



DOI: 10.4274/jcrpe.galenos.2025.2025-7-14  
J Clin Res Pediatr Endocrinol 2026;18(1):113-122

# Associations Between Dietary Diversity Score and Adiposity Indexes in Obese Adolescents

Rukiye Bozbulut, Mehmet Ali Oktay, Ulaş Akçay, Esra Döğ er, Aylin Kılı nç Uğ urlu,  
 Mahmut Orhun Ç amurdan, Aysun Bideci

Gazi University Faculty of Medicine, Department of Pediatric Endocrinology, Ankara, Türkiye

**Cite this article as:** Bozbulut R, Oktay MA, Akçay U, Döğ er E, Kılı nç Uğ urlu A, Ç amurdan MO, Bideci A. Associations between dietary diversity score and adiposity indexes in obese adolescents. J Clin Res Pediatr Endocrinol. 2026;18(1):113-122

## What is already known on this topic?

Visceral adipose tissue is considered an independent risk factor for cardiometabolic risk. Diet and lifestyle changes will affect visceral adipose tissue. However, the relationship between dietary diversity and adiposity-related biomarkers used to determine visceral adiposity and predict cardiometabolic risk is unknown.

## What this study adds?

High dietary diversity was associated with lower insulin resistance and lower visceral adiposity, triglyceride/glucose, and lipid accumulation product indices, all of which predict cardiometabolic risk.

## ABSTRACT

**Objective:** Nutrition may affect visceral adipose tissue, but the effect of dietary diversity on visceral adiposity is unknown. Our aim was to investigate the relationship between dietary diversity and visceral adiposity indices and biochemical parameters in obese adolescent.

**Methods:** Subjects were obese adolescents. Participants' biochemical parameters, anthropometric measurements, and blood pressures were measured. Two days of retrospective food intake records were collected, and dietary diversity scores (DDS) were calculated and divided into tertiles. A DDS score of <4.09 was classified as tertile 1 (low); 4.09-4.96 as tertile 2 (medium); and >4.96 as tertile 3 (high). Visceral adiposity, triglyceride/glucose, lipid accumulation product, and body shape indexes were calculated according to previously published formulas.

**Results:** The study included 141 obese adolescents (70 males, 49.6%) aged between 12 and 18 years. Insulin and Homeostasis Model assessment for Insulin Resistance (HOMA-IR) values were higher in individuals in Tertile 1 compared to those in other tertiles ( $p<0.001$ ). The triglyceride/glucose index was lower in individuals in Tertile 3 compared to those in Tertile 1 ( $p=0.028$ ). In individuals in Tertile 3, fibre ( $p=0.002$ ), vegetable

**Corresponding Author:** Rukiye Bozbulut, PhD, Gazi University Faculty of Medicine, Department of Pediatric Endocrinology, Ankara, Türkiye

**E-mail:** dyt\_rukiye@hotmail.com **ORCID:** orcid.org/0000-0003-4317-9226

**Conflict of interest:** None declared

**Received:** 24.07.2025 **Accepted:** 28.10.2025 **Epub:** 12.11.2025 **Publication Date:** 13.03.2026



( $p < 0.001$ ), and whole grain ( $p < 0.001$ ) intake were higher than in other tertiles, while refined grain ( $p < 0.001$ ) and meat consumption ( $p = 0.013$ ) were lower than in other tertiles. A negative correlation was found between the DDS and fasting blood glucose ( $\rho = -0.177$ ;  $p = 0.036$ ), insulin ( $\rho = -0.633$ ;  $p < 0.001$ ), triglycerides ( $\rho = -0.223$ ;  $p = 0.008$ ), HOMA-IR ( $\rho = -0.656$ ;  $p < 0.001$ ), visceral adiposity index ( $\rho = -0.228$ ;  $p = 0.007$ ), triglyceride/glucose index ( $\rho = -0.251$ ;  $p = 0.003$ ), and lipid accumulation product index ( $\rho = -0.200$ ;  $p = 0.018$ ). When confounding factors were controlled for, fasting blood glucose emerged as a significant factor affecting DDS.

**Conclusion:** High DDS in obese adolescents are associated with lower visceral adiposity, and lower triglyceride/glucose and lipid accumulation product indexes, indices associated with visceral obesity. As DDSs increased, fasting blood sugar, insulin, triglyceride, and HOMA-IR levels decreased.

**Keywords:** Dietary diversity, visceral adiposity, triglyceride/glucose index, lipid accumulation product, body shape indices

## Introduction

Obesity has emerged as a global health concern because chronic obesity will affect cell metabolism and is associated with increased adipose tissue deposition, thereby increasing the risk of metabolic syndrome, which in turn is known to increase the risk of cardiovascular disease, hypertension, and type 2 diabetes (1). The increase in the prevalence of obesity among children and adolescents is a risk factor for chronic diseases in adulthood and affects future morbidity/mortality. Therefore, identifying risk factors for obesity in adolescents is important as it will facilitate intervention to prevent the development of persistent obesity and overweight which will reduce the risk of cardiovascular disease and other metabolic conditions (2).

In recent years, the location and distribution of fat in the body has been shown to be potentially more important than the total amount of fat in terms of metabolic risk. In general, visceral obesity is reported to play a central role in the development of chronic disease compared to regional or general obesity (3). Visceral adipose tissue is a hormonally active component of the body's fat mass, stored in the abdominal cavity, near the digestive organs (4). It is considered an independent risk factor for metabolic syndrome due to its role in regulating glucose, lipid metabolism, and blood pressure (5). It has been found to be associated with cardio-metabolic pathologies, and the amount and activity of visceral fat is a clinically useful biomarker when determining risk for these diseases (6). To date, body composition variables used as predictors of metabolic syndrome include body mass index (BMI), waist circumference (WC), or waist-to-hip ratio. In addition, visceral fat tissue can be measured using costly and less practical methods, such as bioelectrical impedance analysis, dual-energy X-ray absorptiometry, computed tomography, and magnetic resonance imaging (7,8). For example, BMI is a widely used auxological parameter but it cannot distinguish between muscle mass and body fat mass, an increase in muscle mass may be diagnosed as excess weight and mis-classified as obesity. Therefore, additional anthropometric indicators are needed to assess abdominal visceral obesity (9). In the past few years, some lipid and visceral obesity-related indices, such

as visceral adiposity index, triglyceride/glucose index, lipid accumulation product (LAP) index, atherogenic index of plasma, cardiometabolic index, and body roundness index, have also been proposed as supplementary indices to estimate the presence of obesity and the distribution pattern of adipose tissue, especially visceral adiposity (10). Visceral adiposity index, triglyceride/glucose index, LAP index, and body shape index have been shown to be better predictors of insulin resistance and metabolic syndrome risk than traditional indices in pediatric population (11). These indices are mathematical models calculated using anthropometric and biochemical data. They are used to indicate visceral adiposity, adiposity dysfunction, the homeostasis model assessment for insulin resistance (HOMA-IR), metabolic dysfunction, and cardiometabolic risk. Thus, they can help predict significant health risks with a simple formulation and facilitate early intervention (11).

Current evidence shows that lifestyle changes and diet will affect deposition of visceral adipose tissue (4). When examining the effects of diet on health, the importance of dietary diversity has been highlighted. Dietary diversity ensures a more balanced intake of nutrients and other non-nutrient components into the body (12). Studies have found a negative correlation between greater dietary diversity and the incidence of cardiovascular disease, cancer, metabolic syndrome, and osteoporosis (13,14,15). A study found that increased consumption of plant-based diets was associated with better anthropometric measurements, increased high-density lipoprotein (HDL) cholesterol levels, and reduced LAPs (3). Another study suggested that increased dietary protein intake and animal-derived monounsaturated fatty acids may be positively associated with changes in visceral fat dysfunction and visceral adiposity index (16). In contrast, another study found no effect of Western-style, healthy, and combined diets on triglyceride/glucose index and visceral fat levels (4). However, the relationship between dietary diversity and adiposity-related biomarkers is unknown. Therefore, the aim of the present study was to investigate the effects of dietary diversity on visceral adiposity, triglyceride/glucose, LAPs, and body shape indexes, which are used to determine visceral adiposity and predict cardiometabolic risk, in obese adolescents.

## Methods

### Study Design, Setting, and Participants

This study included obese adolescents aged 12-18 years who attended the Clinic of Pediatric Endocrinology Outpatient at Gazi University Faculty of Medicine between February 2025 and May 2025. The inclusion criteria were obese adolescents, defined as a BMI  $\geq 95^{\text{th}}$  percentile, who had no previously diagnosed chronic condition, did not take hormone therapy, and did not use medication. Exclusion criteria included having any concomitant chronic medical condition (syndromic, metabolic, or neurological), except for metabolic syndrome secondary to obesity, or not having clinically normal mental faculty.

Clear explanations were provided about the purpose of the study, after which written informed consent was obtained from the adolescents in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Gazi University Ethics Committee (approval number: 2025-164, date: 05.02.2025).

### Data Collection and Evaluation

Data was collected in face-to-face interviews through a questionnaire that included adolescent socio-demographics, dietary habits, anthropometric measurements, body composition analyses, biochemical findings, dietary diversity score (DDS) table, and two-day food consumption records (4,6).

### Anthropometric Measurements and Body Composition Analysis

Body weight measurement and body composition analysis [fat mass, percentage of fat, fat-free mass (FFM)] were conducted with the InBody 720 (1-1000 kHz) a combination scale and body composition analyzer (InBody Co., Korea). Height was measured (cm) with feet close together and the head in Frankfort plane with a portable stadiometer with a 0.1 cm accuracy. BMI was calculated as weight (kg)/height (m<sup>2</sup>). BMI-standard deviation score (SDS) and body weight-SDS were calculated according to the standards established for Turkish children (17). WC (cm) was measured from the midpoint between the lowest rib and the iliac crest.

### Biochemical Parameters and Blood Pressure

The levels of fasting blood glucose, fasting insulin, total cholesterol, low density lipoprotein-cholesterol (LDL-C), HDL-cholesterol (HDL-C), triglyceride, and liver transaminases [alanine aminotransferase (ALT) and aspartate aminotransferase (AST)] of the participants, which are routinely analyzed at Gazi University Faculty of Medicine, Department of Pediatric Endocrinology, were recorded. Venous blood samples were obtained from all patients from the antecubital region between 8.00 and 8.30 am after an 8-12 hour overnight fast. Fasting glucose was measured with the enzymatic ultraviolet (UV) (hexokinase) method using an AU5800 autoanalyzer (Beckman Coulter Inc., Brea, CA, USA).

HDL-C, LDL-C, total cholesterol, and triglyceride levels were also measured on the AU5800 using enzymatic colorimetric methods. Insulin levels were measured with a one-step principle enzymatic immunoassay method using a Beckman UniCel Dxl 800 (Beckman Coulter Inc., Brea, CA, USA). Serum AST and ALT levels were measured by kinetic UV method on the AU5800 (Beckman Coulter Inc., Brea, CA, USA). Blood pressure measurements of the adolescent were taken by the researchers in accordance with the standard measurement protocol (18). HOMA-IR value was calculated using the standard fasting blood glucose (mg/dL) x fasting insulin ( $\mu\text{U/mL}$ )/405 formula (19). Unit changes have been made in the parameters in accordance with the formulas.

### Cardio-Metabolic Risk Markers

Cardio-metabolic risk markers were calculated as:

Visceral adiposity index=in girls  $[\text{WC}/((36.58)+(1.89 \times \text{BMI}))] \times (\text{TG}/0.81) \times (1.52/\text{HDL-C})$ ,

in boys= $[\text{WC}/((39.68)+(1.88 \times \text{BMI}))] \times (\text{TG}/1.03) \times (1.31/\text{HDL-C})$  (20)

Triglyceride/glucose index= $\ln$  [fasting triglyceride (mg/dL) x fasting blood glucose (mg/dL)/2] (21)

LAP index=(WC-58) x TG in girls, (WC-65) x TG in boys (22)

Body shape index= $\text{WC}/(\text{BMI}^{2/3} \times \text{height}^{7/6})$  (23).

### Dietary Intake and Calculation of DDS

DDS is most often determined by counting the number of selected food groups consumed by individuals over a reference period, which usually ranges between 1-7 days (24). Two-day food consumption records were obtained from the participants. Adolescents were taught by the dietitian on how to keep food consumption records. The Food and Nutrient Photo Catalogue was used to ensure that patients correctly specified the amount of food they consumed. The food diversity score table was filled in by the researcher according to retrospective food consumption records, using data from one weekday and one day from a weekend. The DDS score was calculated according to the completed food diversity table.

The food diversity score table consists of five main food groups: grains, vegetables, fruits, meat, and dairy products. Under these five groups, 23 food sub-groups were evaluated in terms of score. These subgroups were:

1. Grains group with seven subgroups: white bread, biscuits, pasta, whole grains, cereals, rice, refined grains,
2. Fruits were divided into 2 subgroups: berries and citrus, and other fruits and juices.
3. Vegetables group with seven subgroups: potatoes, tomatoes, other starchy vegetables (sweetcorn, pea, eggplant, squash),

legumes (pease, beans, - lentils), yellow vegetables (carrots and pumpkin), and green vegetables (bell peppers, all kinds of cabbage, broccoli, celery, cucumbers, garlic, onion, green beans, zucchini, leeks, parsley, lettuce, radish, spinach, turnips).

4. The meat group was divided into four subgroups: red meat, poultry, fish, and eggs.

5. The dairy group was divided into three subgroups: milk (low-fat and full-fat), yogurt (low-fat and full-fat), and cheese.

Fats and sugars were excluded from the DDS calculation.

To be considered as a consumer of a food group, it is necessary that at least a half-serving of that food group should be consumed per day by individuals. Each of the five main groups is evaluated at two scores. If all food groups-are consumed, the DDS is 10 points. This two scores was divided among the subgroups. For example; There are 7 subgroups in the grain group. Someone who consumes 5 of the grain groups;  $(2/7) \times 5 = 1.43$  points. The points obtained from five groups are summed, and the total DDS score is obtained (2).

### Statistical Analysis

Data were analyzed using SPSS, version 29.0 (IBM Corp, Armonk, NY, USA). Compliance with normal distribution was examined using Shapiro-Wilk and Kolmogorov-Smirnov tests. Mean  $\pm$  standard deviation and median [interquartile range (IQR) Q1-Q3] values were used in descriptive statistics for continuous variables. Independent two-sample t-test was used to compare normally distributed data according to paired groups, and Mann-Whitney U test was used to compare non-normally distributed data. To create balanced groups according to DDS, dietary diversity status was divided into tertiles based on 33.3% and 66.6% percentiles of the series. Individuals in the top 33.3 percent were classified as having low dietary diversity, while those in the 33.3 percent to 66.6 percent decile were considered to have moderate dietary diversity. Those with values above 66.6 percent were classified as having high dietary diversity. A DDS  $< 4.09$  was classified as tertile 1 (46 individuals), 4.09-4.96 as tertile 2 (48 individuals), and  $> 4.96$  as tertile 3 (47 individuals). One-way analysis of variance (ANOVA) was used to compare normally distributed data for groups of three and more than three, and multiple comparisons were analyzed with the Tukey HSD test. Kruskal-Wallis test was used to evaluate non-normally distributed data for groups of three or more, and multiple comparisons were subsequently analyzed with Dunn's test, if indicated. Pearson correlation analysis was used for normally distributed data, and Spearman correlation analysis was used for non-normally distributed data. Multiple Linear Regression Analysis was performed to determine the effect of independent variables on the dependent variable (DDS). Variables that showed a significant correlation with DDS were included in the multiple regression model, taking into account

confounding factors (age, gender, BMI-SDS, total energy intake, Statistical significance was accepted if  $p < 0.05$ .

### Results

The mean age of the adolescents was  $14.81 \pm 1.94$  years. Of the individuals, 70 (49.6%) were boys. Table 1 shows the distribution of general characteristics of the individuals according to gender. A statistically significant difference was found between genders for BMI-SDS, body weight-SDS, fat percentage, systolic and diastolic blood pressure, visceral adiposity index, and body shape index ( $p < 0.05$ ). The BMI-SDS and body weight-SDS scores of boys were lower than those of girls ( $p < 0.05$ ). It was found that girls had higher fat percentage ( $p = 0.012$ ) and lower systolic and diastolic blood pressure than boys ( $p < 0.05$ ). The visceral adiposity index was higher in girls ( $p = 0.048$ ), while the body shape index was higher in boys ( $p = 0.020$ ). Other demographic data, anthropometric measurements, biochemical findings, and index scores were similar between genders ( $p > 0.05$ ).

DDS by gender is shown in Table 2. Boys have higher fruit group DDS ( $p = 0.005$ ) and milk group DDS ( $p = 0.018$ ) than girls. No significant difference was found between the meat group DDS, the vegetable group DDS, the grain group DDS, and total DDS by gender ( $p > 0.05$ ).

Comparison of anthropometric measurements, biochemical findings, and index scores by DDS are presented in Table 3. Significant differences were observed between tertiles in terms of insulin ( $p < 0.001$ ), HOMA-IR ( $p < 0.001$ ), and triglyceride/glucose index ( $p = 0.034$ ) values. Insulin and HOMA-IR values differed between the three tertiles, with individuals in Tertile 1 having higher insulin and HOMA-IR values than those in the other tertiles ( $p < 0.001$ ). The triglyceride/glucose index value was found to be lower in individuals in Tertile 3 compared to those in Tertile 1 ( $p = 0.028$ ). In individuals in Tertile 3, fibre ( $p = 0.002$ ), vegetable ( $p < 0.001$ ), and whole grain ( $p < 0.001$ ) intake was higher than in other tertiles, while refined grain ( $p < 0.001$ ) and meat consumption ( $p = 0.013$ ) were lower than in other tertiles. There were no significant differences between individuals for the other parameters according to tertiles ( $p > 0.05$ ).

Table 4 shows the relationship between DDS and anthropometric measurements, biochemical findings, and index scores. DDS was negatively correlated with fasting blood sugar ( $\rho = -0.177$ ;  $p = 0.036$ ), insulin ( $\rho = -0.633$ ;  $p < 0.001$ ), triglycerides ( $\rho = -0.223$ ;  $p = 0.008$ ), HOMA-IR ( $\rho = -0.656$ ;  $p < 0.001$ ), visceral adiposity index ( $\rho = -0.228$ ;  $p = 0.007$ ), triglyceride/glucose index ( $\rho = -0.251$ ;  $p = 0.003$ ), and LAP index ( $\rho = -0.200$ ;  $p = 0.018$ ).

The results of the multiple regression analysis are shown in Table 5. In the regression analysis, at least one of the independent variables was found to be a significant factor (DDS:  $F = 6.917$  and

p<0.001). Fasting blood glucose (B=-0.017; p=0.039) was found to have significant effects on DDS and explained approximately 35% of the variance (R<sup>2</sup>adj=0.355).

## Discussion

Identifying risk factors for obesity in adolescents will be important for identifying the most appropriate way to intervene, ideally before obesity, and reduce cardiovascular risk (2). Diet, insulin resistance, and adiposity, particularly visceral fat, contribute

significantly to the development of obesity (4). Previous studies have examined the potential contribution of diet to serum insulin levels and body (4,25,26). However, there are few studies on the effect of diet composition on visceral adiposity, and triglyceride/glucose, LAP, and body shape indexes, which are strong predictors of cardiometabolic risk. This study found that as the DDS increased, the scores for the visceral adiposity index, triglyceride/obesity index, and LAP index, used to predict metabolic obesity, decreased. DDS is an important parameter

**Table 1. Distribution of general characteristics of individuals by gender**

	Boys (n=70)	Girls (n=71)	Total (n=141)	p
Age (years)	14.50±1.82	15.11±2.02	14.81±1.94	0.061*
Mother's age (years)	40.47±5.64	41.25±5.98	40.87±5.81	0.426*
Father's age (years)	43.96±5.32	44.90±5.64	44.43±5.48	0.308*
BMI-SDS	2.01 (1.61-2.55)	2.39 (1.76-2.99)	2.16 (1.72-2.75)	0.012**
Body weight-SDS	1.73±0.91	2.35±1.42	2.04±1.23	0.003*
Fat mass (kg)	24.30 (19.90-34.80)	26.20 (21.20-32.70)	25.50 (20.70-33.10)	0.561**
Fat percentage (%)	33.65±8.28	36.65±5.44	35.16±7.13	0.012*
Fasting blood sugar (mg/dL)	90 (84-96)	88 (82-93)	89 (84-94.60)	0.178**
Insulin (µU/L)	20.61 (13.04-31.11)	23.15 (13.70-29.38)	21.70 (13.70-30.75)	0.928**
Total cholesterol (mg/dL)	161.81±33.68	164.01±32.06	162.92±32.78	0.692*
LDL (mg/dL)	94 (78-108.92)	93 (77-102)	93 (78-105)	0.585**
HDL (mg/dL)	43 (38.30-49.70)	46.50 (40.21-51.50)	44 (39.50-50.70)	0.136**
Triglycerides (mg/dL)	110.30 (84.90-159.90)	101 (76-131.60)	102.60 (80.80-150.80)	0.158**
Systolic blood pressure (mmHg)	130 (120-140)	130 (120-130)	130 (120-140)	0.022**
Diastolic blood pressure (mmHg)	75 (70-80)	70 (70-75)	70 (70-80)	0.006**
HOMA-IR	4.48 (2.93-6.96)	5.03 (3.15-6.92)	4.87 (3.13-6.93)	0.916**
Visceral adiposity index	1.55 (1.01-2.38)	1.82 (1.37-2.68)	1.68 (1.13-2.50)	0.048**
Triglyceride/glucose index	8.58 (8.26-8.84)	8.35 (8.13-8.68)	8.43 (8.17-8.82)	0.104**
Lipid accumulation product index	44.60 (33.91-70.23)	38.43 (28.39-64.67)	41.72 (30.17-65.33)	0.362**
Body shape index	0.0834±0.0045	0.0814±0.0054	0.0824±0.0051	0.020*

\*Independent two-sample t-test value is given as mean ± standard deviation, \*\*Mann-Whitney U test value is given as median (Q1-Q3: IQR-interquartile range). BMI-SDS: body mass index standard deviation score, VA-SDS: body weight standard deviation score, HDL: high-density lipoprotein, LDL: low-density lipoprotein, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance

**Table 2. Distribution of dietary diversity scores by gender**

	Boys (n=70)	Girls (n=71)	Total (n=141)	p
Meat group DDS	1.13 (0.72-1.43)	1.23 (0.87-1.51)	1.19 (0.81-1.46)	0.126**
Fruit group DDS	1.00 (0.66-1.49)	0.76 (0.39-1.12)	0.88 (0.51-1.23)	0.005**
Vegetable group DDS	0.92 (0.51-1.15)	0.90 (0.55-1.29)	0.90 (0.51-1.18)	0.479**
Dairy group DDS	0.71 (0.41-1.00)	0.54 (0.37-0.77)	0.65 (0.39-0.90)	0.018**
Cereal group DDS	0.90 (0.29-1.33)	0.91 (0.48-1.46)	0.90 (0.43-1.37)	0.349**
Total DDS	4.56±1.12	4.43±0.79	4.50±0.97	0.425*

\*Independent two-sample t-test value given as mean ± standard deviation, \*\*Mann-Whitney U test value given as median (Q1-Q3: IQR-interquartile range), p<0.05. DDS: dietary diversity score

**Table 3. Comparison of anthropometric measurements, biochemical findings and index scores according to tertiles of dietary diversity score**

	1 <sup>st</sup> tertile [ $<4.09$ ] low (n=46)	2 <sup>nd</sup> tertile [4.09-4.96] medium (n=48)	3 <sup>rd</sup> tertile [ $>4.96$ ] high (n=47)	p
BMI-SDS	2.17 (1.76-2.75)	2.11 (1.72-2.77)	2.20 (1.71-2.79)	0.946**
Body weight-SDS	2.12±1.24	2.17±1.08	1.84±1.36	0.371*
Fat mass (kg)	25.75 (21.20-34.00)	25.75 (21.40-32.85)	24.40 (19.30-33.90)	0.716**
Fat percentage (%)	35.03±7.45	35.04±7.15	35.40±6.93	0.961*
Fasting blood sugar (mg/dL)	91 (87-96)	86 (80.15-94.30)	88 (83-93)	0.072**
Insulin (µU/L)	31.72 (23.17-42.83) <sup>a</sup>	21.70 (14.84-27.37) <sup>b</sup>	13.04 (10.38-20.68) <sup>c</sup>	$<0.001^{**}$
Total cholesterol (mg/dL)	161.92±34.53	167.31±26.82	159.41±36.54	0.489*
LDL (mg/dL)	93.50 (79-108.28)	90 (77.50-103)	94 (77.80-107.20)	0.782**
HDL (mg/dL)	42.65 (39.90-48)	46.15 (40-53)	43.70 (37.20-50.70)	0.266**
Triglycerides (mg/dL)	111.75 (89.40-166.50)	102.80 (81.85-155.90)	98.30 (66.10-131.60)	0.074**
Systolic blood pressure (mmHg)	130 (120-140)	130 (120-140)	125 (120-140)	0.369**
Diastolic blood pressure (mmHg)	70 (70-80)	70 (70-80)	70 (70-80)	0.910**
HOMA-IR	7.07 (5.03-10.05) <sup>a</sup>	4.79 (3.46-6.49) <sup>b</sup>	2.80 (2.28-4.40) <sup>c</sup>	$<0.001^{**}$
Visceral adiposity index	2.03 (1.26-2.77)	1.60 (1.39-2.53)	1.52 (0.95-2.30)	0.081**
Triglyceride/glucose index	8.57 (8.27-8.90) <sup>a</sup>	8.46 (8.17-8.87) <sup>a,b</sup>	8.31 (8.05-8.63) <sup>b</sup>	0.034**
Lipid accumulation product index	48.31 (34.44-71.50)	45.04 (32.32-72.03)	37.93 (25.70-61.16)	0.106**
Body shape index	0.0816±0.004	0.0829±0.004	0.0828±0.005	0.435*
Energy (kcal)	2118.26±103.44	2133.61±188.13	2097.81±216.22	0.319*
Carbohydrates (%)	49.08±3.5	48.62±2.9	48.79±3.5	0.459*
Proteins (%)	14.04±2.66	13.87±3.04	14.21±2.15	0.501*
Fats (%)	35.92±2.74	36.23±3.12	35.61±2.18	0.662*
Fiber (g)	20.61.±2.19 <sup>a</sup>	19.74±3.15 <sup>a</sup>	24.69±2.57 <sup>b</sup>	0.002*
Whole grains (g)	103.17.±25.23 <sup>a</sup>	147.47±15.19 <sup>a</sup>	239.52±13.08 <sup>b</sup>	$<0.001^*$
Refined grains (g)	352.14±18.35 <sup>a</sup>	271.22±20.15 <sup>a</sup>	205.35±31.28 <sup>b</sup>	$<0.001^*$
Fruits (g)	296.55±126.17	319.63±149.37	336.13±105.40	0.103*
Vegetable (g)	288.24±100.15 <sup>a</sup>	269.38±93.63 <sup>a</sup>	361.79±65.48 <sup>b</sup>	$<0.001^*$
Dairies (g)	455.86±76.84	478.5±101.62	446.32±92.17	0.516*
Meat (g)	171.77±62.11 <sup>a</sup>	163.80±54.22 <sup>a</sup>	127.52±55.13 <sup>b</sup>	0.013*
Legumes (g)	19.88±10.14 <sup>a</sup>	17.65±11.29 <sup>a</sup>	23.93±14.86 <sup>b</sup>	0.004*

\*One-way analysis of variance value is given as mean ± standard deviation, \*\*Kruskal-Wallis test value is given as median (Q1-Q3: IQR-interquartile range). \*c: There is no difference between groups with the same letter.  
BMI-SDS: body mass index-standard deviation score, BW-SDS: body weight standard deviation score, HDL: high-density lipoprotein, LDL: low-density lipoprotein, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance

used to assess nutrient adequacy, overall diet quality, and the diet-disease relationship. It has been reported that a higher DDS is closely associated with a healthy diet with better nutrient adequacy and diet quality (2). It has been shown that DDS has an inverse relationship with metabolic syndrome and also with high blood pressure, high triglyceride levels, and abnormal glucose homeostasis (27). In the present study, a negative relationship was identified between DDS and fasting blood sugar, insulin, triglycerides, and HOMA-IR. When we excluded confounding factors, the single factor affecting DDS was fasting blood glucose.

Visceral adipose tissue is considered an independent risk factor for cardiovascular diseases due to its role in regulating glucose, lipid metabolism, and blood pressure (9). The visceral adiposity index has been identified as a new cardiometabolic risk marker in recent decades because it reflects abdominal fat distribution and dyslipidaemia. The triglyceride/glucose index and LAP index are good markers of insulin sensitivity and are associated with insulin resistance (4). It has been reported that visceral adipose tissue is affected by changes in diet and lifestyle (4,9). In the present study, as the DDS scores of obese adolescents increased,

Table 4. Relationship between dietary diversity score and anthropometric measurements, biochemical findings, and index scores		
	Dietary Diversity Score	
	r	p
Body weight-SDS	-0.080	0.347*
Fat percentage (%)	-0.024	0.780*
Total cholesterol (mg/dL)	-0.062	0.468*
Body shape index	0.074	0.384*
Energy (kcal) (day)	-0.077	0.369*
	rho	p
BMI-SDS	-0.009	0.920**
Fat mass (kg)	-0.075	0.379**
Fasting blood sugar (mg/dL)	-0.177	0.036**
Insulin (μU/L)	-0.633	<0.001**
LDL (mg/dL)	-0.018	0.834**
HDL (mg/dL)	0.047	0.580**
Triglycerides (mg/dL)	-0.223	0.008**
Systolic blood pressure (mmHg)	-0.144	0.088**
Diastolic blood pressure (mmHg)	-0.038	0.657**
HOMA-IR	-0.656	<0.001**
Visceral adiposity index	-0.228	0.007**
Triglyceride/glucose index	-0.251	0.003**
Lipid accumulation product index	-0.200	0.018**

\*Pearson correlation analysis, \*\*Spearman correlation analysis.  
BMI-SDS: body mass index-standard deviation score, BW-SDS: body weight standard deviation score, HDL: high-density lipoprotein, LDL: low-density lipoprotein, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance

Table 5. Multiple regression results for different factors affecting the dietary diversity score						
Dependent	Independent	Unstandardized coefficients		Standardized coefficients		Significance of the model
		B±SE	95% CI	Beta	p	
Dietary diversity score	Constant	9.505±2.862	3.841/15.169		0.001	F=6.917 p<0.001 R²=0.355
	Fasting blood sugar (mg/dL)	-0.017±0.008	-0.032/-0.001	-0.204	0.039	
	Insulin (μU/L)	-0.035±0.018	-0.071/0.001	-0.592	0.057	
	Triglycerides (mg/dL)	-0.008±0.005	-0.018/0.003	-0.594	0.155	
	HOMA-IR	0.022±0.078	-0.133/0.177	0.087	0.782	
	Visceral adiposity index	0.094±0.106	-0.116/0.305	0.212	0.378	
	Triglyceride/glucose index	-0.017±0.394	-0.796/0.762	-0.009	0.966	
	Lipid accumulation product index	0.006±0.006	-0.005/0.018	0.299	0.279	

B: unstandardized coefficient, SE: standard error, CI: confidence interval, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance

the visceral adiposity index, triglyceride/glucose index, and LAP index used to predict metabolic obesity decreased. In an earlier study examining the effects of different dietary patterns on body composition, it was found that the Western-style dietary pattern positively affected the fat mass index/FFM index ratio, while the “vegetable and fruit”-based dietary pattern negatively affected the fat mass index/FFM index ratio (28). It has been reported that adolescents with low DDS have a higher body fat percentage than adolescents with high DDS (29). However, in our study, no relationship was found between DDS and anthropometric measurements, such as BMI, fat percentage, fat mass. This may be explained because our study sample consisted of obese individuals and that energy, carbohydrate, fat, and protein intake were similar across DDS groups which may have contributed to this finding.

The inverse relationship between DDS and metabolic risks may be attributed to the increased consumption of healthier food groups associated with high DDS (2). The present study found that although adolescents’ energy intakes were similar regardless of their DDS scores, adolescents with high DDS consumed more fibre, vegetables, whole grains, legumes, and less refined grains and meat. Vizzuso et al. (11) found that energy intake was positively associated with BMI z-score, but no association was found with visceral adiposity index. In this study, while total energy intake was not associated with cardiometabolic risk markers, it was observed that meal pattern affected DDS and DDS was associated with cardiometabolic risk markers. In another study, healthy plant-based diet index scores were found to be associated with better anthropometric measurements and HDL-C levels compared to unhealthy plant-based diet index scores, and were also found to reduce LAP levels (3). It has been reported that healthy diet models had no effect on triglyceride/glucose indices compared to a Western-style diet or a mix of healthy and Western-style diets, but they did cause a decrease in LAP levels. Individuals with the highest healthy diet model scores were 71% less likely to have high LAP levels compared to those in the lowest category (4). Mazidi et al. (26) also reported positive correlations between the visceral adiposity index and glucose/insulin homeostasis markers and the consumption of carbohydrates and sugar, total fat and saturated fatty acids, as well as negative correlations between fibre, vitamin, and mineral intake and the visceral adiposity index and LAP indices, findings similar to those of the present study. In addition, it has been noted that there is an inverse relationship between a diet rich in monounsaturated and polyunsaturated fatty acids and fasting blood glucose and LAP indices (26). Studies have reported a negative relationship between the Dietary Approaches to Stop Hypertension diet index, which is based on increasing the consumption of vegetables, fruits, whole grains, legumes, and white meat, while reducing the consumption of red meat, refined carbohydrates, and sugary beverages, and the visceral adiposity

index (30). and a negative relationship between the anti-inflammatory diet and triglyceride/glucose indices (4). A study examining the relationship between whole grain consumption and insulin resistance, glucose homeostasis, and inflammation found that high whole grain consumption was associated with lower C-reactive protein, apolipoprotein B, fasting blood glucose, insulin, homeostatic model assessment of insulin resistance (HOMA-β), hemoglobin A1c, and glucose levels when comparing the group with high whole grain product consumption to the group with low whole grain product consumption (26).

Adolescents are generally influenced by their peers, have greater freedom of choice in food, and tend to choose unhealthy foods. Good growth and development require a variety of foods from various food groups (vegetables, fruits, whole grains, and animal-based foods) and a balanced intake of vitamins. Dietary diversity consists of all food groups (grains, vegetables, fruits, meat, and dairy products) necessary for growth and development, and high dietary diversity is associated with healthy food groups, such as vegetables, fruits, and fibre (2). In the present study, individuals with high dietary diversity were found to have a reduced risk of metabolic syndrome. The proposed mechanism explaining the results obtained from implementing a dietary model with high dietary diversity is that the higher fibre content of vegetables, whole grain products, and legumes may lead to lower nutrient absorption or energy intake, affecting total fat mass and visceral fat accumulation (1,26). Higher fibre intake has been shown to improve insulin resistance and reduce visceral adiposity (4,31). High fibre intake, which is broken down into short-chain fatty acids by the gut microbiota, is known to improve insulin sensitivity or insulin resistance (3). Low-glycemic index carbohydrates found in vegetables, whole grains, and legumes may also reduce insulin resistance (32). The chronic low grade inflammatory state is a common condition in obesity and associated with multiple metabolic complications (1,32). Moreover, the anti-inflammatory and antioxidant properties of vegetables, fibre, and legumes may be associated with lower systemic inflammation. Soluble fibre, in particular, binds to bile acids in the small intestine, increasing the excretion of bile salts in the feces, lowering cholesterol, and regulating postprandial insulinemic and glycemic responses (33).

High intake of antioxidants and micronutrients from plant-based foods also represents another potential cardioprotective mechanism. This antioxidant capacity, combined with the potential to modulate nitric oxide production, enhances the ability of polyphenolic compounds to maintain vascular homeostasis (34). In the present study, refined grain and meat consumption were significantly reduced in the tertile with the highest dietary diversity. Low intakes of animal protein and saturated fatty acids have been reported to effectively prevent obesity. In addition, animal proteins are rich in other nutrients,

such as iron, sodium, and nitrites obtained from processed meats, increasing the risk of cardiometabolic diseases (35). Refined grains have high carbohydrate content, which leads to a high dietary glycemic load. Compared to whole grain products, refined grains are rapidly absorbed due to their high glycemic load, leading to increased fasting blood sugar and insulin resistance. Unlike refined grains, whole grain products are high in dietary fibre, trace elements, and phytochemicals, and their nutrients and nutritional components have beneficial effects on metabolic syndrome (36).

### Study Limitations

This study has some limitations. The study included only obese adolescents from a single tertiary center. Without a healthy control group, the ability to generalize the findings or assess relative risk is limited. The diet history method has some limits in accuracy. All self-reported dietary assessment methods are subject to both random and systematic measurement errors. However, retrospective food consumption records do not have the potential recall bias caused by food consumption frequency questionnaires. The cross-sectional nature of the study, preventing any causal inferences, the division of DDS into tertiles, potentially leading to misclassification in the data, and the small sample size are the other limitations of the study. This study also has strengths. It is the first study to examine the effect of dietary diversity on cardiometabolic risk markers, such as visceral adiposity, triglyceride/glucose, LAP, and body shape indices. Other strengths include the control of a wide range of potential confounding factors to obtain an independent relationship, the calculation of DDS from food consumption records by a trained dietitian, and the homogeneity of the sample due to the adolescents participating in the study being from the same geographical region and sharing similar cultures, lifestyles, and eating habits. Finally, using food combinations rather than single foods to examine the specified relationships provided more accurate information and should be considered an additional strength.

### Conclusion

DDS were inversely associated with visceral adiposity, triglyceride/glucose, and LAP indexes in this cohort of obese adolescents. Furthermore, as dietary diversity scores increased, fasting blood sugar, insulin, triglyceride, and HOMA-IR levels decreased. Increased dietary diversity was found to be positively associated with biomarkers of metabolic syndrome. Strategies aimed at increasing dietary diversity through nutritional interventions may have a positive effect, particularly on insulin resistance and cardio-metabolic risk. Extensive prospective studies focusing on different populations are needed to confirm these findings.

### Ethics

**Ethics Committee Approval:** Ethical approval was obtained from the Gazi University Ethics Committee (approval number: 2025-164, date: 05.02.2025).

**Informed Consent:** Clear explanations were provided with regard to the purpose of the study, after which written informed consent was obtained from the adolescents in accordance with the Declaration of Helsinki.

### Footnotes

#### Authorship Contributions

Surgical and Medical Practices: Aysun Bideci, Mahmut Orhun Çamurdan, Aylin Kılınç Uğurlu, Esra Döğër, Mehmet Ali Oktay, Ulaş Akçay, Concept: Rukiye Bozbulut, Mehmet Ali Oktay, Ulaş Akçay, Esra Döğër, Aylin Kılınç Uğurlu, Mahmut Orhun Çamurdan, Aysun Bideci, Design: Rukiye Bozbulut, Mehmet Ali Oktay, Ulaş Akçay, Esra Döğër, Aylin Kılınç Uğurlu, Mahmut Orhun Çamurdan, Aysun Bideci, Data Collection or Processing: Rukiye Bozbulut, Mehmet Ali Oktay, Ulaş Akçay, Analysis or Interpretation: Esra Döğër, Aylin Kılınç Uğurlu, Rukiye Bozbulut, Mehmet Ali Oktay, Ulaş Akçay, Literature Search: Rukiye Bozbulut, Writing: Rukiye Bozbulut.

**Financial Disclosure:** The authors declared that this study received no financial support.

### References

1. Gholami F, Karimi Z, Samadi M, Sovied N, Yekaninejad MS, Keshavarz SA, Javdan G, Bahrampour N, Wong A, Clark CCT, Mirzaei K. The association between dietary pattern and visceral adiposity index, triglyceride-glucose index, inflammation, and body composition among Iranian overweight and obese women. *Sci Rep.* 2023;13:13162.
2. Susmiati S, Lipoeto NI, Khairina I. Dietary diversity score and adolescent obesity among West Sumaterans girl. *Nutrición Clínica y Dietética Hospitalaria.* 2024;44:237-244.
3. Shahavandi M, Djafari F, Shahinfar H, Davarzani S, Babaei N, Ebaditabar M, Djafarian K, Clark CCT, Shab-Bidar S. The association of plant-based dietary patterns with visceral adiposity, lipid accumulation product, and triglyceride-glucose index in Iranian adults. *Complement Ther Med.* 2020;53:102531. Epub 2020 Aug 20
4. Amini MR, Shahinfar H, Babaei N, Davarzani S, Ebaditabar M, Djafarian K, Clark CCT, Shab-Bidar S. Association of dietary patterns with visceral adiposity, lipid accumulation product, and triglyceride-glucose index in Iranian adults. *Clin Nutr Res.* 2020;9:145-156.
5. Kim SK, Kim HJ, Hur KY, Choi SH, Ahn CW, Lim SK, Kim KR, Lee HC, Huh KB, Cha BS. Visceral fat thickness measured by ultrasonography can estimate not only visceral obesity but also risks of cardiovascular and metabolic diseases. *Am J Clin Nutr.* 2004;79:593-599.
6. Akbaş F, Atmaca HU, Değirmenciöğlü Ş. Evaluation of the relationship between metabolic syndrome, visceral adiposity index and lipid accumulation product in patients with obesity. *J Acad Res Med.* 2021;11:56-61.
7. Frühbeck G, Busetto L, Dicker D, Yumuk V, Goossens GH, Hebebrand J, Halford JGC, Farpour-Lambert NJ, Blaak EE, Woodward E, Toplak H. The ABCD of obesity: an EASO position statement on a diagnostic term with clinical and scientific implications. *Obes Facts.* 2019;12:131-136. Epub 2019 Mar 7

8. Elffers TW, de Mutsert R, Lamb HJ, de Roos A, Willems van Dijk K, Rosendaal FR, Jukema JW, Trompet S. Body fat distribution, in particular visceral fat, is associated with cardiometabolic risk factors in obese women. *PLoS One*. 2017;12:e0185403.
9. Yu SR, Shin KA. Visceral adiposity index and lipid accumulation product as effective markers of different obesity phenotypes in Korean adults: a cross-sectional analysis. *Diabetes Metab Syndr Obes*. 2023;16:495-504.
10. Kahaer M, Zhang B, Chen W, Liang M, He Y, Chen M, Li R, Tian T, Hu C, Sun Y. Triglyceride glucose index is more closely related to hyperuricemia than obesity indices in the medical checkup population in Xinjiang, China. *Front Endocrinol (Lausanne)*. 2022;13:861760.
11. Vizzuso S, Del Torto A, Dilillo D, Calcaterra V, Di Profio E, Leone A, Gilardini L, Bertoli S, Battezzati A, Zuccotti GV, Verduci E. Visceral adiposity index (VAI) in children and adolescents with obesity: no association with daily energy intake but promising tool to identify metabolic syndrome (MetS). *Nutrients*. 2021;13:413.
12. de Oliveira Otto MC, Anderson CAM, Dearborn JL, Ferranti EP, Mozaffarian D, Rao G, Wylie-Rosett J, Lichtenstein AH; American Heart Association Behavioral Change for Improving Health Factors Committee of the Council on Lifestyle and Cardiometabolic Health and Council on Epidemiology and Prevention; Council on Cardiovascular and Stroke Nursing; Council on Clinical Cardiology; and Stroke Council. Dietary diversity: implications for obesity prevention in adult populations: a science advisory from the American Heart Association. *Circulation*. 2018;138:e160-e168. Erratum in: *Circulation*. 2018;138:e712.
13. Mirmiran P, Azadbakht L, Azizi F. Dietary diversity within food groups: an indicator of specific nutrient adequacy in Tehranian women. *J Am Coll Nutr*. 2006;25:354-361.
14. Azadbakht L, Esmailzadeh A. Dietary diversity score is related to obesity and abdominal adiposity among Iranian female youth. *Public Health Nutr*. 2011;14:62-69. Epub 2010 Mar 31
15. Kant AK, Schatzkin A, Harris TB, Ziegler RG, Block G. Dietary diversity and subsequent mortality in the first national health and nutrition examination survey epidemiologic follow-up study. *Am J Clin Nutr*. 1993;57:434-440.
16. Li H, Li D, Wang X, Ding H, Wu Q, Li H, Wang X, Li K, Xiao R, Yu K, Xi Y. The role of dietary patterns and dietary quality on body composition of adolescents in Chinese college. *Nutrients*. 2022;14:4544.
17. Neyzi O, Bundak R, Gökçay G, Günöz H, Furman A, Darendeliler F, Baş F. Reference values for weight, height, head circumference, and body mass index in Turkish children. *J Clin Res Pediatr Endocrinol*. 2015;7:280-293.
18. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, Jones DW, Kurtz T, Sheps SG, Roccella EJ. Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Circulation*. 2005;111:697-716.
19. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*. 1985;28:412-419.
20. Amato MC, Giordano C, Galia M, Criscimanna A, Vitabile S, Midiri M, Galluzzo A; AlkaMeSy Study Group. Visceral adiposity index: a reliable indicator of visceral fat function associated with cardiometabolic risk. *Diabetes Care*. 2010;33:920-922. Epub 2010 Jan 12
21. Guerrero-Romero F, Simental-Mendía LE, González-Ortiz M, Martínez-Abundis E, Ramos-Zavala MG, Hernández-González SO, Jacques-Camarena O, Rodríguez-Morán M. The product of triglycerides and glucose, a simple measure of insulin sensitivity. Comparison with the euglycemic-hyperinsulinemic clamp. *J Clin Endocrinol Metab*. 2010;95:3347-3351. Epub 2010 May 19
22. Ebrahimi M, Seyedi SA, Nabipoorashrafi SA, Rabizadeh S, Sarzaeim M, Yadegar A, Mohammadi F, Bahri RA, Pakravan P, Shafiekhani P, Nakhjavani M, Esteghamati A. Lipid accumulation product (LAP) index for the diagnosis of nonalcoholic fatty liver disease (NAFLD): a systematic review and meta-analysis. *Lipids Health Dis*. 2023;22:41.
23. Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. *PLoS One*. 2012;7:e39504. Epub 2012 Jul 18
24. Korir L, Ehiakpor DS, Danso-Abbeam G, Djokoto JG, Rizov M. Balanced choices: examining the impact of dietary diversity on BMI, health risks, and rising rates of obesity in Kenya. *Obesities*. 2024;4:509-523.
25. Cañete R, Gil-Campos M, Aguilera CM, Gil A. Development of insulin resistance and its relation to diet in the obese child. *Eur J Nutr*. 2007;46:181-187. Epub 2007 Mar 26
26. Mazidi M, Katsiki N, Kengne AP, Mikhailidis DP, Banach M. Adiposity mediates the association between whole grain consumption, glucose homeostasis and insulin resistance: findings from the US NHANES. *Lipids Health Dis*. 2018;17:219.
27. Heidari S, Kahnooji M, Ayoobi F, Khalili P, Ghaseminasab-Parizi M, Soltani L. Relationship between metabolic syndrome and dietary diversity in the Rafsanjan cohort study. *Sci Rep*. 2025;15:10579.
28. Haq IU, Mariyam Z, Zeb F, Jiang P, Wu X, Shah J, Xu C, Zhou M, Feng Q, Li M. Identification of body composition, dietary patterns and its associated factors in medical university students in China. *Ecol Food Nutr*. 2020;59:65-78. Epub 2019 Sep 9
29. Azadbakht L, Esmailzadeh A. Dietary diversity score is related to obesity and abdominal adiposity among Iranian female youth. *Public Health Nutr*. 2011;14:62-69. Epub 2010 Mar 31
30. Silveira BKS, de Novaes JF, Reis NA, Lourenço LP, Capobianco AHM, Vieira SA, Hermsdorff HHM. "Traditional" and "Healthy" dietary patterns are associated with low cardiometabolic risk in Brazilian subjects. *Cardiol Res Pract*. 2018;2018:4585412.
31. Jenkins DJ, Jenkins AL, Wolever TM, Rao AV, Thompson LU. Fiber and starchy foods: gut function and implications in disease. *Am J Gastroenterol*. 1986;81:920-930.
32. Mazidi M, Gao HK, Kengne AP. Lipid accumulation product and visceral adiposity index are associated with dietary patterns in adult Americans. *Medicine (Baltimore)*. 2018;97:e0322.
33. Gunness P, Gidley MJ. Mechanisms underlying the cholesterol-lowering properties of soluble dietary fibre polysaccharides. *Food Funct*. 2010;1:149-155. Epub 2010 Sep 30
34. Quiñones M, Miguel M, Aleixandre A. Beneficial effects of polyphenols on cardiovascular disease. *Pharmacol Res*. 2013;68:125-131. Epub 2012 Nov 19
35. Bray GA, Lovejoy JC, Smith SR, DeLany JP, Lefevre M, Hwang D, Ryan DH, York DA. The influence of different fats and fatty acids on obesity, insulin resistance and inflammation. *J Nutr*. 2002;132:2488-2491.
36. Guo H, Ding J, Liang J, Zhang Y. Associations of whole grain and refined grain consumption with metabolic syndrome. A meta-analysis of observational studies. *Front Nutr*. 2021;8:695620.