiber intake.[7]

Epidemiological evidence shows that contemporary urban diets are increasingly dominated by ultra-processed foods, which are generally high in fat, simple sugars, and energy.[8] Chronic overconsumption of macronutrients may exceed daily metabolic requirements and promote a long-term positive energy balance.[9] Low dietary fiber intake is also a major concern, despite evidence that dietary fiber may help reduce obesity risk by increasing stool volume, delaying gastric emptying, prolonging satiety, and reducing total energy absorption from foods.[10] Nevertheless, average dietary fiber intake among adults remains substantially below recommended levels.[11] This dietary imbalance may alter metabolic profiles and contribute to increases in Body Mass Index (BMI) and Fat Mass Index (FMI) in adult populations.[12] However, BMI has important diagnostic limitations because it cannot distinguish between skeletal muscle mass and adipose tissue.[13] Individuals may have similar BMI values while exhibiting markedly different body compositions and metabolic profiles.[14] Therefore, Fat Mass Index (FMI) has been proposed as a more specific measure of adiposity because it assesses fat mass relative to height and may provide a more accurate evaluation of body fat accumulation and its relationship with dietary factors in adults with obesity.[13]

Previous studies have extensively investigated the association between macronutrient intake and BMI, while others have evaluated the relationship between dietary intake and body fat percentage. However, studies examining the association between macronutrient and dietary fiber intake and FMI, particularly among adults with obesity in Indonesia, remain limited. Furthermore, evidence regarding whether dietary intake is associated with FMI independently of demographic and lifestyle factors is still inconclusive. Therefore, this study aimed to analyze the association between energy, carbohydrate, protein, fat, and dietary fiber intake and FMI among adults with obesity. In addition, BMI was included as a complementary anthropometric indicator to facilitate comparison with previous studies.

Methods

This study employed an analytical observational study with a cross-sectional design. In a cross-sectional study, the independent and dependent variables are measured simultaneously, making this design appropriate for assessing relationships between variables within a specific population. The study was conducted in the working areas of three ministry offices in Jakarta, Indonesia. Data collection was carried out between February and May 2026.

The target population consisted of adults with obesity residing in Jakarta. Eligible participants were men or women aged 18–59 years with a body mass index (BMI) ≥25 kg/m², based on the Asia-Pacific obesity criteria.[15] Participants were not undergoing any specific dietary intervention.

Female participants were not pregnant or breastfeeding and were premenopausal. A non-probability sampling technique with consecutive sampling was used. Participants were recruited sequentially from the accessible population throughout the data collection period until the required sample size was achieved. All eligible participants received information regarding the study and provided written informed consent prior to participation.

The sample size was calculated using the Lemeshow formula for correlation studies,[16] assuming a 95% confidence level ($Z\alpha/2 = 1.96$), 80% statistical power ($Z\beta = 0.842$), and an anticipated correlation coefficient of $r = 0.30$. Based on Cohen's interpretation, an r value of 0.30 represents a moderate correlation. The minimum required sample size was 85 participants. After accounting for a potential 10% incomplete-response rate, the final minimum sample size was determined to be 95 participants.

The variables analyzed included sociodemographic characteristics (age, sex, education, and occupation), dietary intake, physical activity level, anthropometric measurements, and body composition indicators, including BMI and Fat Mass Index (FMI). Sociodemographic information and physical activity data were collected through direct interviews using the International Physical Activity Questionnaire (IPAQ) short form.[17] Body weight, height, and body composition were measured in the morning after participants had fasted or refrained from eating for at least two hours and while wearing light clothing. To minimize variability related to hydration status, participants were instructed to avoid strenuous physical activity and to empty their bladder before measurement. All measurements were performed twice at a 5-minute interval using a Tanita BC-545N Bioelectrical Impedance Analysis (BIA) device, and the average value was used for analysis.

Dietary intake was assessed using a non-consecutive 2-day dietary recall to reduce day-to-day dietary variation and provide a more reliable estimate of average nutrient intake than a single-day recall. This method is widely used in nutritional epidemiology because it allows detailed assessment of food and beverage consumption, facilitates nutrient quantification, and remains feasible for field-based research while minimizing participant burden.[18] Dietary data were analyzed using NutriSurvey 2007 software and the Indonesian Food Composition Table (TKPI).[19] Fat Mass Index (FMI) was calculated as fat mass (kg), derived from body fat percentage measured by BIA, divided by height squared (m^2).[13]

Data analysis consisted of univariate, bivariate, and multivariable analyses. Univariate analysis was performed to describe participant characteristics, dietary intake, physical activity level, BMI, and FMI. Bivariate analysis was conducted using Spearman's correlation test to assess the relationship between nutrient intake variables and BMI and FMI. Differences in BMI and FMI according to sex were analyzed using the Mann-Whitney U test, while differences across physical activity categories were evaluated using the Kruskal-Wallis test. Multiple linear regression analysis was performed to examine the independent association between macronutrient intake and FMI after adjustment for age, sex, physical activity level, and total energy intake. Statistical significance was established at $p < 0.05$.

Result

Subject Characteristics

A total of 100 adults with obesity participated in this study. The mean age of the participants was 35.50 ± 6.66 years. Based on sex, the majority of participants were women (83%), while 17% were men. Anthropometric characteristics showed that the participants had a median body weight of 74.95 kg (57.60–133.10 kg) and a median height of 158.15 cm (143.80–179.70 cm). The median body mass index (BMI) was 29.99 kg/m² (25.30–52.65 kg/m²), indicating that all participants met the obesity criterion of BMI ≥25 kg/m². The median body fat percentage was 42.70% (23.10–64.90%), while the median fat mass was 31.65 kg (15.25–86.38 kg). Furthermore, the median fat mass index (FMI) was 12.51 kg/m² (5.85–34.17 kg/m²), and the median visceral fat level was 9.5 (6.0–20.0).

Based on physical activity level, the largest proportion of participants were classified as having moderate physical activity (48%). Twenty-five participants (25%) had low physical activity, whereas 27 participants (27%) had high physical activity. Nutritional intake characteristics showed that the median energy intake was 1,562.35 kcal/day (1,090.85–3,145.00 kcal/day). The median carbohydrate intake was 182.50 g/day (79.00–381.10 g/day), with an average contribution of 47.15 ± 7.93% of total energy intake. The median protein intake was 64.38 g/day (29.20–145.90 g/day), with a median contribution of 15.95% of total energy intake (8.78–36.74%). The median fat intake was 62.78 g/day (32.65–148.50 g/day), while the average contribution of fat to total energy intake was 36.67 ± 7.07%. The median dietary fiber intake was 9.3 g/day (1.60–18.30 g/day). Participant characteristics are presented in Table 1.

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Table 1. Characteristics of Study Participants (n = 100)

Characteristic	n
Age, years*	35.50 ± 6.66
Sex**	
Men	17 (17.0)
Women	83 (83.0)
Body weight, kg	74.95 (57.60–133.10)
Body height, cm	158.15 (143.80–179.70)
Body mass index, kg/m^2	29.99 (25.30–52.65)
Body fat percentage, %	42.70 (23.10–64.90)
Fat mass, kg	31.65 (15.25–86.38)
Fat mass index, kg/m^2	12.51 (5.85–34.17)
Visceral fat level	9.5 (6.0–20.0)
Physical activity level**	
Low	25 (25.0)
Moderate	48 (48.0)
High	27 (27.0)
Energy intake, kcal/day	1562.35 (1090.85–3145.00)
Carbohydrate intake, g/day	182.50 (79.00–381.10)
Carbohydrate intake, % of energy*	47.15±7.93
Protein intake, g/day	64.38 (29.20–145.90)
Protein intake, % of energy	15.95 (8.78–36.74)
Fat intake, g/day	62.78 (32.65–148.50)
Fat intake, % of energy*	36.67±7.07
Dietary fiber intake, g/day	9.3 (1.60–18.30)

* Data are presented as mean ± SD for normally distributed variables and median (min–max) for non-normally distributed variables.
** Data are presented as n (%)

Associatuon between Macronutrient and Dietary Fiber Intake with BMI and FMI

Based on the correlation analysis presented in Table 2, no significant associations were observed between macronutrient or dietary fiber intake and BMI or FMI among adults with obesity. For BMI, all intake variables showed p-values >0.05. Energy intake showed a very weak and non-significant correlation with BMI (r = 0.016; p = 0.877). Similarly, carbohydrate intake, protein intake, fat intake, and dietary fiber intake, whether expressed as absolute intake or percentage of total energy intake, were not significantly associated with BMI.

Similar findings were observed for FMI. No significant associations were found between energy, macronutrient, or dietary fiber intake and FMI. All correlation coefficients were very weak, and all p-values exceeded 0.05, indicating the absence of significant associations between the dietary intake variables examined and FMI.

Association of Sex and Physical Activity with BMI and FMI

Based on the analysis presented in Table 3, BMI and FMI differed significantly between men and women. The median BMI was 28.76 kg/m² (25.30–35.69 kg/m²) in men and 30.54 kg/m²

(25.91–52.65 kg/m²) in women, with a significant difference observed between groups (p = 0.047). A more pronounced difference was observed for FMI. The median FMI was 7.99 kg/m² (5.85–11.81 kg/m²) in men and 13.54 kg/m² (9.76–34.17 kg/m²) in women (p < 0.001). Overall, women had higher BMI and FMI than men, with the difference being particularly marked for FMI.

Table 2. Correlation between Macronutrient and Dietary Fiber Intake and BMI and FMI

Dietary Intake Variable	BMI (n=100)		FMI (n=100)	
	r	p[a]	r	p[a]
Energy intake, kcal/day	0.016	0.877	-0.068	0.502
Carbohydrate intake, g/day	0.064	0.528	-0.013	0.900
Carbohydrate intake, % of energy	-0.003	0.976	-0.022	0.828
Protein intake, g/day	0.066	0.516	-0.048	0.633
Protein intake, % of energy	-0.004	0.969	-0.088	0.383
Fat intake, g/day	0.005	0.957	-0.030	0.765
Fat intake, % of energy	0.005	0.455	-0.019	0.854
Dietary fiber intake, g/day	-0.037	0.712	-0.031	0.758

[a]Spearman's rank correlation test was used because BMI and FMI were not normally distributed

Table 3. Association of Sex with BMI and FMI

Body Composition Indicator	Sex		p[b]
	Men (n=17)	Women (n=83)	
BMI, kg/m^2	28.76 (25.30–35.69)	30.54 (25.91–52.65)	0.047
FMI, kg/m^2	7.99 (5.85–11.81)	13.54 (9.76–34.17)	< 0.001

[b]Mann-Whitney U test

Based on the analysis presented in Table 4, the median BMI was 31.25 kg/m² (25.45–40.90 kg/m²) among participants with low physical activity, 30.29 kg/m² (25.91–52.65 kg/m²) among those with moderate physical activity, and 29.76 kg/m² (25.30–46.90 kg/m²) among those with high physical activity. Although a trend toward lower BMI was observed with increasing physical activity level, the difference was not statistically significant (p = 0.492).

Similar findings were observed for FMI. The median FMI was 12.41 kg/m² (6.85–22.41 kg/m²), 12.62 kg/m² (6.22–34.17 kg/m²), and 12.47 kg/m² (5.85–27.95 kg/m²) in the low, moderate, and high physical activity groups, respectively. No significant differences in FMI were observed across physical activity categories (p = 0.978).

Table 4. Association Between Physical Activity Level and BMI and FMI

Body Composition Indicator	Physical Activity Level			p[c]
	Low (n = 25)	Moderate (n = 48)	High (n = 27)	
BMI, kg/m^2	31.25 (25.45–40.90)	30.29 (25.91–52.65)	29.76 (25.30–46.90)	0.492
FMI, kg/m^2	12.41 (6.85–22.41)	12.62 (6.22–34.17)	12.47 (5.85–27.95)	0.978

[c]Kruskal-Wallis test

Multiple linear regression analysis adjusted for total energy intake, age, sex, and physical activity showed that protein intake was significantly associated with FMI (B = 0.053, 95% CI: 0.009–0.098, p = 0.020). In contrast, carbohydrate, fat, and dietary fiber intake were not significantly associated with FMI. Sex remained a significant predictor in all models (p < 0.001), whereas total energy intake, age, and physical activity were not significantly associated with FMI. The adjusted R^2 values ranged from 0.263 to 0.305 (Table 5).

Table 5. Multivariable Linear Regression Analysis of Factors Associated with Fat Mass Index

Predictor	Model 1		Model 2		Model 3		Model 4	
	B (95% CI)	p	B (95% CI)	p	B (95% CI)	p	B (95% CI)	p
Carbohydrate intake	-0.013 (-0.036–0.011)	0.280						
Protein intake			0.053 (0.009–0.098)	0.020				
Fat intake					-0.006 (-0.060–0.048)	0.826		
Fiber intake							-0.008 (-0.244–0.229)	0.950
Total energy intake	0.003 (0.000–0.006)	0.091	-0.001 (-0.003–0.002)	0.592	0.002 (-0.001–0.005)	0.299	0.001 (-0.001–0.003)	0.202
Age (years)	0.072 (-0.043–0.187)	0.215	0.091 (-0.022–0.205)	0.114	0.062 (-0.052–0.176)	0.286	0.063 (-0.053–0.179)	0.285
Sex	6.514 (4.503–8.526)	<0.001	6.916 (4.916–8.917)	<0.001	6.481 (4.457–8.506)	<0.001	6.473 (4.448–8.498)	<0.001
Physical activity	0.670 (-0.361–1.700)	0.200	0.691 (-0.317–1.698)	0.177	0.657 (-0.380–1.694)	0.211	0.6652 (-0.410–1.714)	0.226
R^2	0.309		0.340		0.301		0.300	
Adjusted R^2	0.272		0.305		0.264		0.263	
SE of the estimate	3.623		3.542		3.645		3.646	

Note: Dependent variable = Fat Mass Index (FMI). B = unstandardized regression coefficient; CI = confidence interval; R^2 = coefficient of determination; SE = standard error. Each model included one dietary predictor and was adjusted for total energy intake, age, sex, and physical activity. Male was used as the reference category for sex. Low physical activity was used as the reference category for physical activity

Discussion

The study participants were adults with obesity, predominantly women of productive age. This finding is consistent with epidemiological evidence showing that the prevalence of obesity is higher among women than men.[20–22] The higher proportion of female participants was not intentional but resulted from the consecutive sampling method, in which all eligible individuals available during the recruitment period were invited to participate. Anthropometric and body composition measurements indicated high adiposity, characterized by a median BMI of 29.99 kg/m², body fat percentage of 42.70%, FMI of 12.51 kg/m², and visceral fat level of 9.5. The median BMI was consistent with the study inclusion criteria requiring participants to have a BMI ≥25 kg/m².[15] Consistent with BMI status, body fat percentage was also elevated. Proposed obesity cut-off points for body fat percentage are 25% for men and 30% for women.[23,24] Similarly, the median FMI exceeded the proposed obesity cut-off point of 6.6 kg/m².[23] According to the TANITA BIA classification, visceral fat levels of 1.0–9.5 are considered normal, 10.0–14.5 indicate increased risk, and values above 15.0 indicate high cardiometabolic risk.[25] Although the median visceral fat level was within the normal range, several participants were categorized as high risk, with the highest value reaching 20.

The median energy intake of subjects was 1562.35 kcal/day, with a range of 1090.85–3145.00 kcal/day. This value indicates a wide variation in energy intake between subjects. In the adult population with obesity, reported energy intake does not always appear high because self-reported intake data, such as food recalls, are prone to underreporting, especially in individuals with a high BMI.[26] The distribution of macronutrients in this study showed an average carbohydrate contribution of 47.15 ± 7.93% of energy. This value is lower than the common carbohydrate consumption pattern in Asian populations. In Indonesia, cereals contribute approximately 47.71% of energy and 71.57% of daily carbohydrate intake, indicating that the Indonesian diet is still heavily dependent on cereal-based carbohydrate sources.[7] Analysis of the Korea National Health and Nutrition Examination Survey shows that the average energy contribution from carbohydrates in Korean adults has decreased over time, but remained at around 63.6% of energy in 2017. Diet quality tended to be lower in groups with very low and very high carbohydrate proportions, while a proportion of around 50–65% of energy was considered more consistent with better diet quality and a better health profile.[27] Although carbohydrate intake was relatively low, the quality of carbohydrate sources should also be considered when evaluating their relationship with BMI and FMI, particularly whether carbohydrates originate from high-fiber foods such as whole grains, fruits, vegetables, and legumes or from refined, low-fiber food sources.[28]

The median protein intake of subjects in this study was 64.38 g/day, with a range of 29.20–145.90 g/day. Protein's contribution to energy was 15.95%, with a range of 8.78–36.74%. This proportion is relatively comparable to protein intake patterns in Asian adult populations. The SCRiPT (Socio-Cultural Research in Protein Transition) study on population-based samples in Indonesia showed that the average protein intake in adults was around 59.4 g/day in men and 51.5 g/day in women.[29] The average contribution of fat to energy in the subjects was 36.67 ± 7.07%, with a median fat intake of 62.78 g/day. This proportion is relatively high compared to some Asian population data, but it is appropriate for the Indonesian population. The FRPTM Indonesia Study of adult respondents aged ≥25 years showed that the oil and fat group was the largest contributor to fat intake, at around 50.69% of total fat intake, and the second largest contributor to energy intake after cereals.[7] This proportion is relatively higher than the WHO recommendation, which limits total fat to 35% of total energy in adults. The WHO also emphasizes that in addition to the quantity of fat, the quality of the fat is also important, namely that the fat should primarily come from unsaturated fatty acids.[30]

The most striking finding was low fiber intake, with a median of only 9.30 g/day and a range of

1.60–18.30 g/day. This figure is well below the WHO recommendation of at least 25 g of natural fiber per day for individuals aged 10 years and older.[31] The low fiber intake in this study is also in line with Indonesian data which shows that vegetable and fruit consumption is still low, resulting in low daily fiber intake.[7]

In the unadjusted analysis, no significant associations were observed between energy, carbohydrate, protein, fat, or dietary fiber intake and BMI or FMI among adults with obesity. All correlation coefficients were very weak and statistically non-significant. However, after adjustment for age, sex, physical activity, and total energy intake, protein intake was positively associated with FMI, whereas carbohydrate, fat, and dietary fiber intake remained unrelated to FMI. Differences between unadjusted and adjusted analyses may occur because Spearman correlation analysis evaluates the crude association between two variables, whereas multiple regression estimates the independent association of each macronutrient after accounting for potential confounding factors. In this study, sex showed the strongest association with FMI, suggesting that differences in body composition between men and women may have masked the independent association between protein intake and FMI in the crude analysis. The positive association between protein intake and FMI should not be interpreted as evidence that higher protein intake causes an increase in body fat. Due to the cross-sectional design of the study, reverse causality cannot be ruled out. Individuals with higher FMI may consume higher amounts of protein due to higher overall dietary intake, larger body size, or dietary modifications aimed at weight management.

These findings are inconsistent with previous randomized controlled trials that generally report that high-protein diets are associated with reduced fat mass, particularly during energy-restricted weight-loss interventions.[32] This may reflect differences in study design, participant characteristics, and the inability of cross-sectional studies to establish temporal relationships. Obesity has multifactorial causes and is not fully understood, so BMI and FMI can be influenced by many factors other than macronutrient and fiber intake.[33] Weight gain indicates a positive energy balance, which is when energy intake exceeds energy expenditure. However, this process is complex and involves a two-way relationship between weight regulation, energy intake, energy expenditure, and other biological factors.[34] BMI and FMI are not always directly associated with short-term dietary intake because they reflect long-term energy balance and adaptations in energy homeostasis, including genetic, developmental, environmental, and biological influences on body fat accumulation.[35] The 24-hour dietary recall is a widely used method for estimating dietary intake; however, its accuracy may be affected by reporting bias and day-to-day variation in food consumption.[36] Assessment of energy and nutrient intake using a 2-day dietary recall may not fully reflect usual dietary intake because of intra-individual variation, although it can provide acceptable estimates for inter-individual comparisons. The number of recall days required to estimate usual intake may vary according to the nutrient examined, age, and sex.[37] A systematic review also showed the phenomenon that individuals with obesity who have a body mass index ⩾30 are associated with reporting much lower than actual food intake.[26] Inter-individual variability in underreporting of self-reported energy and other nutrient intakes weakens the association between diet and disease.[38]

Overall diet quality can be more informative than assessing single nutrients such as carbohydrates, protein, fat, or fiber alone.[39] In addition to the amount of macronutrients, the quality and overall consumption patterns can affect the metabolic condition of individuals with obesity.[40] Physiological mechanisms such as hormones regulating hunger and satiety, food rewards, resting energy expenditure, adaptive thermogenesis, and lipid metabolism play a role in regulating body weight and the tendency for changes in body composition.[41] Genetic factors also contribute about 40–50% to the variation in human weight status, and their contribution may be greater in individuals with severe obesity.[42] Even sleep restriction can increase energy intake,

fat intake, body weight, hunger, appetite, meal frequency, and portion size. Therefore, sleep duration and sleep quality may indirectly influence BMI and FMI.[43]

The study population was predominantly female (83%), and this imbalance may have influenced the observed associations because significant differences in BMI and FMI were found between men and women. Women generally have higher levels of adiposity than men, especially when assessed using fat mass relative to height. At the same BMI, women generally have a higher percentage of body fat than men, so body composition-based indicators such as FMI may be more sensitive in describing sex-specific differences in adiposity.[44] Biologically, differences in adiposity between men and women are influenced by sex hormones, particularly estrogen and testosterone, which play a role in regulating the distribution and function of adipose tissue.[45] Consequently, the predominance of women in this study may limit the generalizability of the findings, particularly to obese adult men, and sex may also act as a potential confounding factor in the relationship between dietary intake and FMI.

There were no significant differences in BMI or FMI based on physical activity levels. Although there was a trend toward a lower median BMI in the high physical activity group, this difference was not statistically significant. Biologically, physical activity can reduce total and visceral fat mass, and in some individuals, changes in body composition can occur without significant weight loss.[46] However, the effects of physical activity on body weight and fat mass are often small and influenced by duration, intensity, type of exercise, energy intake, compensatory eating behaviors, and individual metabolic adaptations.

The results of this study align with several previous studies showing that the association between macronutrient and fiber intake and obesity indicators is not always statistically significant. Several studies in Indonesia reported no association between protein, fat, carbohydrate, or fiber intake and nutritional status based on body mass index.[47,48] Similar findings have also been reported in international studies, showing that macronutrient intake was not significantly associated with fat mass, and fiber intake was not always associated with BMI or body composition indicators.[49,50]

This study has several limitations. First, its cross-sectional design precludes causal inference between macronutrient intake and FMI, and reverse causality cannot be excluded. Second, dietary intake was assessed using non-consecutive 2-day dietary recalls, which may not adequately reflect habitual dietary intake because of day-to-day variation. In addition, self-reported dietary assessment is susceptible to recall bias and underreporting, particularly among individuals with obesity. Third, the study population consisted predominantly of women recruited through consecutive sampling, which may limit the generalizability of the findings to obese adult men. Finally, although the regression models were adjusted for total energy intake, age, sex, and physical activity, residual confounding from unmeasured factors, including sleep quality, psychological stress, genetic predisposition, medication use, and other lifestyle factors, cannot be excluded. Future longitudinal studies using validated measures of habitual dietary intake, such as food frequency questionnaires (FFQs), together with more comprehensive assessment of lifestyle and metabolic factors, are warranted to better clarify the relationship between dietary macronutrient intake and adiposity.

Clinically, the results of this study demonstrate that assessing obesity based solely on macronutrient levels over a short period of time is insufficient. Obesity is a multifactorial condition influenced by the interaction of long-term eating patterns, diet quality, physical activity, body composition, basal metabolic rate, hormonal factors, genetics, and other lifestyle factors. These findings highlight the need for an individualized and multidimensional approach to obesity assessment and management. BMI measurements should be complemented by body composition indicators such as FMI, while clinical interventions should include improving diet quality, increasing physical activity, reducing sedentary behavior, and evaluating other factors such as sleep quality, stress, and metabolic status.

Conclusion

BMI and FMI are likely influenced not only by short-term macronutrient and dietary fiber intake, but also by long-term dietary patterns, diet quality, physical activity, basal metabolic rate, sex, and individual biological factors. Although no significant associations were observed in the unadjusted analyses, protein intake was positively associated with FMI after adjustment for age, sex, physical activity, and total energy intake.

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Author's Contributions

The first author was responsible for the entire data collection process. All authors contributed to the conceptualization and design of the study, statistical analysis, interpretation of the findings, and the drafting and revision of the manuscript. All authors reviewed and approved the final version of the manuscript and accept responsibility for its content.

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Data and Materials Availability

The datasets generated and analyzed during this research are not publicly available due to confidentiality and privacy considerations.

Consent to Participate

Informed consent was obtained from all participants before they participated in the study. All participants were informed about the purpose of the study, the procedures involved, and their rights as research participants, including the right to withdraw from the study at any time without consequence.

Ethics Statement

This study, a subsidiary of the main study analyzing oxidative stress in obese adults, was conducted in accordance with ethical principles in health research. Prior to implementation, the research protocol was submitted to the Health Research Ethics Committee of the Faculty of Medicine, University of Indonesia, for ethical approval. The study could only be conducted after obtaining a certificate of ethical review and permission from the institution where the research was conducted, under the reference number KET-86/UN2.F1/ETIK/PPM.00.02/2026.

Consent for Publication

All participants provided informed consent for the publication of the research findings. The manuscript does not contain any person's identifiable data

Conflict of Interest

We declare that we have no conflicts of interest.

AI Usage Declaration

A generative AI tool (chatgpt, gemini, grammarly) was used for brainstorming and English grammar. All AI-assisted output was independently reviewed and verified by the authors, who are fully responsible for the content of this publication.

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