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The Association between Dietary Inflammatory and Obesity Indices in University Students in Tehran

Narges Khamoush Cheshm; MSc [1], Asal Ataie-Jafari; PhD [1], Shahryar Eghtesadi; PhD [*1], Aniseh Nikravan; PhD [2], Nitin Shivappa; MPH, PhD [3,4,5] & James R. Hebert; ScD [3,4,5]

[1] Department of Nutrition, Science and Research Branch, Islamic Azad University, Tehran, Iran; [2] Department of Health Services Administration, Science and Research Branch, Islamic Azad University, Tehran, Iran; [3] Cancer Prevention and Control Program, University of South Carolina, Columbia, SC 29208, USA; [4] Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, Columbia, SC 29208, USA; [5] Department of Nutrition, Connecting Health Innovations LLC, Columbia, SC 29201, USA.

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****Corresponding author:***
segtesadi@gmail.com
Department of Nutrition, Science and Research Branch, Islamic Azad University, Tehran, Iran.

Postal code: 1477893855
Tel: +98 912 2789412

ABSTRACT

Background: Obesity as a major cause of low-grade chronic inflammation is a global public health issue. Inflammation arising from obesity affects organs, such as kidney and liver, and is associated with chronic diseases. The present study aims to investigate the association between the dietary inflammatory index (DII) and obesity indices in university students. **Methods:** This cross-sectional study included 361 college students selected using a two-stage cluster random sampling. The inclusion criteria were healthy girls and boys in the 18-35 years age group, and the exclusion criteria included the presence of chronic diseases, such as diabetes, cardiovascular diseases, taking supplements to weight loss or weight gain, and using alcohol and tobacco. DII scores were calculated from dietary data collected using a semi-quantitative food frequency questionnaire (FFQ). Anthropometric measurements were taken, and body composition was analyzed by bioelectrical impedance analysis (BIA). **Results:** The mean age of the students was 21.94 ± 4.04 years, 53.2% were female, and the mean DII was 1.26 ± 1.08. Among the participants, 36.8% were overweight and obese and 9.1% suffered from abdominal obesity. The DII score was not associated with body weight, body mass index (BMI), body fat, waist circumference or visceral fat (both unadjusted and after adjustment for covariates). **Conclusion:** The present study showed no association between the DII and obesity indices. Given the proven effects of both the DII and obesity on health indicators, it would be a good strategy to conduct studies with prospective designs to determine the exact effects of DII on obesity indicators.

Keywords: *Dietary inflammatory index; Obesity indices; Fat mass; Anthropometric; Body mass index*

Introduction

Obesity is one of the main public health issues in both developed and developing countries (Ruiz-Canela *et al.*, 2015). The prevalence of overweight and obesity in adults was respectively reported at 39% and 13% by the WHO (World Health Organization) in 2016 (Salimi *et al.*, 2019). The prevalence of overweight and obesity in Middle Eastern countries is 54% among women

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and 31% among men, and can be traced to the deaths of 150,000 people in these countries (Kord Varkaneh *et al.*, 2017). More than half (63.2%) of individuals aged 15-65 years were reported to be overweight and obese according to the first national study and the study of glucose and lipids in Tehran (Asghari *et al.*, 2011).

The concentration of systemic inflammation biomarkers such as C-reactive Protein (CRP), Tumor Necrosis Factor alpha (TNFα), Interleukin 6 and 8 (IL6 and IL8), increases in obesity, which is known as a low degree of chronic inflammation (Benelli *et al.*, 2006). Inflammation caused by obesity has metabolic effects on several organs, including adipose tissue, liver, muscle, pancreas, and brain, and these conditions are associated with metabolic diseases, such as hyperglycemia, hypertension, and dyslipidemia. Metabolic differences can be seen depending on the location of the fat cells. Excessive fat accumulation in visceral adipose tissue is associated with higher health risks than subcutaneous fat accumulation (Correa-Rodríguez *et al.*, 2018, Ruiz-Canela *et al.*, 2015).

Numerous studies have shown a positive association between inflammatory markers and obesity indices (Herder *et al.*, 2005, Kim *et al.*, 2006, Lambert *et al.*, 2004, Santos *et al.*, 2005). A study found a positive relationship between CRP and waist circumference and waist-to-height ratio (Malshe and Udipi, 2017). Recently, there has been a hypothesis that obesity can be the result of low levels of chronic inflammation (Fogarty *et al.*, 2008). Therefore, there is a mutual relationship between inflammation and obesity (Ramallal *et al.*, 2017).

Diet is another environmental factor that has been proven to have an important effect on systemic inflammation. The results show that high consumption of whole grains, olive oil, fruits, vegetables and fish, low consumption of red meat, and low to moderate consumption of wine (Mediterranean diet pattern) is associated with a decrease in inflammation. In contrast, the Western diet (rich in refined grains, red meat, high-fat dairy products) is associated with high levels of inflammatory biomarkers (Estruch *et al.*, 2006, Johansson-Persson *et al.*, 2014). Fiber, complex carbohydrates, omega-3 fatty acids, vitamin C, vitamin E, magnesium and beta-carotene have anti-inflammatory effects, while saturated fatty acids and sugar have inflammatory effects (Richard *et al.*, 2013).

The dietary inflammation index (DII) was designed to assess the inflammatory potential of the diet, first described by Shivappa *et al.* In 2009 and updated in 2014 (Shivappa *et al.*, 2014). The DII is used to assess the inflammatory potential of the diet based on the inflammatory and anti-inflammatory properties of specific foods, spices, macronutrients, micronutrients, and flavonoids (Shivappa *et al.*, 2014).

Various studies have been performed on the relationship between DII and obesity indices. In two observational studies, a significant relationship was observed between DII score and anthropometric indices in adults (Ruiz-Canela *et al.*, 2015, Sokol *et al.*, 2016). Weight gain and overweight showed a positive relationship with high levels of DII score in a prospective study (Estruch *et al.*, 2006). However, this relationship was not observed in obese and normal teachers in another study (San *et al.*, 2018). A prospective study also found a direct relationship between DII and weight, BMI (Body Mass Index), waist-to-hip circumference, and fat percentage (Alam *et al.*, 2018). However, in another study of college students, no significant relationship was found between DII and the above items (Kim *et al.*, 2018).

Due to the different results observed in various studies and few research in Iran, especially in the relationship between DII and obesity indices and body fat percentage, this study aims to investigate the relationship between DII and obesity indices in university students in Tehran. The research hypothesis is that students with a higher inflammatory index of the diet have higher weight and obesity indices. Also in this study, the obesity indices (weight, BMI, waist, waist to height ratio, body fat percentage, body muscle percentage, and visceral fat) were described in relation to the DII.

Materials and Methods

Study design and participants: This cross-sectional study was conducted in 2019. A total of 381 healthy single students were calculated using the Cochran's formula based on a statistical population (about 40,000 students), aged 18-35 years, studying at the Islamic Azad University of Science and Research Branch and were selected using two-stage random sampling method. The study inclusion criteria consisted of no history of chronic diseases such as diabetes, liver and kidney diseases, and not having any special diet such as a vegetarian and weight-loss diets. The participants who consumed less than 1000 kcal per day (according to the food frequency questionnaire (FFQ)) were excluded from the study and finally 361 participants were included in the study.

$$\left(n = \frac{\frac{Z^2pq}{d^2}}{1+\frac{1}{N}\left(\frac{Z^2pq}{d^2}-1\right)}\right)$$

Measurements: Dietary intake was evaluated by a 147-item FFQ, the validity and reliability of which were established in previous studies (Esfahani *et al.*, 2010). The participants were asked to report their food consumption frequencies on a daily, weekly, monthly or yearly basis. Then, reported food quantities were converted to grams per day using household measure. Then, each food item, according to the prescribed protocol, was analyzed for content of energy and other nutrients using Nutritionist IV software (version 3.5.2, N-Squared Computing, Salem, OR, USA).

The DII is actually a scoring algorithm based on an extensive review of the literature (1950 to 2010) linking 1943 articles to food parameters including various macronutrients and micronutrients. Each food parameter was scored according to whether it increased (+1), decreased (-1) or had no effect (0) on the six inflammatory IL-1ß, IL-4, IL-6,IL-10, CRP and TNFα. The DII is calculated based on the intake of 45 nutritional parameters whose inflammatory score, mean, and SD of the global intake of each nutritional parameter are calculated (Shivappa *et al.*, 2014).

In the DII score calculation process, first, intakes of each of 45 food parameters were obtained from the FFQ. Then, the values obtained for each variable were subtracted from the corresponding mean global intake and divided by the global SD to obtain the z-score. To minimize the effect of “right skewness”, the z-score was converted to a portion (value 0 to 1) and centered by the by each by 2 and subtracting 1. In the next step, the numbers obtained for each of the food parameters were multiplied by the corresponding inflammatory score, and then the inflammation score of all of the food parameters were summed to obtain the total inflammatory score for each person. A higher (more positive) DII score indicates a more pro-inflammatory diet and lower scores represent an anti-inflammatory diet (Shivappa *et al.*, 2014). The theoretical minimum of the DII score is -8.87, while the maximum score is 7.98.

In the present study, 34 dietary food parameters were used to calculate the DII including energy, protein, total fat, saturated fatty acids (SFA), MUFA (Monounsaturated fatty acids), PUFA (Polyunsaturated fatty acids), trans fatty acids, omega 3 and omega 6 fatty acids, cholesterol, carbohydrates, fiber, caffeine, Vitamin A, beta carotene, thiamine, riboflavin, niacin, vitamin B6, folate, vitamin B12, vitamin C, vitamin D, vitamin E, iron, magnesium, selenium, zinc, tea, garlic, onion, pepper, turmeric, and thyme. Because the 147-item FFQ and N4 software were not able to collect information on other dietary data (Eugenol, saffron, Flavan-3-ol, Flavones, Flavonols, Flavanones, Anthocyanidins, Isoflavones, Ginger, and Rosemary) required to calculating DII, this index was calculated by 34 dietary parameters. Alcohol was not reported in this largely abstinence group.

The anthropometric assessments were performed using the techniques provided by the World Health Organization. The height was recorded using a calibrated stadiometer (Seca206, Germany) with an accuracy of 0.1 cm with the subject standing straight, without shoes. Weight, body mass index (BMI), percent body fat (PBF), and lean body mass (LBM) were also measured by body impedance analysis (Omron, BF511, Kyoto, Japan) (Alidadi *et al.*, 2019). Waist circumference (WC) was measured midway between the lowest ribs margin and the iliac crest at the level of the umbilicus and at the end of normal expiration. Measurements were performed using non-stretchable tape, without any pressure on it with the least count 0.1 cm. Waist to height ratio (WHtR) was calculated by dividing the waist circumference (cm) by the height (cm) of students. Abdominal obesity was described as WC in men > 102 and > 88 cm in women (World Health Organization, 2011). To ensure the accuracy of anthropometric measurements, 50 participants were randomly measured after two weeks with body impedance analysis and the results were similar to the previous results.

A general questionnaire was used to collect the additional variables including age, sex, education level, socioeconomic status (Daneshi-Maskooni *et al.*, 2013) and drug use (including supplements). The data related to physical activity were collected using the International Physical Activity Questionnaire (IPAQ) which was validated in the study of Moghaddam in Iran (Moghaddam *et al.*, 2012). Supplement consumption in this study was considered as a confounder and its effect was adjusted in data analysis.

Ethical considerations: the protocol of which was approved by the Ethics Committee of the Islamic Azad University, Science and Research Branch with the ID: IR.IAU.SRB.REC.1398.080. Informed written consent was obtained from each participant. All methods were performed in accordance to standard and relevant protocols.

Data analysis: The participants were categorized based on tertiles of DII. One-way ANOVA and Chi-square test were used to determine the existence of a significant correlation between quantitative and qualitative variables and tertiles of DII, respectively. Linear regression was used to see whether there is a correlation between DII score and anthropometric indices such as BMI, WC, PBF, LBM, and visceral body fat. In this modeling technique, dependent variables were considered quantitative. Logistic regression models were also used to see whether there is a correlation between DII, overweight, obesity, and abdominal obesity. In this model, unlike linear regression model, the dependent variable was considered collectively. Confounders such as age, sex, and other variables that could negatively affect the afore-mentioned correlations were controlled and adjusted. In all multiple models, the third tertile of DII was considered as the reference. All statistical analysis was performed using SPSS 24, IBM Corporation, Armonk, NY, USA) and P-value < 0.05 was set as the nominal level for statistical significance.

Results

A total of 361 participants with a mean age of 21.94 ± 4.04 years included in the study, and 192 (53.2%) students were female and the rest were male. The overall mean of DII was 1.26 ± 1.08. The DII score ranged from -2.22 to 4.15 in the study participants. About one third (36.8%) of the participants were overweight or obese and 33 (9.1%) of participants suffered from abdominal obesity. **Table 1** shows the basic information of the participants. The results of this study showed that education level and severity of physical activity were significantly correlated with DII score (P = 0.02 and 0.03, respectively).

Higher DII score was related to greater fat intake (g/day, P = 0.03). The results also showed that an increase in DII was associated with increase of energy intake from fat (P < 0.001) and decrease of energy intake from carbohydrate and protein (P < 0.001 and P = 0.01, respectively). By increasing DII, there was a significant difference between the average intake of saturated fatty acids, vitamin A, β-carotene, vitamin C, vitamin B6, magnesium, garlic and pepper in the tertiles of DII (P < 0.05). By increasing DII score, the average intake of saturated fatty acids increased and the average intake of vitamin A, β-carotene, vitamin C, vitamin B6, magnesium, garlic, and pepper decreased (P < 0.05, **Table 2**). **Table 2** shows the mean of anthropometric indices across DII tertiles. There were no significant differences between crude and adjusted results (adjusted for age, sex, and energy intake) with respect to all anthropometric indices at different DII levels.

Standardized regression coefficients (B) for obesity indices across tertiles of DII are provided in **Table 3**. The relationship between DII and obesity indices was investigated using simple and multiple linear regression models. The third tertile was used as the reference and the other two tertiles were compared with it. In the crude model, only the DII index was assessed and in the adjusted model analyses were carried based on confounding variables including sex, age, physical activity, economic status, supplementation, and energy intake. There was no significant association between obesity indices such as weight, BMI, WC, and WHtR as well as anthropometric indices such as PBF, LBM, and visceral fat and DII in both crude and adjusted models.

Odds ratios (ORs) for obesity, abdominal obesity, and overweight across tertiles of DII are provided in **Table 3**. Logistic regression was used in this relationship. The third tertile was used as the reference and the other two tertiles were compared with it. In the crude model, only the DII index was assessed and in the adjusted model, analyses were carried based on confounding variables including sex, age, physical activity, economic status, supplementation, and energy intake. There was no significant difference between DII and overweight, obesity, and abdominal obesity in both crude and adjusted models.

Table 1. Characteristics of the participants according to tertiles of the DII.

Variables	Tertile 1 -2.22-0.78 (n=120)		Tertile 2 0.79-1.72 (n=121)		Tertile 3 1.73-4.15 (n=120)		All (n=361)		P-value[a]
	N	%	N	%	N	%	N	%	
Sex									
Male	57	15.8	60	16.6	52	14.4	169	46.8	0.61
Female	63	17.5	61	16.9	68	18.8	192	53.2	
Educational level									
Bachelor	91	25.2	100	27.7	109	30.2	300	83.1	0.02
Master	25	6.9	20	5.5	9	2.5	54	15	
PhD	4	1.1	1	0.3	2	0.6	7	1.9	
Economic levels									
Poor	11	3	4	3.9	14	3.9	39	10.8	0.88
Moderate	49	13.6	53	14.7	53	14.7	155	42.9	
Wealthy	60	16.6	54	15	53	14.7	167	46.3	
Physical activity level									
Low	35	9.7	44	12.2	47	13	126	34.9	0.03
Moderate	42	11.6	37	10.2	50	13.9	129	35.7	
High	43	11.9	40	11.1	23	6.4	106	29.4	

[a]: Chi-square test, DII: Dietary inflammatory index

Table 2. Nutrient intake and body composition parameters according to the tertiles of the DII score.

Variables	Tertile 1 (-2.22-0.78) (n=120)		Tertile 2 (0.79-1.72) (n=121)		Tertile 3 (1.73-0.15) (n=120)		All (n=361)		P-value[a]
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Energy (kcal)	3091.3	1214.0	3267.3	1425.0	3247.7	1337.0	3202.0	1327.9	0.53
Carbohydrate (g)	494.9	209.4	508.0	238.6	487.6	232.2	496.9	226.6	0.77
Protein (g)	110.6	45.4	113.1	47.5	107.8	46.7	110.8	46.7	0.67
Total fat (g)	89.2	38.6	100.0	49.5	103.9	49.1	97.7	46.3	0.03
Protein (% of total kcal)	14.42	2.5	14.1	2.3	13.4	2.6	13.9	2.5	0.01
Carbohydrate (% of total kcal)	63.6	6.1	61.8	6.3	59.3	8.0	61.6	7.1	< 0.001
Total fat (% of total kcal)	21.9	5.1	24.0	6.0	27.2	7.4	24.3	6.6	< 0.001
Cholesterol (mg)	309.7	215.8	314.4	208.2	326.4	263.8	316.8	230.0	0.84
Saturated fatty acid (g)	25.9	11.0	31.4	16.8	32.2	16.6	29.8	15.3	0.002
Mono-unsaturated fatty acid (g)	29.3	13.1	31.6	16.5	31.7	14.1	30.9	14.7	0.35
Poly-unsaturated fatty acid (g)	17.9	8.9	19.3	11.1	19.3	9.2	18.8	9.8	0.47
Omega-3 (g)	1.2	0.7	1.3	0.9	1.3	0.8	1.3	0.8	0.19
Omega-6 (g)	14.9	8.0	16.3	9.6	16.5	8.3	15.9	8.7	0.24
Fiber (g)	59.84	31.0	59.9	33.3	56.7	33.8	58.8	34.1	0.70
Beta carotene (µg)	8677.8	6251.2	4724.3	3366.6	2854.9	2071.7	5417.0	4899.8	< 0.0001
Vitamin A (µg RAE)	1101.0	658.0	801.2	562.0	266.2	352.5	822.8	580.8	< 0.0001
Vitamin C (mg)	381.5	272.1	287.6	254.1	180.9	19.0	283.4	258.9	< 0.0001
Vitamin D (µg)	2.9	2.4	3.0	2.4	2.4	1.8	2.7	2.2	0.10
Vitamin E (mg)	15.7	7.7	14.7	8.8	13.8	8.1	14.7	8.27	0.19
Thiamine (mg)	2.6	1.1	2.8	1.4	2.9	1.4	2.8	1.2	0.19
Riboflavin (mg)	2.7	1.2	2.8	1.4	2.4	1.1	2.6	1.2	0.12
Niacin (mg)	33.9	14.7	34.0	15.9	32.2	15.6	33.4	15.4	0.58
Vitamin B6 (mg)	2.8	1.2	2.7	1.2	2.4	1.1	2.6	1.2	0.01
Folate (mg)	732.0	278.8	728.0	294.1	762.5	350.0	740.8	308.7	0.63
Vitamin B12 (mg)	4.8	2.8	5.4	4.5	4.7	3.2	5.0	3.6	0.31
Iron (mg)	25.1	10.8	25.5	11.4	24.4	11.9	35.0	11.3	0.78
Zinc (mg)	15.6	6.5	16.1	7.0	15.0	6.7	15.5	6.7	0.41
Selenium (µg)	160.7	81.2	171.3	91.8	165.1	90.6	165.7	87.9	0.64
Magnesium (mg)	600.5	261.5	581.6	266.4	502.7	244.4	561.7	260.4	0.008
Caffeine (mg)	112.4	119.0	100.9	74.5	104.7	92.0	104.7	92	0.54
Onion (g)	16.5	17.1	16.3	18.5	16.2	22.1	16.3	19.3	0.99
Garlic (g)	0.97	2.4	0.3	0.7	0.3	0.6	0.7	1.5	0.002
Peeper (g)	17.6	25.2	12.2	18.0	8.8	14.6	12.8	20.0	0.002
Black Tea (g)	449.6	515.4	406.9	339.4	412.3	361.5	422.9	412.0	0.68
Spices (g)	2.8	2.6	2.8	2.8	3.1	2.8	2.9	2.8	0.70
Weight (kg)	70.5	16.8	70.3	14.8	67.1	16.0	69.3	15.9	0.17
BMI (kg/m²)	24.6	4.6	24.5	4.4	23.6	4.5	24.2	4.5	0.17
PFM (%)	30.1	9.6	29.7	10.7	29.1	10.5	29.7	10.2	0.75
PMM (%)	31.4	6.6	32.0	7.5	31.1	7.3	31.5	7.2	0.64
VFR	5.7	3.4	5.3	3.0	5.0	3.3	5.3	3.2	0.23
WC (cm)	81.8	12.8	81.8	11.3	80.4	12.2	81.3	12.1	0.60
WhtR	0.4	0.0	0.4	0.0	0.4	0.0	0.4	0.0	0.76

[a]: ANOVA test, BMI: Body mass index; FM: Fat mass; PFM: Percentage fat mass; FFM: Fat free mass; VFR: Visceral fat ratio, WC: Waist circumference, and WhtR: Waist/height ratio.

Table 3. Odds ratio (OR) and confidence intervals (95% Cl) and P-trend of the association between DII score and anthropometric variables.

Variables		Tertile 3 (1.73-4.15) (n=120)	Tertile 2 (0.79-1.72) (n=121)	Tertile 1 (-2.22-0.78) (n=120)	P-trend
Weight (kg)	a	1	3.2 (-.79, 7.20)	3.39 (-.61, 7.40)	0.09
	b	1	1.38 (-1.96, 4.72)	1.68 (-1.74, 5.11)	0.33
WC (cm)	a	1	1.36 (-1.69, 4.41)	1.37 (-1.68, 4.43)	0.37
	b	1	0.04 (-2.47, 2.55)	0.49 (-2.08, 3.07)	0.7
WhtR	a	1	0.002 (-0.014, 0.019)	0.006 (-0.011, 0.02)	0.47
	b	1	-0.003 (-0.019, 0.013)	0.003 (-0.10, 0.02)	0.7
BMI (kg/m²)	a	1	0.88 (-0.24, 2.02)	0.99 (-0.14, 2.13)	0.08
	b	1	0.60 (-0.5, 1.71)	0.24 (-0.42, 1.84)	0.22
PMM (%)	a	1	0.85 (-0.96, 2.66)	0.24 (-1.57, 3.59)	0.78
	b	1	0.16 (-0.78, 1.1)	-0.17 (-1.13, 0.79)	0.72
PFM (%)	a	1	0.58 (-2.00, 3.17)	1.0 (-1.59, 3.59)	0.45
	b	1	1.14 (-0.91, 3.19)	1.11 (-0.99, 3.22)	0.29
VFR	a	1	0.28 (-0.53, 1.11)	0.71 (-0.10, 1.54)	0.08
	b	1	-0.06 (-0.8, 0.66)	0.35 (-0.39, 1.11)	0.35
Abdominal obesity	a	1	0.91 (.38, 2.16)	1.11 (.45, 2.72)	0.82
	b	1	1.06 (0.42, 2.68)	1.26 (.45, 3.5)	0.66
Obesity (BMI≥30)	a	1	1.51 (0.67, 3.4)	1.20 (0.51, 2.8)	0.68
	b	1	1.32 (0.56, 3.08)	1.17 (0.46, 2.95)	0.73
Over weight (25≤BMI<30)	a	1	1.14 (0.62, 2.08)	1.67 (0.93, 3.08)	0.07
	b	1	1.16 (0.62, 2.17)	1.60 (0.9, 3.08)	0.10

BMI: Body mass index; FM: Fat mass; PFM: Percentage fat mass; FFM: Fat free mass; VFR: Visceral fat ratio, WC: Waist circumference; WhtR: Waist/Height Ratio; a: Model 0, linear regression analysis without adjustment; b: Model I, linear regression analysis with adjustment for age and sex; energy intake, physical activity, Educational level, Economic levels and supplements. 1: Tertile 3 was considered as a reference, Abdominal obesity: Waist circumference > 102 cm in male and waist circumference > 88 cm in female.

Discussion

In the present study, no association was observed between the DII and energy intake. In a study of 110 students, Kim *et al.* found no significant association between DII and energy intake (Kim *et al.*, 2018). However, in the study conducted by Mazidi *et al.*, there was a positive correlation between DII and energy intake (Mazidi *et al.*, 2018). Similarly, in another study conducted in Italy, Shivappa *et al.* found a significant correlation between DII and energy intake (Shivappa *et al.*, 2018). Furthermore, the present study showed that higher fat intake was associated with a higher DII score. Moreover, a lower percentage of energy intake from carbohydrates and protein was associated with a higher DII score. In a study conducted by Kim *et al.* on 110 students, no association was found between protein and carbohydrate intake and DII, but there was a direct relationship between fat intake and DII (Kim *et al.*, 2018). Correa-Rodriguez *et al.* conducted a study on 599 participants with a mean age of 20 years, and the results demonstrated that there was a significant relationship between energy, carbohydrate and protein intake and DII, but it was not correlated with total fat intake (Correa-Rodríguez *et al.*, 2018). The discrepancies observed in different studies may be due differences in dietary habits or the effect of physical activity on daily energy intake. For example, in the present study, the majority of male participants had moderate to vigorous physical activity and therefore had higher energy intakes.

In the present study, no significant association was observed between obesity indices and DII. In line with the current study, in a study investigating the association between DII with CRP and metabolic syndrome in 1712 Chinese adults aged

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18-75 years, no significant association was observed between DII and BMI (Ren *et al.*, 2018). Also, another study conducted on 532 European adults to examine the association between DII and inflammatory markers, no significant relationship was found between the DII and BMI (Shivappa *et al.*, 2017). Moe Sun *et al.* conducted a study on overweight and normal teachers, and the results showed that no significant association was found between DII and overweight (San *et al.*, 2018). However, in a study conducted on a large Italian population people, Shivappa *et al.* found an inverse association between DII and BMI (Shivappa *et al.*, 2018). Kord Varkaneh *et al.* also found a significant relationship between DII and BMI and waist circumference, but there was no correlation with general obesity (Kord Varkaneh *et al.*, 2017). In a cross-sectional study performed on 606 East Azerbaijan participants with a mean age of 42 years, there was no significant association between DII and waist circumference (Nikniaz *et al.*, 2018).

In a similar study on 503 Indonesian people aged 19-56 years, Muhammad *et al.* investigated the association between DII, weight, blood pressure, lipid profile, and leptin level. The results showed no significant correlation between DII, weight, waist circumference, and body fat percentage. This correlation remained non-significant even after adjusting for confounding factors (Muhammad *et al.*, 2019).

Kim *et al.* conducted a study of 110 students to investigate the association between DII and glycemic index, and they found that there was no significant relationship between DII and weight, BMI, WC, and fat percentage (Kim *et al.*, 2018). Camargo-Ramos *et al.* also conducted a study on 90 overweight men and women with sedentary lifestyle with the aim of investigating the association between DII and heart risk factors. They reported that there was no significant association between DII and weight, WC, BMI, obesity, overweight, and body fat percentage (Camargo-Ramos *et al.*, 2017). In their study, Cora et al. evaluated the association of DII with bone health and body composition in the young population, and the results showed no association between DII and BMI, fat percentage, muscle percentage, and visceral fat before and after adjusting for confounding factors (Correa-Rodríguez *et al.*, 2018). However, in a prospective study of Alam *et al.* performed on 651 men, there was a direct and significant association between DII and weight, waist-to-hip ratio, and body fat percentage (Alam *et al.*, 2018).

Discrepancies in the results from studies may be due to differences in the number of participants, race of the subjects, the number of dietary parameters used to compute the DII score, different food intake data collection methods, and the impact of confounding factors.

To the best of the authors' knowledge, this is one of the first studies that has examined the association between DII and obesity in Iran. The study of healthy young populations who are rarely investigated in relevant studies in Iran can be considered as strength of the present study. The relationship between DII with body fat percentage and muscle percentage has rarely been investigated in Iran and was also a feature of the present study. The study of both genders (though similar studies are mostly focused on females in Iran) and the availability of confounding factors that made it easier to apply the adjustment in the modified model were also among the advantages of this study. Despite its strengths, this study has a number of weaknesses including small sample size, dietary assessments that are subject to recall biases, and its cross-sectional design. Future studies should be conducted to overcome these weaknesses, especially larger perspective studies in unique populations that may be at higher risk of metabolic obesity (Mazidi *et al.*, 2018, Sethna *et al.*, 2020, Vahid *et al.*, 2020).

Conclusion

This study showed no significant association between DII and anthropometric indices such as weight, BMI, WC, WHR, body fat percentage, muscle mass percentage, and visceral fat. Taking into account the effect of diet on overall health and inflammation, more well-designed prospective studies as well as clinical trials are warranted to discover the effect of diet on health indices, including the prevention of overweight and obesity.

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Authors' contributions

Khamoush Cheshm N, Ataie-Jafari A, and Eghtesadi S designed and conceived the research. Khamoush Cheshm N recruited participants and collected data. Shivappa N, Herbert J, and Nikravan A analyzed the data and interpreted the results. Eghtesadi S and Ataie-Jafari A drafted the manuscript. All authors read and approved the final manuscript.

Conflict of interests

The authors declare that they have no conflict interests.

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