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Children-Dietary Inflammatory Index and Adherence to the Mediterranean Diet in Children with Obesity: Are They Associated with Cardiometabolic Risk Parameters?

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ABSTRACT

Purpose: This study was planned to assess the relationship between the children's dietary inflammatory index (cDII), adherence to the Mediterranean diet (AMD), and metabolic control parameters in children with overweight and obesity.

Methods: This cross-sectional study was conducted in children with overweight and obesity aged 7-18 years. Sociodemographic, biochemical, dietary, and lifestyle data were collected using a questionnaire. Mediterranean Diet Quality Index (KIDMED) was used to evaluate AMD. Anthropometric measurements were performed. Dietary intake and cDII were assessed with a three-day food consumption record.

Results: The mean cDII score was 2.2±0.94 (range from -0.43 to 4.39). Of the total participants, 12% had high and 38.7% had low AMD. There were no significant differences between cDII and biochemical and anthropometric parameters. The proportion of participants with insulin resistance was higher in the low AMD group than in the moderate/high adherence group (53.4% vs. 37.0%, p=0.047). There was no significant relationship between AMD and lipid profile. Logistic regression analysis showed that participants with low AMD were 2.055 times (95% CI 1.009-4.186, OR=2.055) more likely to have high insulin levels than participants with high AMD (p=0.047).

Conclusion: This study showed that low AMD was associated with high insulin levels, but cDII was not associated with cardiometabolic risk factors in children with overweight and obesity.

Keywords: Diet, inflamation, Mediterranean diet, childhood obesity, cardiometabolic risk

Obezitesi Olan Çocuklarda Çocuk-Diyet İnflamatuar İndeksi ve Akdeniz Diyetine Uyum: Kardiyometabolik Risk Parametreleri ile İlişkili mi?

ÖZET

Amaç: Bu çalışma, fazla kilolu ve obezitesi olan çocuklarda çocukların diyet inflamatuvar indeksi (cDII), Akdeniz diyet uyumu (AMD) ve metabolik kontrol parametreleri arasındaki ilişkiyi değerlendirmek için planlandı.

Yöntemler: Bu kesitsel çalışma 7-18 yaş arası fazla kilolu ve obezitesi olan çocuklarda yapılmıştır. Sosyodemografik, biyokimyasal, diyet ve yaşam tarzı verileri bir anket kullanılarak toplanmıştır. AMD'yi değerlendirmek için Akdeniz Diyet Kalite İndeksi (KIDMED) kullanıldı. Antropometrik ölçümler yapıldı. Besin alımı ve cDII üç günlük besin tüketim kaydı ile değerlendirildi.

Bulgular: Ortalama cDII skoru 2,2±0.94 (-0,43 ile 4,39 arası) idi. Toplam katılımcıların %12'si yüksek ve %38,7'si düşük AMD'ye sahipti. cDII ile biyokimyasal ve antropometrik parametreler arasında anlamlı fark yoktu. İnsülin direnci olan katılımcıların oranı düşük AMD grubunda orta/yüksek uyum grubuna göre daha yüksekti (%53,4'e karşı %37,0, p=0,047). AMD ile lipit profili arasında anlamlı bir ilişki yoktu. Logistik regresyon analizi düşük AMD'li katılımcıların yüksek insülin düzeylerine sahip olma olasılığının, yüksek AMD'li katılımcılara göre 2,055 kat (%95 CI 1,009-4,186, OR=2,055) daha fazla olduğunu gösterdi.

Sonuç: Bu çalışma, fazla kilolu ve obezitesi olan çocuklarda düşük AMD'nin yüksek insülin seviyeleri ile ilişkili olduğunu, cDII'nin kardiyometabolik risk faktörleri ile ilişkili olmadığını göstermiştir.

Anahtar Kelimeler: Diyet, inflamasyon, Akdeniz diyeti, çocukluk çağı obezitesi, kardiyometabolik risk

Childhood obesity has recently emerged as a major public health issue (1). It is an important risk factor for cardiometabolic disorders such as type 2 diabetes, insulin resistance, dyslipidemia, and hypertension. In addition, it is a potential risk factor for obesity in later life and is associated with higher rates of morbidity and mortality in adulthood (2). In parallel with the increase in obesity, cardiometabolic diseases are become highly prevalent, accounting for an estimated 17.9 million fatalities per year (3).

Unhealthy diets that are typically high in sugars, processed carbohydrates, saturated and trans fats have the potential to increase oxidative stress and proinflammatory cytokines. It has been reported that proinflammatory diets are correlated with systemic inflammation and cardiometabolic risk indicators (3-5). Contrastly, healthier eating patterns such as the "Mediterranean diet (MD)" rich in fruits, vegetables, whole grains, legumes, poultry, and fish are linked to lowered cardiometabolic risk and decreased systemic inflammation (3). The MD is potentially effective in maintaining cardiovascular health in adults (6, 7). While there is considerable evidence for the MD's metabolic benefits in adults, the effects of the MD on metabolic markers in children are not clear (7).

General dietary patterns do not adequately reflect the overall inflammatory potential of the diet. Therefore, the dietary inflammatory index (DII) has been developed to assess the inflammatory effects of consumed micro and macronutrients, and various food parameters (3, 8). The proinflammatory or anti-inflammatory effects of food parameters were determined by evaluating the production of inflammatory blood biomarkers. The DII scores have been associated with inflammatory biomarkers, cardiometabolic risk factors, and metabolic syndrome (MetS) in adults (5). However, few studies have investigated the relationship between DII and cardiometabolic risk factors in children, and the findings were conflicted (9, 10).

Given the increasing prevalence of cardiometabolic disorders in pediatric populations and their potential impact on future health, it is critical to determine dietary factors that contribute to poor cardiometabolic health in childhood (3). There is a gap in the literature regarding the relationship between dietary inflammatory potential and cardiometabolic risk factors in children. In addition, no data comparing the effect of adherence to the MD (AMD) and the "Children's Dietary Inflammatory Index" (cDII) on cardiometabolic health exist. Therefore, this study was planned to evaluate the relationship between AMD, cDII, and metabolic control parameters in children with obesity.

MATERIAL AND METHODS

Participants

This cross-sectional study was conducted in 150 children with overweight and obesity between November 2022 and May 2023 aged 7-18 years and admitted to the outpatient pediatric clinic of a university hospital. To determine the relationship between insulin levels and cDII for r = 0.3 effect size (the medium effect size), 95% power, and 5% type 1 error, the sample size was calculated as 134 using G*Power (versiyon 3.1.9.7) programme. Participants using medications that may affect body weight, blood glucose, and lipid profile, those who regularly used any nutritional supplements in the last three months, those with growth retardation, genetic and endocrine problems, those with chronic diseases, and those on a weight loss diet were excluded from the study. A total of 150 participants were included to the study. Each participant and his or her parents signed a written informed consent.

This study was carried out in accordance with the Helsinki Declaration criteria and approved by non-interventional clinical trials ethics committee with reference number 0391 and date 22.09.2022.

Data Collection

The study data were obtained through a questionnaire using face to face interview technique. The questionnaire consisted of six sections. In the first section, general information about the participants (age, gender, educational status, etc.) was taken. In the second section, participants' eating habits were evaluated. In the third section, the anthropometric measurements and body composition analyses were performed and recorded in the questionnaire. In the fourth section, "Mediterranean Diet Quality Index for Children (KIDMED)" was applied to evaluate AMD. In the fifth section, 3-day food consumption records were taken to calculate cDII. In the sixth section, a 24-hour physical activity record form was filled out.

Dietary Intake and cDII

A 3-day food consumption record was taken to evaluate the dietary intake of the participants and to calculate the cDII. The researcher taught participants and their parents how to keep food consumption records. The data obtained were analyzed using the nutrient analysis program (BEBIS).

The cDII is an index that was developed by allocating pro- or anti-inflammatory weights to 25 food components (energy, carbohydrate, protein, total fat, folic acid, fiber, iron, selenium, zinc, magnesium, vitamin A, vitamin D, vitamin B12, thiamine, vitamin C, vitamin E, riboflavin, niacin, vitamin B6, saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), cholesterol, alcohol, polyunsaturated fatty acid (PUFA), and beta carotene). These 25 food components obtained from a three-day food consumption record were used to calculate cDII in this study. Energy-adjusted cDII was utilized to minimize the difference in energy intake between participants by converting whole food parameters per 1000 kcal consumption. First, the z-scores were calculated and converted into percentile scores to normalize each dietary component. Second, to obtain a symmetric distribution, each percentile score was doubled and then "1" was subtracted. Third, the centralized percentile values for each food parameter were multiplied by the "customized full inflammatory effect score" and the resulting values were summed to obtain the cDII score. A high cDII score indicates that the diet shifts to the pro-inflammatory direction, while a low cDII score indicates that the diet has anti-inflammatory properties (11). Participants were categorized into low (<2.28) and high (≥ 2.28) cDII groups based on median cDII score

Anthropometric Measurements

Body weight and composition analyses were performed using the Tanita Body Composition 532 Innerscan brand bioelectrical impedance analyzer. Height was measured with a stadiometer with the head in the Frankford plane, with the feet together, the knees straight, and the heels, hips, and shoulder blades in contact with the vertical level (12). Body Mass Index (BMI) was calculated with the formula "BMI=[body weight (kg)/height (m^2)]". Waist, hip, and neck circumference measurements were made using a non-stretchable tape in accordance with the measurement method (12). BMI and height z scores were determined using the "WHO Antro Plus" program. Children with a BMI z score > +1 were included in this study.

Adherence to the MD

The KIDMED was applied to measure AMD. The KIDMED, developed by Serra-Majem et al. (13), is an index consisting of a total of 16 statements containing the characteristics of the MD, which can be applied spontaneously or interviewed. It was developed to measure dietary adequacy between the ages of 2-24. Of the expressions included in the KIDMED, 12 were positive and 4 were negative expressions, and those who answered yes to positive expressions got +1 and those who answered yes to negative expressions got -1 point. Afterward, total scores were divided into 3 groups ≥8 points for high AMD, 4-7 points for moderate AMD, and ≤3 points as low AMD (13).

Cardiometabolic Risk Factors

Biochemical parameters (fasting blood glucose, fasting insulin, low-density lipoprotein (LDL) cholesterol, alanine aminotransferase (ALT), triglyceride, high-density lipoprotein (HDL), and total cholesterol) were recorded from the patient files to assess cardiometabolic risk factors. Blood lipids of participants were grouped as high total cholesterol (≥200 mg/dL), high LDL cholesterol (≥130 mg/dL), high triglyceride (≥100 mg/dL for 0-9 years, ≥130 mg/dL for 10-18 years of age), and low HDL cholesterol (<40 mg/dL) (14). A fasting blood glucose level of ≥100 mg was classified as impaired fasting glucose and a fasting insulin level of ≥15 µU/mL was classified as hyperinsulinemia (15). The following formula was used to calculate the homeostatic model assessment of insulin resistance (HOMA-IR) =[Fasting blood glucose (mg/dL) × Fasting insulin (µU/mL)/405]. Insulin resistance was considered to be present if HOMA–IR ≥3.16 in pubertal participants and HOMA–IR ≥2 in prepubertal participants (16).

Physical Activity Levels

A 24-hour physical activity record form was used to determine the physical activity levels of participants. The time spent by the participants on daily sleep, laying activities, sitting activities, and light, moderate, and heavy activities were recorded on the physical activity record form. According to physical activity level (PAL values, participants were grouped as inactive (PAL<1.4), moderately active (PAL=1.4-1.69), and active (PAL≥1.7) (17).

Statistical Analysis

Statistical analyses were performed using the SPSS software version 25. To assess the conformity of the data to the normal distribution and analytical methods (Kolmogorov-Smirnov test) were used. Normally distributed data were expressed as mean and standard deviation, non-normally distributed data as the median and interquartile range (IQR), and categorical data as frequency and percentage. The Chi-Square test was used for categorical variables, the Student's t-test for regularly distributed data, and the Mann-Whitney U test for non-normally distributed variables when comparing two groups. In the comparison of the three groups, one-way ANOVA was used for normally distributed variables and the Kruskal-wallis test was used for non-normally distributed variables.

Posthoc tests were carried out when a significant difference was observed between the three groups (Tukey's test was used if variances were homogeneous, and the Tamhane T2 test was used if variances were not homogeneous). A partial correlation analysis was carried out to evaluate the relationship between anthropometric measurements and the KIDMED score, controlling for age. Logistic regression analysis was performed to evaluate the relationship between high insulin levels and insulin resistance with dietary indices. In the distribution of cardiometabolic risk factors according to the MD adherence groups of the participants, those with high and moderate adherence to the MD were combined. A p-value less than 0.05 was considered statistically significant in all analyses.

RESULTS

The general characteristics of the participants according to cDII and AMD groups are given in Table 1. The mean age was 12.2±2.82 years, 47.3% of them boys and 52.7% girls. The cDII mean of the participants was determined as 2.2±0.94, (range from -0.43 to 4.39) and the mean KIDMED score was 4.3±2.57. Of the total participants, 38.7% had low, 49.3% had moderate, and 12.0% had high AMD (not shown in table). The mean age of the participants with low and moderate AMD was found to be higher than those with high AMD group (p<0.001).

The energy and dietary intake of the participants according to cDII and AMD groups are presented in Table 2. The energy, carbohydrate, protein, animal protein, fat, SFA, MUFA, cholesterol, and vitamin B12 intake of the participants in the high DII group were significantly higher than those in the low cDII group. The low cDII group had higher fiber, vitamin E, and C intake and consumption of vegetables and fruits compared to the high cDII group. Vegetable consumption of the participants with high AMD was higher than those with low and moderate AMD (p=0.008).

The comparison of the biochemical, anthropometric, and body composition parameters of the participants according to the cDII and AMD groups is given in Table 3. Insulin levels and HOMA-IR values of participants with low AMD were significantly higher than those with high and moderate AMD. The LDL and total cholesterol levels of the participants with low AMD were found to be lower than those with high AMD. There were no significant differences between cDII groups and biochemical and anthropometric parameters. The body weights, neck, waist, and hip circumferences of the participants with low AMD were found to be significantly higher (p<0.05). There was no significant correlation between the KIDMED and body weight, height, neck, and hip circumferences (not shown in the table) when partial correlation analysis was performed by controlling the age.

The distribution of cardiometabolic risk factors according to cDII and AMD groups is shown in Table 4. The proportion of participants with high insulin levels (53.4%) was higher in participants with low AMD than in those with moderate/high AMD (32.6%) (p=0.011). The proportion of participants with insulin resistance was higher in the low AMD group than in the moderate/high AMD group (53.4% vs. 37.0%, p=0.047).

Binary logistic regression analysis was performed to evaluate the association of cDII score and AMD with high insulin levels and insulin resistance (Table 5). As a result, participants with low AMD were 2.055 times (95% CI 1.009-4.186, OR=2.055) more likely to have high insulin levels than participants with high AMD. The cDII scores and AMD were not associated with insulin resistance (Table 5).

DISCUSSION

This study showed a relatively low prevalence of high AMD over the studied population (12%). This finding is in line with a study conducted on Turkish adolescents with obesity, in which only 13.6 % of the participants adhered to the MD (18). cDII score of the studied population was ranged from -0.43 to 4.39. If the DII score is negative, the diet is thought to have anti-inflammatory effects; if the score is positive, the diet is assumed to have inflammatory effects (19). The DII score of Brazilian adolescents was found to be ranged from −2.8 to 4.3 (20). Açık et al. (10) found the mean cDII score in adolescents to be ranged from−3.22 to 4.09. Similarly, DII scores ranged from −4.87 (most anti-inflammatory) to 4.75 (most pro-inflammatory) in school-aged children (3). The data obtained showed that the diet in children with obesity shifted in a proinflammatory direction and moved away from the MD. These results suggest the need to improve diet quality in the studied population.

Table 1. General characteristics of the participants according to cDII and MD adherence groups

		cDII groups			Adherence to the MD groups			
	Total	**Low cDII (n=75)**	**High cDII (n=75)**	**p value**	**Low (n=58)**	**Moderate (n=74)**	**High (n=18)**	**p value**
Age (years) (x±SD)	12.2±2.82	12.1±2.88	12.4±2.77	0.437	13.2 ±2.51[a]	12.0±2.95[b]	10.3± 2.05[c]	**<0.001** a>b, a>c
Gender n (%)								
Boys	71 (47.3)	34 (45.3)	37 (49.3)	0.625	28 (48.3)	36 (48.6)	7 (38.9)	0.746
Girls	79 (52.7)	41 (54.7)	38 (50.7)		30 (51.7)	38 (51.4)	11 (61.1)	
Father education status n (%)								
No education	2 (1.3)	2 (2.7)	-	0.423	1 (1.7)	1 (1.4)	-	0.746
Primary school	55 (36.7)	29 (38.7)	26 (34.7)		17 (29.3)	30 (40.5)	8 (44.4)	
Secondary school	40 (29.7)	18 (24.0)	22 (29.3)		19 (32.8)	18 (24.3)	3 (16.7)	
High school/University	50 (33.3)	25 (33.3)	25 (33.3)		19 (32.8)	24 (32.4)	7 (38.9)	
Mother education status n (%)								
No education	9 (6.0)	5 (6.7)	4 (5.3)	0.492	4 (6.9)	3 (4.1)	2 (11.1)	0.736
Primary school	63 (42.0)	33 (44.0)	30 (40.0)		24 (41.4)	32 (43.2)	7 (38.9)	
Secondary school	24 (16.0)	14 (18.7)	10 (13.3)		11 (19.0)	12 (16.2)	1 (5.6)	
High school/University	54 (36.0)	23 (30.7)	31 (41.3)		19 (32.8)	27 (36.5)	8 (44.4)	
Number of children in the family n (%)								
1	24 (16.0)	12 (16.0)	12 (16.0)	0.679	13 (22.4)	9 (12.2)	2 (11.1)	0.309
2	64 (42.7)	28 (37.3)	36 (48.0)		21 (36.2)	32 (43.2)	11 (61.1)	
3	45 (30.0)	26 (34.7)	19 (25.3)		16 (27.6)	24 (32.4)	5 (27.8)	
4 and more	17 (11.3)	9 (12.0)	8 (10.7)		8 (13.8)	9 (12.2)	50 (0.0)	
Family income								
Low	121 (80.7)	57 (76.0)	64 (85.3)	0.780	46 (79.3)	13 (17.6)	14 (77.8)	0.269
Moderate	26 (17.3)	17 (22.7)	9 (12.0)		9 (15.5)	61 (82.4)	4 (22.2)	
Good	3 (2.0)	1 (1.3)	2 (2.7)		3 (5.2)	0 (0.0)	0 (0.0)	
BMI z score n(%)								
Overweight (z score 1-2)	17 (11.3)	7 (9.3)	10 (13.3)	0.362	8 (13.8)	7 (9.5)	2 (11.1)	0.716
Obese (>2 z score)	132 (88.0)	67 (89.3)	65 (86.7)		49 (84.5)	67 (90.5)	16 (88.9)	
Physical activity n (%)								
Inactive	99 (66.0)	57 (76.0)	42 (56.0)	**0.040**	39 (67.2)	48 (64.9)	12 (66.7)	0.974
Moderate active	41 (27.3)	13 (17.3)	28 (37.3)		15 (25.9)	21 (28.4)	5 (27.8)	
Active	10 (6.7)	5 (6.7)	5 (6.7)		4 (6.9)	5 (6.8)	1 (5.6)	

The bold values are indicates significant at p < 0.05. Each variable was identified with a different letter (a, b, c).
Abbreviations: BMI: Body mass index, cDII:children's dietary inflamatory index, MD: Mediterranean diet

Table 2. Energy and dietary intake of participants according to DII and adherence to the MD groups

		cDII groups			Adherence to the MD groups			
	Total	**Low cDII (n=75)**	**High cDII (n=75)**	**p[1]**	**Low (n=58)**	**Moderate (n=74)**	**High (n=18)**	**p[2]**
Energy (kcal)	1290.4 (609.15)	1176.6 (474.50)	1407.7 (727.22)	**0.002**	1317.5 (655.91)	1286.5 (614.10)	1269.7 (397.95)	0.851
Carbohydrate (g)	156.4 (80.40)	143.8 (65.11)	175.6 (91.85)	**0.020**	162.7 (95.38)	155.7 (76.99)	156.8 (75.50)	0.696
Carbohydrate (%)	49.0 (10.00)	51.0 (9.00)	49.0 (12.00)	0.543	49.0 (9.25)	50.0 (9.00)	48.0 (12.75)	0.381
Protein (g)	48.0 (24.70)	45.9 (20.19)	50.7 (29.87)	**0.028**	47.2 (22.77)	49.4 (26.55)	49.9 (18.01)	0.861
Protein (%)	15.0 (4.00)	16.0 (5.00)	15.0 (5.00)	0.272	15.5 (5.25)	15.5 (4.00)	16.0 (2.50)	0.989
Plant protein (g)	19.8 (11.89)	18.5 (8.16)	21.1 (13.23)	0.198	18.4 (14.86)	19.9 (10.3)	19.6 (5.8)	0.827
Animal protein (g)	28.0 (17.28)	26.7 (16.20)	32.3 (24.26)	**0.023**	28.4 (20.98)	27.6 (17.68)	31.4 (12.32)	0.949
Total fat (g)	49.5 (26.00)	43.2 (18.25)	54.5 (29.86)	**<0.001**	46.9 (27.80)	50.1 (23.63)	46.2 (19.88)	0.958
Total fat (%)	34.0 (10.00)	34.0 (7.00)	36.0 (10.00)	0.129	34.5 (8.50)	33.5 (11.00)	36 (9.00)	0.436
Saturated fat (g)	17.6 (11.23)	15.4 (8.10)	20.8 (13.55)	**<0.001**	17.4 (11.97)	17.7 (11.14)	16.9 (13.03)	0.874
MUFA (g)	16.3 (10.43)	15.3 (8.64)	18.8 (11.18)	**0.006**	17.2 (10.72)	16.9 (10.91)	15.9 (7.80)	0.946
PUFA (g)	9.8 (6.11)	9.4 (5.43)	9.8 (6.95)	0.386	10.1 (5.80)	9.4 (6.96)	9.2 (6.11)	0.757
Omega -3 (g)	0.7 (0.65)	0.6 (0.44)	1.0 (0.84)	0.006	0.78 (0.66)	0.79 (0.72)	0.67 (0.25)	0.626
Omega-6 (g)	8.5 (5.67)	7.8 (5.38)	8.5 (6.12)	0.466	8.4 (5.41)	8.1 (6.32)	7.89 (6.31)	0.943
Cholesterol (mg)	228.3(171.4)	202.2(161.9)	279.3(217.92)	**0.015**	224.1(171.58)	231.3 (196.5)	198.3(165.7)	0.596
Fiber (g)	12.8 (6.25)	14.1 (5.95)	11.6 (6.41)	**0.001**	12.2 (8.26)	13.2 (5.32)	13.8 (4.35)	0.354
Vitamin E (mg)	9.2 (6.51)	10.1 (6.03)	8.29 (5.62)	**0.023**	7.7 (6.27)	9.6 (6.02)	9. (8.88)	0.504
Tiamin (mg)	0.6 (0.29)	0.6 (0.26)	0.5 (0.35)	0.132	0.5 (0.36)	0.6 (0.24)	0.6 (0.12)	0.884
Riboflavin (mg)	0.9 (0.49)	0.9 (0.48)	1.0 (0.63)	0.147	0.9 (0.58)	0.9 (0.44)	0.8 (0.48)	0.396
Niasin (mg)	8.4 (4.62)	8.4 (5.64)	8.6 (4.49)	0.819	8.6 (5.59)	8.5 (4.78)	8.3 (4.57)	0.785
Vitamin B6 (mg)	0.7 (0.35)	0.8 (0.33)	0.7 (0.39)	0.015	0.7 (0.37)	0.7 (0.35)	0.8 (0.39)	0.479
Folic acid (µg)	186.3 (93.91)	197.1 (79.19)	182.0 (103.47)	0.075	174.7 (117.61)	194.9 (75.66)	189.9 (76.81)	0.398
Vitamin B12 (µg)	2.8 (2.44)	2.4 (1.87)	3.4 (3.34)	**0.029**	2.5 (2.73)	2.9 (2.31)	2.7 (2.03)	0.732
Vitamin C (mg)	55.8 (50.96)	67.9 (46.44)	40.3 (41.52)	**<0.001**	49.4 (48.09)	58.9 (51.35)	70.6 (37.70)	0.110
Iron (mg)	6.4 (3.09)	6.4 (2.70)	6.6 (3.70)	0.590	6.5 (3.63)	6.6 (3.06)	6.4 (3.16)	0.896
Magnesium (mg)	172.1 (69.44)	178.9 (66.22)	169.5 (91.12)	0.278	163.4 (95.57)	177.9 (65.19)	187.8 (46.36)	0.343
Zinc (mg)	6.5 (3.86)	6.5 (3.45)	6.5 (4.80)	0.579	6.5 (3.97)	6.44 (4.35)	6.41 (3.23)	0.941
Selenium (µg)	11.7 (15.18)	11.1 (12.16)	12.6 (16.8)	0.214	10.7 (16.08)	12.2 (14.6)	12.7 (16.96)	0.883
Food groups								
Vegetables	121.0 (120.00)	160.0 (119.50)	92.0 (90.00)	**<0.001**	111.5 (134.25)[a]	119.5 (104.75)[b]	170.5 (107.25)[c]	**0.008** c>b, c>a
Fruits	119.0 (213.00)	147.0 (186.00)	48.0 (175.00)	**<0.001**	92.5 (161.25)	150.5 (247.00)	123.5 (233.00)	0.061
Cereals	32.0 (46.00)	33.0 (44.00)	30.0 (42.00)	0.930	32.5 (37.25)	24.0 (41.50)	34.0 (53.25)	0.268
Meat and meat products	45.0 (78.00)	44.0 (59.00)	45.0 (93.00)	0.731	50.0 (87.75)	40.5 (53.25)	59.0 (129.25)	0.400
Dairy product	168.0 (186.00)	173.0 (173.00)	166.0 (184.00)	0.405	167.5 (192.50)	181.0 (177.75)	165.0 (232.75)	0.317

Data are expressed as median (IQR). The bold values are indicates significant at $p < 0.05$. [1]Difference between groups was obtained using Mann Whitney test. [2]Difference between groups was obtained using Kruskal–Wallis test. MUFA: Monounsaturated fatty acids. PUFA: polyunsaturated fatty acid.

Table 3. Biochemical, anthropometric, and body composition parameters according to cDII and MD adherence groups of the participants

		cDII groups			Adherence to the MD groups			
	Total	Low cDII (n=75)	High cDII (n=75)	p[1]	Low (n=58)	Moderate (n=74)	High (n=18)	p[2]
Biochemical parameters								
Fasting glucose (mg/dL)	87.0 (9.00)	87.0 (11.00)	87.5 (8.050)	0.789	88.0 (9.00)	88.0 (9.00)	85.5 (6.50)	0.433
Fasting insulin (IU/mL)	13.0 (10.10)	12.7 (8.88)	13.2 (10.38)	0.945	14.0 (9.93)[a]	12.4 (10.70)[b]	11.7 (8.44)[c]	**0.005** a>b, a>c
Total-C (mg/dL)	164.0 (39.00)	166.5 (36.75)	162.0 (48.50)	0.470	153.0 (56.00)[a]	167.0 (59.00)[b]	198.5 (136.75)[c]	**0.003** b>a, c>a
HDL-C (mg/dL)	45.0 (11.00)	45.0 (9.50)	46.0 (13.50)	0.146	42.0 (11.00)	47.0 (11.00)	45.5 (37.50)	0.152
LDL-C (mg/dL)	91.0 (34.00)	92.0 (25.25)	91.0 (40.00)	0.648	90.0 (28.00)[a]	96.0 (59.00)b	129.0 (108.75)[c]	**0.029** c>a
Trigliserid (mg/dL)	109.0 (54.00)	116.0 (46.00)	102.0 (63.50)	0.044	102.0 (41.00)	104.0 (57.00)	122.0 (100.25)	0.251
HOMA-IR	2.7 (2.26)	2.7 (2.21)	2.7 (2.14)	0.722	3.4 (2.97)[a]	2.8 (2.43)[b]	2.4 (7.75)[c]	**0.003** a>b, a>c
ALT (U/L)	19.0 (16.00)	21.0 (16.00)	19.0 (11.50)	0.163	17.0 (26.00)	18.0 (16.00)	23.0 (32.25)	0.285
Anthropometric measurements and body composition								
Body weight (kg)	71.5±21.91	70.6± 23.56	71.6± 20.5	0.942	79.6±18.59	68.1±23.01	60.2±19.08	0.001
Height z score	0.7±1.22	0.9±1.13	0.7±1.25	0.271	0.8±1.23[a]	0.5±1.18[b]	1.4±1.22[c]	**0.030** c<b
BMI z score	2.7±0.74	2.8±0.79	2.7±0.73	0.304	2.8±0.86	2.7±0.63	2.7±0.78	0.650
Neck circumference (cm)	35.8±3.44	35.7±3.25	35.5±3.28	0.298	36.7±3.30[a]	35.2±3.17[b]	35.2±4.31[c]	**0.023** a>b
Waist circumference (cm)	94.0±12.69	94.1 ±12.76	93.2 ±12.00	0.269	98.9±11.78[a]	91.8±12.29[b]	87.3±12.12[c]	**<0.001** a>b, a>c
Hip circumference (cm)	105.5±14.21	104.6 ±13.45	105.4±14.81	0.914	110.7±11.45[a]	103.6±14.44[b]	96.7±15.73[c]	**<0.001** a>b, a>c
Waist /hip ratio	0.8±0.86	0.8± 0.64	0.8± 0.10	0.190	0.8±0.06	0.8±0.07	0.9±0.15	0.535
Waist /height ratio	0.6±0.58	0.6±0.54	0.6±0.57	0.095	0.6±0.06	0.6±0.05	0.5±0.05	0.131
Body fat (%)	36.2 (10.40)	36.9 (10.40)	35.1 (10.40)	0.339	36.9 (11.40)	34.6 (9.48)	36.3 (9.35)	0.317

The bold values are indicates significant at p < 0.05. Each variable was identified with a different letter (a, b, c). [1]Difference between groups was obtained using Student test or Mann Whitney test. [2]Difference between groups was obtained using ANOVA or Kruskal–Wallis test.
Abbreviations: *C: Cholesterol, BMI: Body mass index. HOMA-IR, homeostatic model assessment for insulin resistance;*

Table 4. Distribution of cardiometabolic risk factors according to DII and MD adherence groups of participants

	cDII groups			Adherence to the MD		
	Low cDII	High cDII	p	Low	Moderate/High	p
	n (%)	n (%)		n (%)	n (%)	
Total Cholesterol						
Normal (Total Cholesterol <200)	62 (83.8)	57 (78.1)	0.379	50 (87.7)	69 (76.7)	0.131
High (Total Cholesterol ≥200)	12 (16.2)	16 (21.9)		7 (12.3)	21 (23.3)	
Fasting Glucose						
Normal (Fasting glucose <100)	70 (93.3)	69 (92.0)	0.754	53 (91.4)	86 (93.5)	0.631
High (Fasting glucose ≥100)	5 (6.7)	6 (8.0)		5 (8.6)	6 (6.5)	
LDL Cholesterol						
Normal (<130)	64 (86.5)	59 (81.9)	0.451	52 (91.2)	71 (79.8)	0.101
High (≥130)	10 (13.5)	13 (18.1)		5 (8.8)	18 (20.2)	
Triglyceride						
Normal	36 (48.6)	44 (60.3)	0.157	35 (61.4)	45 (50.0)	0.176
High	38 (51.4)	29 (39.7)		22 (38.6)	45 (50.0)	
HDL Cholesterol						
Normal (≥40 mg/dL)	52 (71.2)	60 (83.3)	0.082	42 (73.7)	70 (79.5)	0.411
Low (<40 mg/dL)	21 (28.8)	12 (16.7)		15 (26.3)	18 (20.5)	

Table 4. Distribution of cardiometabolic risk factors according to DII and MD adherence groups of participants (continued from Table 4)						
	cDII groups			Adherence to the MD		
	Low cDII	High cDII	p	Low	Moderate/High	p
	n (%)	n (%)		n (%)	n (%)	
Serum Insulin level						
Normal (<15 µU/mL)	43 (57.3)	46 (61.3)	0.618	27 (46.6)	62 (67.4)	**0.011**
High (≥15 µU/mL)	32 (42.7)	29 (38.7)		31 (53.4)	30 (32.6)	
Insulin Resistance						
Yes	42 (56.0)	43 (57.3)	0.869	27 (46.6)	58 (63.0)	**0.047**
No	33 (44.0)	32 (42.7)		31 (53.4)	34 (37.0)	

The bold values are indicates significant at p < 0.05. aDifference between groups was obtained using the Chi-Square test
Abbreviations: *cDII: children's dietary inflamatory index; MD: Mediterranean diet.*

Table 5. Association between serum insulin levels and AMD and cDII scores									
	Factors associated with high serum insulin levels					Factors associated with insulin resistance			
	B	OR	%95 CI	p value		B	OR	%95 CI	p value
Moderate/high adherence to the MD	-					-			
Low adherence to the MD	0.720	2.055	1.009-4.186	0.047		0.543	1.720	0.853-3.471	0.130
cDII score	-0.142	0.867	0.602-1.238	0.433		-0.116	0.891	0.629-1.263	0.516
Constant	-1.060	0.347	-	0.268		-0.642	0.526		0.492
Hosmer and Lemeshow test	χ^2=8.851; p=0.355					Hosmer and Lemeshow test	χ^2=10.846; p=0.211		

Age, gender, and physical activity level were controlled in both models. Participants with moderate/high adherence to MD were used as the reference. OR, odds ratio; CI, confidence interval.

Diet contributes significantly to the development of type 2 diabetes and other diseases associated with insulin resistance and inflammation (21, 22). Previous studies showed that proinflammatory diets are associated with increased inflammatory and oxidative biomarkers, the incidence of cardiovascular disease, certain cancers, and measures of adiposity in childhood (9, 23). A study of Brazilian adolescents found a moderately pro-inflammatory diet positively correlated with high HOMA-IR among girls and high total cholesterol in boys (20). Seremet et al. (24) reported that a higher DII score is associated with an increased risk of metabolic syndrome in adolescents and some metabolic syndrome components. Conversely, Carvalho et al. (25) demonstrated that there is no relationship between DII and metabolic syndrome and insulin resistance in young Brazilian adults. Similarly, no significant relationship was found between cDII groups and cardiometabolic risk factors in this study. The failure to show that cDII is linked to MetS and insulin resistance may be related to the fact that risk factors for chronic diseases act over a long period until they result in the development of the disease. Therefore, it's likely that the pro-inflammatory diet's effect on boosting these outcomes hasn't yet had a chance to show. Moreover, this result can be explained by the fact that cardiometabolic disorders are influenced not only by diet, but also by other factors such as lifestyle, environmental, psychological, and genetic factors (3). The present study did not examine the relationship between these other factors and cardiometabolic risk.

It has been reported that high AMD may be effective in maintaining metabolic health in adolescents with obesity (2). However, the results of studies evaluating the effects of the MD on the lipid profile are inconsistent. While it was found that the lipid profile improved after 16 weeks of the MD intervention in children and adolescents with obesity (26), in another study was found no significant change in lipid profile after 12 weeks of MD intervention in adolescents with obesity (27). Kim et al. (7) showed that adolescents with higher AMD have higher HDL

cholesterol compared to those with low AMD, but no relationship between AMD and MetS, triglyceride, total and LDL cholesterol. The present study showed that there is no significant relationship between MD adherence and lipid profile. This result is in line with results that no association between cDII and metabolic control parameters and can be explained by the fact that risk factors for chronic diseases act for a long time until they result in the development of the disease. To understand the relationship between AMD and lipid profile, prospective studies in which dietary factors and many variables that have the potential to affect lipid profile are evaluated together are needed.

In this study, participants with low AMD were 2.055 times (95% CI 1.009-4.186, OR=2.055) more likely to have high insulin levels than participants with high AMD. In addition, the proportion of patients with insulin resistance was found to be higher in the group with low AMD than in the group with moderate/high adherence. Similar to these results, the patients with low AMD possessed a metabolic profile characterized by higher HOMA-IR, triglyceride, and lower HDL (28). A meta-analysis study revealed that all MetS components are positively impacted by high AMD, and long-term AMD can reduce cardiometabolic risk factors (29). In a study of children aged 6-17 years, HOMA-IR decreased as AMD increased (18). Various mechanisms may explain the inverse relationship between AMD and insulin levels and insulin resistance: The MD can have a positive effect on the glycemic response, thanks to the many nutrients and bioactive components it contains. Whole grain foods, especially abundant in the MD, contain micronutrients that act as cofactors for enzymes that play a role in insulin secretion and glucose metabolism (6, 7). MUFA and PUFA from olive oil and nuts have been reported to have positive effects on insulin sensitivity by improving the inflammatory responses of adipose tissue. Polyphenols, which are important bioactive components of the MD, affect glucose metabolism by promoting glucose uptake in tissues and thus increasing insulin sensitivity (18).

This study has some limitations. First, the causality of the relationship remains unclear, as the study was designed as cross-sectional. Another limitation is that data were gathered by self-report, which may result in false reporting and recall bias. To address recall bias participants were requested to keep food diaries at home for three days, according to thorough written instructions. However, the present study also has the following strengths: A three-day record of food consumption provided more reliable results in calculating dietary intake and cDII. To the best of our knowledge, this is the first study to evaluate the associations between cDII, AMD, and cardiometabolic risk factors in children with obesity.

CONCLUSION

This study showed that low AMD was associated with high insulin levels, but cDII was not associated with cardiometabolic risk factors in children with overweight and obesity. These results support that AMD might be beneficial in maintaining metabolic health among adolescents with obesity.

DECLARATIONS

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Conflicts of interest/Competing interests

The authors declare that there are no conflicts of interest.

Ethics approval

For this study, the Ethics Committee Approval (IRB number: 0391 and date 22.09.2022) was obtained from the Non- Interventional Clinical Trials Ethics Committee of İzmir Katip Çelebi University. Study procedures were performed according to the principles of the Declaration of Helsinki and written informed consent was obtained from all participants and parents.

Availability of data and material

The datasets used for the present study will be provided by the corresponding author upon reasonable request.

Authors' contributions

GYD: Study conception and design, data analysis and interpretation, and writing orginal draft. CG: Data collection, and data analysis. AK: Data collection, critical revision.

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