



The role of dietary inflammatory index and fruit–vegetable variety in body fat accumulation among adolescents

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ABSTRAK

Latar Belakang: Pada tahun 2023, sebanyak 8,8% remaja Indonesia mengalami overweight dan 2,9% mengalami obesitas. Hal itu dapat terjadi karena pola makan tidak sehat, terutama makanan yang memiliki potensi inflamasi tinggi sehingga mempengaruhi lemak tubuh. Dietary Inflammatory Index (DII) merupakan cara untuk mengetahui tingkat potensi inflamasi makanan. Besarnya nilai potensi inflamasi makanan serta bervariasinya konsumsi buah dan sayur dapat mempengaruhi komposisi lemak tubuh remaja.

Tujuan: Mengetahui hubungan skor inflamasi makanan dan variasi konsumsi buah sayur terhadap lemak tubuh pada remaja r.

Metode: Penelitian menggunakan observasional analitik dengan desain cross-sectional. Sampel dipilih menggunakan metode multistage random sampling dan terpilih 150 remaja berusia 15-18 tahun. Pengambilan data lemak tubuh menggunakan Bio Impedance Analysis (BIA) dan data asupan makan menggunakan Semi Quantitative Questionnaire (SQ FFQ). Penelitian dilakukan di Surakarta pada bulan Mei-Juni 2024.

Hasil: Variasi buah sayur pada remaja memiliki rentang skor 0-18 dan skor Dietary Inflammatory Index DII -1,91 hingga 2,39. Hasil uji Spearman menunjukkan hubungan yang signifikan antara skor inflamasi makanan dengan persen lemak tubuh ($r = 0,18$, $p=0,026$), namun tidak ditemukan hubungan yang signifikan antara konsumsi variasi buah sayur dengan persen lemak tubuh ($r = 0,006$, $p=0,941$).

Kesimpulan: Tingginya potensi inflamasi makanan berhubungan dengan peningkatan lemak tubuh remaja, namun sayur buah tidak berhubungan dengan lemak tubuh remaja.

KATA KUNCI: asupan sayur buah; asupan sayur buah; dietary inflammatory index; lemak tubuh; remaja

ABSTRACT

Background: In 2023, 8.8% of Indonesian teenagers were overweight, while 2.9% were obese. Many teens are overweight or obese because they eat unhealthy, inflammation-causing foods that increase body fat. The Dietary Inflammatory Index (DII) is a method used to determine the level of inflammatory potential in food. The level of the inflammatory potential value in food and the variation in fruit and vegetable consumption can affect the body fat composition of adolescents.

Objectives: To determine the relationship between the inflammatory score of food and the variation in fruit and vegetable consumption on adolescent body fat.

Methods: This study used an analytical observational method with a cross-sectional design. The sample of 150 adolescents aged 15-18 was selected using multistage random sampling. Adolescents' body fat was measured using Bio-Impedance Analysis (BIA) and their dietary intake was assessed using the Semi-Quantitative Questionnaire (SQ-FFQ). The research was conducted in Surakarta from May to June 2024.

Results: The variation of fruits and vegetables in adolescents has a score range of 0-18 and a DII score of -1.91 to 2.39. Spearman correlation showed that the DII score positively correlates with body fat percentage ($r = 0.18$, $p = 0.026$). However, no significant effect was found between fruit and vegetable variety consumption on body fat percentage ($r = 0.006$, $p = 0.941$).

Conclusions: Foods with high inflammatory potential may increase body fat in adolescents, while fruit and vegetable variety does not. The health department should offer guidelines to help the community, especially adolescents, choose non-inflammatory foods and avoid high-inflammatory ones.

KEYWORD: adolescents; body fat; dietary Inflammatory Index; fruit and vegetable intake

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INTRODUCTION

Adolescence is a transition period in which a person's behavior and lifestyle change significantly. Adolescent lifestyle decisions might persist into adulthood, affecting future health concerns. Thus, adolescence is essential for instilling positive dietary and health habits (1). Adolescents today face a wide range of nutritional issues as a result of poor lifestyle choices, including obesity and being overweight. According to the World Health Organization (2), up to 340 million adolescents worldwide are obese, of which 36.3% of Indonesian adolescents are overweight (3).

According to the World Health Organization in 2020 (2), more than 390 million teenagers worldwide are obese, with 8.8% of Indonesian teenagers overweight, and 2.9% obese by 2023 (3). Surakarta has the highest percentage of teenage obesity in Central Java (11.47%), according to Riskesdas(4); consequently, efforts should be made to lower the obesity prevalence in this city. Sedentary behaviors and the eating of

unhealthy foods, both of which have the potential to produce inflammation, are the causes of adolescents' high obesity and overweight rates (5). Adolescents' body fat levels can be used to diagnose obesity and overweight.

Continuous consumption of pro-inflammatory foods can contribute to obesity because it alters the microbiota, allowing fat to accumulate in the liver. Inflammation in the digestive system also promotes lipopolysaccharide (LPS) translocation in bacteria, resulting in adipogenesis (6,7). After learning about the role of food in causing inflammation, the Dietary Inflammatory Index (DII) was developed as a tool for categorizing foods consumed by a person based on their level of inflammatory potential. Previous studies have found that high DII scores are associated with overweight or obesity (8) and body fat in adolescents (9).

Since fruits and vegetables are low-energy and high-fiber foods, eating enough of them can reduce the inflammatory potential of a diet.

Furthermore, vegetables and fruits are rich in folic acid, potassium, magnesium, vitamins A, C, E, and K, and various flavonoids (10), all of which have anti-inflammatory properties. The WHO recommends consuming 400 grams of vegetables and fruits daily, comprising 250 grams of veggies and 150 grams of fruit. In addition to paying attention to the amount of vegetables and fruits consumed, it is essential to consider the various types of vegetables and fruits consumed following the four pillars of balanced nutrition guidelines. Since every fruit and vegetable has different nutritional and phytochemical qualities, it is essential to eat various kinds of them. The intake of several vegetable and fruit components can help the body prevent obesity, such as anthocyanins in the purple color of vegetables and fruits, which can lower BMI values (11), glucosinolates in broccoli, which have anti-obesity effects (12), carotene (13), and other components. As a result, more beneficial components reach the body through various vegetables and fruit consumption, preventing excess fat accumulation. Previous studies have found that variations in fruit and vegetable consumption have a non-linear relationship with BMI values in older adults (13).

This study aims to determine the correlation between the inflammatory potential of food with

the consumption of various fruits and vegetables and body fat in adolescents. So far, researchers have not found any studies combining DII with variations in fruit and vegetable consumption linked to body fat in adolescents aged 16-18 years in Surakarta. Fruit and vegetable variations and DII were chosen by researchers because fruit and vegetable consumption can affect changes in DII values, where several food component parameters in DII are components found in fruits and vegetables.

MATERIALS AND METHODS

This research is an observational analysis with a cross-sectional design. This study was conducted at high schools and vocational institutions in Surakarta, with a total sample size of 161 students selected through a multistage random sampling procedure. The subjects were adolescent students aged 15 to 18 who had not participated in high-intensity sports in the previous two months and had not used diet pills or fiber supplements. However, 11 out of 161 participants were excluded from processing due to unreliable energy intake data (total energy <800 or >4200 kcal for males and <600 or >3500 for females), leaving just 150 students with usable data (**Figure 1**).

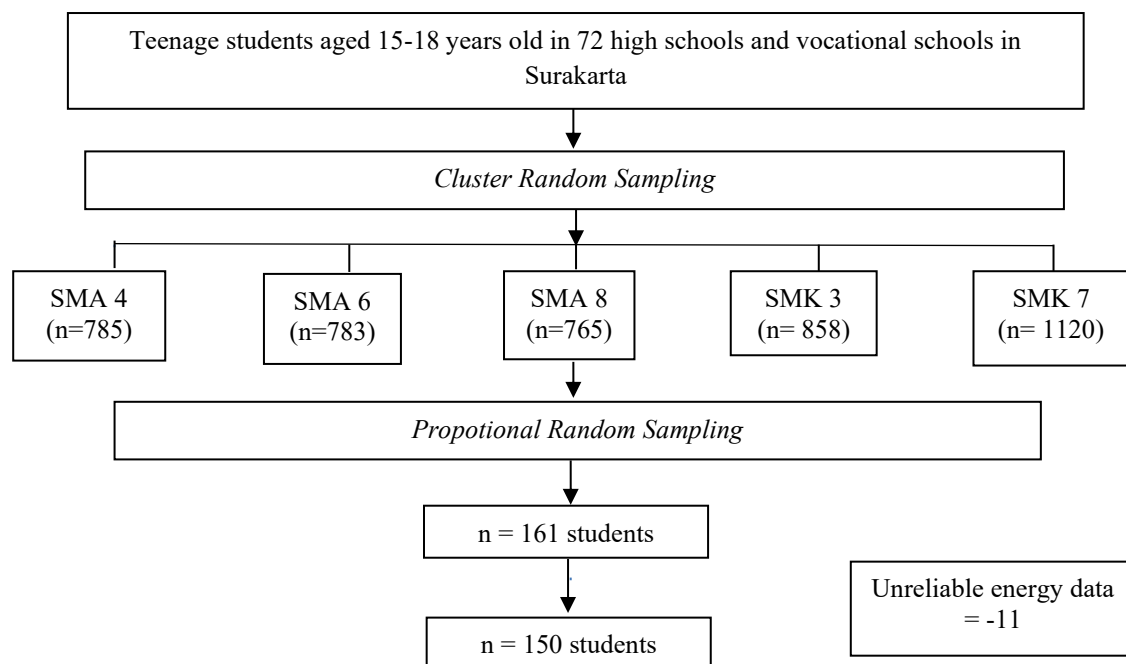


Figure 1. Sample Selection Flow

This study used a semi-quantitative food frequency (SQ-FFQ) questionnaire to assess food consumption over the previous month. The DII score was derived using SQ-FFQ data, as well as fruit and vegetable varieties. Data on food intake was collected using a one-on-one interview to avoid the influence of other people's answers, and the interview was assisted by a photobook of food portions to make adolescents remember the exact portion of food they consume. The Dietary Inflammatory Index score was calculated by first calculating the average daily nutrient intake using the Nutrisurvey program and TKPI (Indonesian Food Composition Table). This study used 26 food parameters from Nutrisurvey and TKPI to calculate a DII score, as described by Shivappa (14). The first stage in calculating the DII score is to determine the z score of each nutrient by subtracting the respondent's daily intake from a database of 11 countries, including 4 Asian countries, and dividing it by the standard deviation, which Shivappa has already determined. The results were converted to percentiles using SPSS Software and divided by 100. The DII score for each respondent was calculated by multiplying the findings by the "overall food parameter-specific inflammatory effect score" and adding up all parameter values.

SQ-FFQ offers 15 varieties of vegetables and 15 types of fruit. Every vegetable or fruit consumed at least once a week receives a one-point score for variation, regardless of

quantity. The fruit-vegetable variance score ranges from 0 to 30, with vegetables scoring 0-15 and fruits scoring 0-15. The vegetable and fruit variety data scale is analyzed in ratio format. The body fat percentage was then determined using Bio Impedance Analysis Omron Karada Scan HBF 375, which has been calibrated by the Health Equipment and Facility Security Center (BPAFK).

Spearman analysis was employed in this study to examine the correlation between the DII score and the percentage of body fat, as well as the variation of vegetables and fruits that affect the body fat percentage. The results of the Spearman test can be said to have a significant relationship if the p-value ≤ 0.05 . The relationship between variables can be considered strong if the correlation coefficient value is $r > 0.5$. If the correlation coefficient is positive, then an increase in one variable can increase another variable; if it is negative, then an increase in one variable can decrease another variable. Research ethics approval was obtained from the Research Ethics Committee of Dr Moewardi General Hospital, Surakarta, Indonesia (804/III/HREC/2024).

RESULTS AND DISCUSSIONS

Characteristics of research subject

This study comprised 161 students from three high schools and two vocational schools in Surakarta, aged 15 to 18. Subjects included students from SMA 4, SMA 6, SMA 8, SMK 3, and SMK 7.

Table 1. Frequency distribution of research subject characteristics

Variable	N (150)	%
Age		
15	15	10
16	62	41.3
17	70	46.7
18	3	2
Gender		
Male	65	43.3
Female	85	56.7
Body Fat Percentage		
Thin	60	40
Normal	52	34.7
Overfat	21	14
Obesity	17	11.3
Physical Activity		
Low	81	54
Medium	69	46

However, only 150 students had data that could be used after 11 out of 161 students had to be excluded from processing because their energy intake data was deemed unreliable (total energy <800 or >4200 kcal for males and <600 or >3500 for females). **Table 1** shows the characteristics of the subjects, including age, gender, and grade level.

According to the table, the majority of respondents are females (56.6%), with 46.6% are

older than 17. The majority of respondents have a normal body fat percentage of 30%, while up to 66 students engage in vigorous physical exercise. According to the graph in **Figure 2**, the distribution of DII scores has an average DII score of 0.19, with the lowest value being -1.91 and the highest score being 2.29. The DII score follows an asymmetrical data distribution, with a tendency to the left.

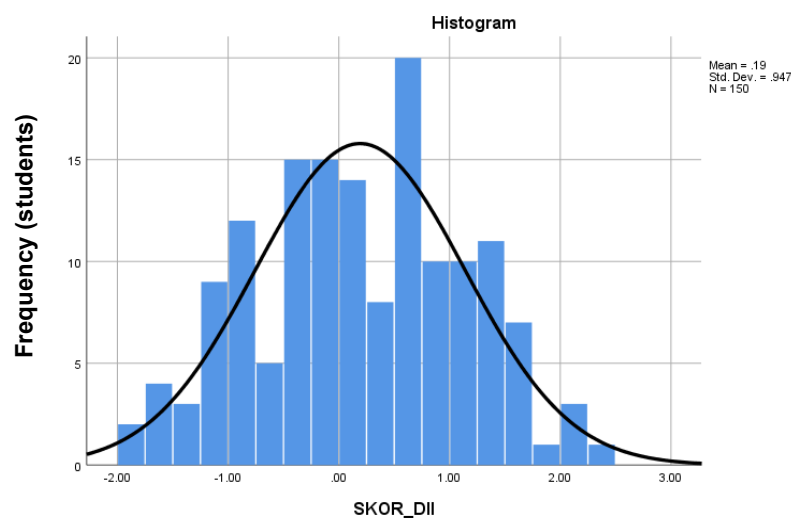


Figure 2. Distribution of DII Scores to Students

Furthermore, based on the graph, it is clear that the DII score between 0 and 1 has the highest number of students, approximately 20 students, while students with a DII score greater than +2 number have one student. Previous research revealed differences in DII scores, with the lowest DII value achieved being -1.72 and the highest DII

score being 3.38 (15). Other research also discovered a different range, -3.66 to 2.51, among adolescents in Central Java (16).

According to **Table 2**, green vegetables are the most commonly consumed by students each week, with 82.6% consuming spinach, cabbage, broccoli, cucumber, and others.

Table 2. Distribution of vegetables and fruits consumed by students once a week

Groups based on Vegetable Color	Vegetables		Fruits	
	n	%	n	%
Green	124	82.6	39	26
Blue and Purple	6	4	13	8.6
Yellow and Orange	91	60.6	71	47.3
Red	43	28.6	67	44.6
White	59	39.3	60	40

Green vegetables are a popular choice among students since, as we all know, they make up the majority of greens consumed in society. Students eat more orange and yellow fruits (47.3%) in the fruit group which includes papayas, pineapples, oranges, and other fruits. Similar

results were also found in Gresik adolescents, where most of them could only consume no more than two types of vegetables and fruits for three in a row. The most commonly consumed vegetables are mustard greens, spinach, bok choy, carrots, and bean sprouts. Meanwhile, broccoli and

chayote are the most rarely consumed vegetables. The most often consumed fruits included oranges, water apples, bananas, papayas, and watermelons, while the rarely consumed fruits included strawberries, longans, durians, and mangosteens (17).

According to the vegetable and fruit variants shown in **Figure 3**, the majority of students, 17 students, could only consume two types of vegetables and fruits every week. In contrast, only

one student consumes 13 different fruits and vegetables. Furthermore, it is shown that 10 students do not meet the recommended intake of diverse fruits and vegetables, whereas two students do, consuming a total of 18 varieties, they are kale, mustard greens, carrots, tomatoes, mushrooms, long beans, bean sprouts, cucumbers, broccoli, watermelon, papaya, bananas, oranges, apples, melons, salak, guava, pears.

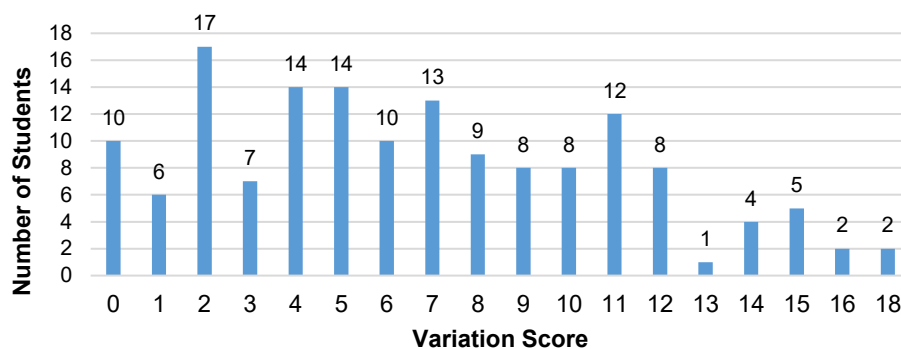


Figure 3. Distribution of the number of vegetable and fruit variations consumed by students

The Correlation between DII Score and Fruit and Vegetable Variation with Body Fat

Table 3 presents the results of a bivariate analysis of variables. According to the results of the Spearman Rank Correlation test, it was found that the significance value of $p < 0.05$ ($p = 0.026$) for the correlation between DII score and body fat percentage, with a correlation coefficient value of 0.181. This suggests that both correlations in this variable are weak and positive, implying that adolescents with higher DII scores have more significant body fat percentages. The determination coefficient value indicates that the DII score may account for 3.3% of the variance in the body fat variable.

Table 3 reveals that a higher DII score increases adolescent body fat. In this study, some adolescents with excess fat in their bodies have positive DII scores and consume foods high in fat and sugar. This is consistent with previous research, which found that adolescents tend to consume foods high in sugar, saturated fats, and salt from their snacks (18). Various processes can explain the correlation between increased inflammatory potential and body fat. Excessive intake of nutrients, such as fat and carbohydrates,

might be recognized as a danger by the body's receptors, either directly or indirectly through modulation of the gut microbiota (9). This suggests that when food enters the body, toll-like and nod-like receptors are activated, which raises inflammatory markers in adipose tissue. Low inflammation in many tissues, including the liver, muscles, and adipose tissue, may lead to insulin resistance, energy balance disorders, and glucose or lipid metabolism abnormalities, all contributing to increasing body fat (19). In addition, body fat, particularly abdominal fat, exacerbates inflammation (20). The findings of this study are consistent with Gholamalizadeh's(9), which investigated the correlation between DII scores and body fat in adolescent males and discovered that DII values more than 0.4 are 2.5 times more likely to increase body fat than adolescent boys with lower DII scores. Other studies have found that foods with anti-inflammatory properties are associated with a lower incidence of obesity (21). Other studies have also found that a high DII score is associated with increased body fat and visceral fat in women (22). According to additional studies, individuals who have a high DII score will weigh more than they should (14).

Table 3 shows no statistically significant correlation between fruit and vegetable variation and body fat percentage, with a significance value of $p > 0.05$ ($p = 0.941$). One of the reasons for the lack of a correlation is the processing method used for vegetables and fruits. Several types of fruit processing were used in this study, including raw, juiced, and salad. Consuming fruit in salad or juice may increase calories because it contains sugar, mayonnaise, and condensed milk, all of which have an impact on body fat. Several methods of processing vegetables, including boiling, steaming, grilling, and frying, have been shown to reduce their phytochemical composition due to the presence of phenols that dissolve in boiled water or changes in the phenolic structure after heating (23,24), particularly when the vegetables are heated repeatedly. In addition, vegetables often get stir-fried with extra oil, which increases body

fat. However, this study did not examine the processing of vegetables consumed by adolescents. Similar studies have indicated that the variety of vegetables and fruits does not correlate with the growth in body fat mass among Chinese adults (13). Since earlier cohort studies have demonstrated that higher consumption of fruits and vegetables tends to be associated with slight weight gain and lower body fat, the researchers' failure to take into account both the quantity and type of fruit and vegetable intake at the same time is another reason why there was no relationship between fruit and vegetable variation in the study (13). Furthermore, food intake interviews only estimate food quantities based on images provided by researchers, which might lead to adolescents reporting results that are either higher or lower than their actual intake.

Table 3. Bivariate correlation of DII score and fruit-vegetable intake with body fat percentage

Variables	Correlation Coefficient (ρ)	Coefficient of Determination (ρ^2)	P Value
DII Score and Percentage of Body Fat	0.181	0.033	0.026*
Variations of Fruits and Vegetables and Body Fat	0.006	0	0.941

More than just the variables studied influence body fat production; physical activity and gender can also play a role. According to research (25), adolescents with more physical exercise have lower body fat. This is because physical exercise increases muscle mass, and lipolysis, and reduces inflammation, all of which can impact body fat (26). Not only does physical activity contribute to body fat accumulation, but gender also plays a role. Women are known to have higher body fat because the hormone estrogen stimulates the growth of fat tissue. In contrast, men have the hormone androgen, which inhibits the development of fat tissue in the body. In women, the hormone estradiol helps to reduce lipid usage by decreasing hepatic lipid oxidation (27,28).

There are various limitations to this study, including the presence of several parameters whose data were not investigated, such as alcohol, caffeine, garlic, ginger, omega 3, omega 6, tea, pepper, rosemary, and flavonol, due to researchers' constraints in studying flavonol concentration in food. The second researcher has

not investigated how the food is processed, which may cause changes in the nutrient content of food. The next researcher did not collect data on daily adolescent supplement usage because it could influence the DII score results. However, this study has certain advantages, including the use of BIA as a body fat-measuring technology that has been recognized for its effectiveness

CONCLUSION AND RECOMMENDATION

It was discovered that 14% of students have a body fat percentage in the overfat category, while 11.3% are in the obesity category. The research found a correlation between the inflammatory score of food and body fat in adolescents, implying that consuming foods with high inflammatory potential can contribute to an increase in body fat. The variety of fruits and vegetables was found to be uncorrelated with body fat.

Students with excess body fat should pay attention to the food they consume daily, considering the potential inflammatory effects on

their bodies. Additionally, the school should educate about foods with inflammatory potential and promote the availability of anti-inflammatory foods in the school environment to prevent obesity in adolescents. It is suggested that the health department develop guidelines for the community in choosing types of food that do not have inflammatory potential and can be used as educational material for the community, especially adolescents, to avoid high-inflammatory foods.

REFERENCES

1. Rachmi CN, Jusril H, Ariawan I, Beal T, Sutrisna A. Eating behaviour of Indonesian adolescents: A systematic review of the literature. *Public Health Nutrition*. 2020;24(Lmic).
2. WHO. Obesity and Overweight [Internet]. 2022 [cited 2024 Oct 24]. Available from: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>
3. Kemenkes. Dalam Angka Dalam Angka. Laporan SKI 2023 Dalam Angka. 2023.
4. Tim Risesdas 2018. Laporan Provinsi Jawa Tengah RISKESDAS 2018. Lembaga Penerbit Balitbangkes. 2019.
5. Vahid F, Bourbour F, Gholamalizadeh M, Shivappa N, Hébert JR, Babakhani K, et al. A pro-inflammatory diet increases the likelihood of obesity and overweight in adolescent boys: A case-control study. *Diabetology & Metabolic Syndrome*. 2020 Apr 7;12(1).
6. Lozano CP, Wilkens LR, Shvetsov YB, Maskarinec G, Park SY, Shepherd JA, et al. Associations of the Dietary Inflammatory Index with total adiposity and ectopic fat through the gut microbiota, LPS, and C-reactive protein in the Multiethnic Cohort-Adiposity Phenotype Study. *American Journal Clinical Nutrition* [Internet]. 2022;115(5):1344–56. Available from: <https://doi.org/10.1093/ajcn/nqab398>
7. Gupta H, Min BH, Ganesan R, Gebru YA, Sharma SP, Park E, et al. Gut Microbiome in Non-Alcoholic Fatty Liver Disease: From Mechanisms to Therapeutic Role. *Biomedicine*. 2022;10(3).
8. Zhang L, Peng H, Wang Y, Ba H. Association of dietary inflammatory index with obesity among children and adolescents in the United States NHANES cohort: a population-based study. *Italian Journal Pediatrics*. 2024 Dec 1;50(1).
9. Gholamalizadeh M, Ahmadzadeh M, Bourbour F, Vahid F, Ajami M, Majidi N, et al. Associations between the dietary inflammatory index with obesity and body fat in male adolescents. *BMC Endocrine Disorders*. 2022 Dec 1;22(1).
10. López-González L, Becerra-Tomás N, Babio N, Martínez-González MÁ, Díaz-López A, Corella D, et al. Variety in fruits and vegetables, diet quality and lifestyle in an older adult mediterranean population. *Clinical Nutrition*. 2021;40(4):1510–8.
11. Jennings A, Koch M, Jensen MK, Bang C, Kassubek J, Müller HP, et al. The role of the gut microbiome in the association between habitual anthocyanin intake and visceral abdominal fat in population-level analysis. *American Journal Clinical Nutrition* [Internet]. 2020;111(2):340–50. Available from: <https://doi.org/10.1093/ajcn/nqz299>
12. Ranaweera SS, Natraj P, Rajan P, Dayarathne LA, Mihindukulasooriya SP, Dinh DTT, et al. Anti-obesity effect of sulforaphane in broccoli leaf extract on 3T3-L1 adipocytes and ob/ob mice. *Journal of Nutritional Biochemistry*. 2022;100:1–15.
13. Li SY, Leung JCS, Lu ZH, Kwok TCY. Quantity and Variety of Fruit and Vegetable Intake with Changes in Measures of Adiposity among Community-Dwelling Chinese Older Adults. *Nutrients*. 2023;15(19).
14. Luglio Muhammad HF, van Baak MA, Mariman EC, Sulistyoningrum DC, Huriyati E, Lee YY, et al. Dietary inflammatory index score and its association with body weight, blood pressure, lipid profile, and leptin in Indonesian adults. *Nutrients*. 2019;11(1).
15. Rakhman FK, Oktafiani LDA. The comparison of Dietary Inflammatory Index (DII) value in obesity and non-obesity. *AcTion Aceh Nutrition Journal*. 2024;9(2):194.
16. Widyastuti T, Susanto H, Noer ER, Muniroh M. Dietary inflammatory index , physical activity , body composition , and high sensitivity c-reactive protein levels in adolescent athletes in Central Java. 2024;12(2):114–24.

17. Ramadhani AK, Afifah AN. Factors Related To Diversity Vegetable and Fruit Consumption in Adolescents at The Coastal Area of Gresik District. *Gorontalo Journal Nutrition Diet.* 2021;1(2):50–64.
18. Angraini DI, Saftarina F, Wijaya SM. The Analysis of Factors to Predict Eating Behavior among Adolescent Girls: A Community-Based Study in Indonesia. *Jurnal Gizi dan Dietetik Indonesia (Indonesian Journal of Nutrition and Dietetics.* 2023;11(2):62.
19. Liu X, Zhang Y, Li Y, Sang Y, Chai Y, Zhang L, et al. Systemic immunity-inflammation index is associated with body fat distribution among U.S. adults: evidence from national health and nutrition examination survey 2011–2018. *BMC Endocrine Disorders* [Internet]. 2024;24(1). Available from: <https://doi.org/10.1186/s12902-024-01725-y>
20. Noer ER, Rose S, Fajrani AM, Rachma DE, Limijadi IEKS, Fitranti DY. High Waist to Height ratio (WHtR) Worsens Inflammatory And Adiposity Profiles In Adult Women With Abdominal Obesity. *Jurnal Gizi dan Dietetik Indonesia (Indonesian Journal of Nutrition and Dietetics)* 2022;10(1):30.
21. Wang YB, Shivappa N, Hébert JR, Page AJ, Gill TK, Melaku YA. Association between Dietary Inflammatory Index, Dietary Patterns, Plant-Based Dietary Index and the Risk of Obesity. *Nutrients.* 2021 May;13(5).
22. Freitas RGBON, Vasques ACJ, da Rocha Fernandes G, Ribeiro FB, Solar I, Shivappa N, et al. Gut bacterial markers involved in association of dietary inflammatory index with visceral adiposity. *Nutrition.* 2024;122.
23. Bai J, Ge Y, Zhao C, Yang L, Ge K, Zhang J. N-3 polyunsaturated fatty acids in fat-1 transgenic mice prevent obesity by stimulating the IL-27 signaling pathway. *Journal of Functional Foods* [Internet]. 2024;118:106288. Available from: <https://www.sciencedirect.com/science/article/pii/S1756464624002901>
24. Putriani N, Perdana J, Meiliana, Nugrahedi PY. Effect of Thermal Processing on Key Phytochemical Compounds in Green Leafy Vegetables: A Review. *Food Reviews International* [Internet]. 2022;38(4):783–811.
25. Dewi RC, Rimawati N, Purbodjati. Body Mass Index, Physical Activity, and Physical Fitness of Adolescence. *Journal of Public Health Research* [Internet]. 2021 Apr 15;10(2):jphr.2021.2230. Available from: <https://doi.org/10.4081/jphr.2021.2230>
26. Saeidi A, Haghighi MM, Kolahdouzi S, Daraei A, Abderrahmane A Ben, Essop MF, et al. The effects of physical activity on adipokines in individuals with overweight/obesity across the lifespan: A narrative review. *Obesity Reviews.* 2021;22(1):1–32.
27. Mauvais-Jarvis F. Sex differences in energy metabolism: natural selection, mechanisms and consequences. *Nature Reviews Nephrology.* 2024 Jan;20(1):56–69.
28. Koceva A, Herman R, Janez A, Rakusa M, Jensterle M. Sex- and Gender-Related Differences in Obesity: From Pathophysiological Mechanisms to Clinical Implications. *International Journal of Molecular Sciences* [Internet]. 2024;25(13). Available from: <https://www.mdpi.com/1422-0067/25/13/7342>.