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The association of dietary inflammatory index and obesity phenotypes in women

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ABSTRACT

Obesity, as a chronic inflammation, is one of the most important health problems in the world. Increased central obesity is associated with increased inflammation. Diet plays a major role in regulating inflammation. The aim of this study was to investigate the relationship between dietary inflammatory index (DII) and obesity in Tehranian women. This cross-sectional study was performed on 199 women living in District 7 of Tehran. Food intake obtained through a food frequency questionnaire (FFQ) and DII was calculated. Weight, height, body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) were measured or calculated. In the final analysis, the effect of age, level of education, smoking status, and physical activity was controlled. The mean age of the subjects was 37.03 years, and the mean BMI was 27.6 kg/m2. The odds of high WC increased with increasing DII score in the crude model (p=0.01) and decreased significantly in the adjusted model (p=0.04). But there was no significant relationship between DII and other variables of abdominal obesity and general obesity (p>0.05). The study states that by increasing the inflammatory index score of the diet, the chance of developing abdominal obesity (waist circumference) decreases. But this result is not true for other variables of abdominal obesity and general obesity.

1. Introduction

Obesity is defined as the abnormal or excessive accumulation of adipose tissue, which can affect a person's health. BMI>30 Kg / m2 is defined as obesity (1). Overweight and obesity-related diseases include cancers (breast, endometrial, ovarian, prostate, colorectal, kidney, and pancreatic cancers), hypertension, stroke, coronary artery disease, heart failure, asthma, osteoarthritis, and gallbladder disease (2, 3). Recent studies show an increasing prevalence of overweight and obesity in both developed and developing countries (4, 5). The global death from obesity is estimated at more than 3.4 million people a year. According to the World Health Organization (WHO) report, obesity is a rapidly increasing epidemic worldwide, with the prevalence of overweight and obesity in the Middle East being 54% among women and 31% among men, leading to 150,000 deaths annually in these countries (6, 7). The WHO reported in 2002 that about 70% of all deaths in Iran are due to chronic diseases, which are due to overweight and obesity (8). On the other hand, obesity and overweight are considered as a chronic inflammation that increases CRP and pro-inflammatory cytokines such as IL6 and TNF-a (9). Dietary patterns can regulate inflammation in the body, meaning that a healthy dietary pattern, such as the Mediterranean diet, reduces inflammation in the body (10). Evidence suggests that inflammatory conditions may improve with higher intake of foods containing antioxidant compounds such as fruits, vegetables, and whole grains, or lower intake of inflammatory foods such as refined carbohydrates, processed meats, trans fatty acids, and saturated fatty acids (11). Since the study of each dietary component alone cannot reveal the overall potential of dietary inflammation, a relatively new tool, the Dietary Inflammatory Index (DII) has been developed based on a review of existing studies in the field of diet. DII is a comprehensive concept that has recently been introduced in nutrition epidemiology and examines the synergistic or antagonistic effects of inflammatory compounds in the diet

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(11). Unhealthy dietary patterns, including Western diets (high in refined carbohydrates, fats, and proteins) are significantly associated with higher levels of inflammation, and a healthy diet such as the Mediterranean diet (rich in fruits, vegetables, and fish) is associated with lower levels of inflammation (11, 12). In one study, a significant association was found between DII and the progression of obesity and overweight, so that the odds of overweight and obesity was 32% higher in participants with the highest intake of inflammatory diet (13). Similarly, a significant association between high levels of inflammatory biomarkers and overweight was observed in another study (14). Due to the correlation of Western dietary pattern with different diseases, several studies have been conducted between DII and various diseases in recent years (15, 16, 17). The diets of Asian countries are different from those of Western countries, and the transfer of Western food patterns to Asian countries in recent years has led to many changes such as increased consumption of refined sugary foods, sodium, saturated fats, trans fats, and therefore increased prevalence of obesity and inflammation in Asian countries (18, 19). However, there are limited studies on the relationship between inflammatory diet and various diseases in Asian countries and Iran (20). The aim of this study was to investigate the relationship between DII and obesity in Tehranian women.

2. Materials and methods

It was a cross-sectional study on women over 25 years old living in District 7 of Tehran. The basis for calculating the sample size in this study was BMI. Mean and standard deviation (SD) have been obtained from studies on Iranian women (21). The mean BMI in healthy women was 27.6 and the SD was 6.22. *Alpha* was considered as 0.05 and *d* was considered as 2% (22):

$$N= [(z1-\alpha / 2) 2 \times s2] / d2$$

Finally, the sample size was estimated at 199. Participants were selected from women who referred to the House of Quran and Sarai Mahalleh in District 7 of Tehran in the fall and winter of 2018. Menopause and pregnant women, those with thyroid disorders, and women who took stimulants or appetite suppressants were excluded. The research protocol of this study was approved by the ethics committee of Islamic Azad University, Tehran Science and Research Branch (IR.IAU.SRB.REC.1398.043).

2.1. Assessment of dietary intake

Nutritional intake was assessed using a valid and reliable 168-item semi-quantitative food frequency questionnaire (FFQ) (23, 24). FFQs were collected by a trained nutritionist through face-to-face interviews. A standard portion size for each food item has been given according to the Willett method. Participants were asked to report their consumption of each item by day, week, month, or year over the past year. Daily frequencies for each item were computed. Then, daily intakes in terms of grams were calculated using the manual for household measures. Analysis of energy and nutrient intake was based on the US Department of Agriculture (USDA) food composition table.

2.2. Calculation of dietary inflammatory index

The Dietary Inflammatory Index is a scoring algorithm based on an extensive review of articles published from 1950 to 2010 that examined the relevance of 1943 articles as a set of dietary parameters including macronutrients and micronutrients. The scoring algorithm for the effect of articles based on the effect of dietary parameters on the inflammatory status was determined based on six inflammatory indices as follows: +1 score, this score is considered as a pro-inflammatory effect of food (significant increase in IL-6, IL-B1, TNF-α or CRP or significant decrease in IL-4 or IL-10). Score-1, this score is considered as the anti-inflammatory effect of food (significant decrease in IL-6, IL-B1, TNF-α or CRP, or significant increase in IL-4 or (IL10. Score 0, this score shows dietary parameters which do not significantly alter inflammatory markers. A complete description of the DII is available elsewhere (11). Briefly, to calculate DII for the participants of this study, their dietary data were first linked to the regionally representative world database that provided a robust estimate of a mean and SD for each parameter (11). These then become the multipliers to express an individual's exposure relative to the 'standard global mean' as a Z-score. This is achieved by subtracting the 'standard glob-al mean' from the amount reported and dividing this value by the SD. To minimize the effect of 'right skewing' (a common occurrence with dietary data), this value is then converted to a centered percentile score. The centered percentile score for each food parameter for each individual was then multiplied by the respective food parameter effect score, which is derived from the literature review, in order to obtain a food parameter-specific DII score for an individual. All of the food parameter-specific DII scores are then summed to create the overall DII score for every participant in the study (11). A total of 37 food parameters were available from the FFQ and therefore could be used to calculate DII.

2.3. Anthropometric measures

Anthropometric measurements including weight, height, waist circumference, and hip circumference were performed according to the standard protocol. Weight was measured with minimal coverage and without shoes, and with an accuracy of 100 g on a Xiaomi scale. Height was measured using a tape mounted on the wall and without shoes, with an accuracy of 0.5 cm. Waist circumference (WC) was measured in the midpoint between the lower edge of the palpable ribs and the upper edge of the pelvis with a resilient meter and parallel to the ground. Hip circumference was measured in the most prominent part and parallel to the surface. Body mass index (BMI) was also calculated by dividing weight in kilograms by height in square meters. Waist circumference (WC)≥88 cm, waist to hip ratio (WHR)≥0.8, and waist to height ratio (WHtR)≥0.05 were considered as abdominal obesity (24). According to the International Obesity Task Force (IOTF), overweight is defined as BMI between 25 and 30, and general obesity is defined as BMI≥30 kg/m2 (26).

2.4. Covariates

Demographic data including age, marital status, number of children, and number of family members, job, educational level, economic status, ethnicity, and smoking status were collected by interview. The level of physical activity was measured by short form of International Physical Activity Questionnaire (IPAQ). Household economic status was determined using a questionnaire including 9-item home appliances and was classified owning less than 3-item as poor economic level, 4 to 6-item as moderate economic level, and more than 7-item as wealthy economic level.

2.5. Statistical Assessment

SPSS.21 (SPSS, Chicago, IL, USA) was used to perform statistical analyzes of this study and the significance level was considered to be 0.05. Demographic, anthropometric, and dietary variables were compared across DII quartiles using Chi-Square and ANOVA tests. Logistic regression analysis was performed to determine the association between DII and obesity indices. Results were reported in a crude model and after adjustment for age, history of disease, drug use, and smoking.

3. Results

In this study, 199 women aged 19 to 58 years were recruited. Global intake was compared with that of Iranian adult women. In this study, it was found that the average intake of all dietary parameters, except for vitamins A, D, as well as garlic and onion intake, was higher than the global average (Table1). Table 2 represents demographic characteristics, physical activity, and anthropometric values across DII quartiles. The mean age was 37.03 years and the mean BMI was 27.6. There was no significant difference in demographic characteristics, physical activity, and anthropometric indices among DII quartiles ($p>0.05$). Table 3 shows participants' food intake across DII quartiles. As it is shown, all dietary intakes decreased with increasing DII, except for protein, total fat, saturated fatty acid, MUFA, and trans fatty acid. There was a significant association between dietary intake of fiber, protein, total fat, saturated fatty acids, MUFA, trans fatty acids, cholesterol, omega-6, garlic, onions, vitamin B_{12}, and vitamin D with DII ($p<0.05$). The associations between DII and odds of general obesity and abdominal obesity are presented in Table 4. Compared to those in the lowest quartile, individuals with higher DII scores had higher odds of general obesity in both crude and adjusted model. However, this association was not significant. In higher quartiles of DII, the odds of high WC significantly increased in both crude and adjusted models ($p<0.05$). Similarly, the odds of WHtR increased in higher DII quartiles, but it was not significant. There was no significant association between WHR and DII in regression models.

Table 1. Comparison of global intake of DII components with intake of Iranian adults.

Intake	Global dietary intake	Dietary intake of study participants*
Carbohydrate (g)	272.2	679±340
Cholesterol (mg)	279.4	290±141
Energy (kcal/day)	2056	4148±1941
Protein (g)	79.4	130±69
Saturated fat (g)	28.6	34±17
Total fat (g)	71.4	122±68
Trans fatty acid (g)	3.15	4.72±6.34
Vitamin B_{12} (µg)	5.15	6.72±6.10
Garlic (g)	59.0	0.85±1.18
Onion (g)	35.9	7.09±10.7
Beta-carotene (µg)	3718	5577±3786
Caffeine (g)	8.05	152±122
Fiber (g)	18.8	23.9±11.7
Vitamin B_9 (µg)	273.0	826±506
Magnesium (mg)	310.1	761±365
MUFA (g)	27.0	35.8±19.6
Vitamin B_3 (mg)	25.90	32.7±16.7
Omega 3 fatty acids (g)	1.06	2.30±3.43
Omega 6 fatty acids (g)	10.80	16.5±7.90
PUFA (g)	13.88	21.8±23.2
Vitamin B_2 (mg)	1.70	3.52±1.51
Selenium (µg)	67.0	154±95.6
Black/green tea (g)	1.69	613+470
Vitamin B_1 (mg)	1.70	2.74±1.60
Vitamin A (re)	983.9	952±698
Vitamin B_6 (mg)	1.47	3.38±1.37
Vitamin C (mg)	118.2	238±163
Vitamin D (µg)	6.26	1.08±1.52
Vitamin E (mg)	8.73	12.3±6.60
Zinc (mg)	9.84	19.4±9.09
Flavonols (g/d)	17.70	47.3±55.1
Flavones (g/d)	1.55	17.2±14.5
Isoflavones (g/d)	1.20	17.6±36.4
Anthocyanidins (g/d)	18.05	42.6±44.0
Flavonones (g/d)	11.70	44.7±56.0
Iron (mg)	13.35	46.8±25.3
Pepper	10.0	11.37±23.37

*Data are expressed as mean ± SD

4. Discussion

This cross-sectional study on women over 25 years of age living in District 7 of Tehran aimed to investigate the relationship between DII and obesity. The results of the present study indicate a direct association between DII and some parameters of abdominal obesity (WC) in these women. But this relationship was not significant for general obesity. In the present study, it was observed that there is no significant relationship between DII and general obesity. Similarly, in a study on 7236 people, there was no direct association between DII and BMI in men. However, there was a significant association between DII and abdominal obesity in women ($p=0.001$) and also in men ($p=0.004$) (27). Another study in 2019 which aimed to examine the relationship between DII and anthropometric indices in Indonesian adults, found no significant association between DII and weight, BMI, WC, and WHR even after adjusting for possible confounders such as

Table 2. Demographic characteristics, physical activity and anthropometric indices of women across DII quartiles*.

Characteristics	Quartiles of the DII				p *
	Q1	Q2	Q3	Q4	
	DII<5.11 (n=49)	5.11≤DII<5.82 (n=47)	5.82≤DII<6.17(n=53)	6.17≤DII (n=50)	
Age, years	36.71±1.25	35.01±0.99	37.34±1.12	38.06±1.02	0.16
Smoking, yes	23.7%	25.2%	25.9%	25.2%	0.39
High education level	25%	24%	26.5%	24.5%	0.42
Physical activity (MET-min/week)	895±598	899±581	927±633	937±667	0.31
BMI kg/m2	26.16±4.33	27.8±5.31	28. 7±5.91	27.8±8.45	0.15
WC (cm)	90.9±10.5	92.9±17.1	94.07±16.7	92.3±12.1	0.75
WHR	0.87±1.13	1.92±7.39	0.86±0.11	2.43±10.9	0.30
WHtR	0.81±0.39	0.87±0.33	0.84±0.36	0.88±0.32	0.79

Abbreviations: BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio.
Quantitative variables are expressed as mean±SD; Qualitative variables are expressed as a percentage.
* ANOVA test or Chi-square test.

Table 3. Intakes of DII components across DII quartiles.

Characteristics	Quartiles of the DII				p *
	Q1	Q2	Q3	Q4	
	DII<5.11(n=49)	5.11≤DII<5.82 (n=47)	5.82≤DII<6.17 (n=53)	6.17≤DII (n=50)	
Energy intake (KJ/day)	3302±606	3381±493	3090±651	2473±624	0.00
Carbohydrate (% of energy)	66.5±8.95	65.5±9.57	64.5±8.50	64.2±8.15	0.55
Total fiber intake (g/4186 KJ)	10.40±4.02	10.50±3.11	11.95±2.77	14.07±2.43	0.00
Protein intake (% of energy)	12.56±2.70	12.56±2.47	12.69± 2.41	13.40±3.13	0.40
Total fat (% of energy)	25.9±7.96	26.70±7.96	27.20±6.73	26.75±6.11	0.81
Saturated fat (% of energy)	7.81±2.49	7.65±1.83	8.70±2.57	8.67±2.57	0.21
MUFA (% of energy)	7.32±1.99	8.41±3.93	7.90±1.94	8.48±2.69	0.15
PUFA (% of energy)	6.30±4.85	3.95±1.62	3.94±1.72	4.03±1.96	0.00
Trans fat	0.001±0.004	0.001±0.003	0.001±0.002	0.001±0.00[illegible]	0.85
Cholesterol	311.7±153	306±163	290±110	252±128	0.14
Omega 3 fatty acids	4.70±5.99	1.67±1.14	1.58±1.22	1.24±1.16	0.00
Omega 6 fatty acids	0.03±0.05	0.02±0.02	0.03±0.03	0.02±0.05	0.83
Onion	11.55±14.19	6.64 ±10.30	4.79±7.95	5.37±8.50	0.006
Garlic	0.92±1.47	0.94±0.97	1.03±1.32	0.50±0.82	0.11
Pepper	12.97±18.82	17.76±41.40	7.84±6.18	6.90±5.88	0.07
Black/green tea (g)	785±568	756±505	532±374	379±254	0.000
Caffeine (mg)	194±139	183±121	139±129	92.1±60.7	0.000
Beta-carotene (µg)	7910±5984	5758±2482	4831±2074	3809±1615	0.000
Thiamin (mg)	3.90±2.28	2.87±1.17	2.41±0.90	1.78±0.73	0.000
Riboflavin (mg)	4.50±1.92	3.77±1.27	3.31±1.08	2.50±0.86	0.000
Niacin	44.7±22.3	34.5±13.5	28.12±8.85	23.34±10.44	0.000
Vitamin A (RE)	1372±1093	906±403	845±431	685±409	0.000
Vitamin B_{12} (µg)	8.03±9.16	6.75±4.84	6.56±4.50	5.54±4.49	0.23
Vitamin B_6 (mg)	4.50±1.82	3.59±0.91	3.07±0.72	2.36±0.71	0.000
Vitamin B_9 (µg)	1205±763	825±341	728±247	549±217	0.000
Vitamin C (mg)	336±269	229±109	209±63.4	179±71.5	0.000
Vitamin D (µg)	1.29±2.05	1.29±1.41	1.11±1.59	0.63±0.58	0.10
Vitamin E (mg)	16.4±6.84	13.3±7.78	10.7±3.38	8.99±5.08	0.000
Zinc (mg)	25.2±11.9	21.0±8.55	17.2±4.33	14.1±5.45	0.000
Iron (mg)	65.4±34.6	46.10±15.6	43.3±21.07	32.7±12.3	0.000
Magnesium (mg)	1066±510	811±231	656±171	512±161	0.000
Selenium (µg)	214±138	164±83.1	133±45.10	105±49.9	0.000
Flavonols (g/d)	60.1±36.4	45.1±37.9	42.2±39.8	31.04±18.12	0.000
Flavones (g/d)	28.06±17.2	16.5±12.2	13.4±8.63	11.21±7.09	0.000
Isoflavones (g/d)	28.6±53.8	14.5±20.15	11.14±20.8	6.09±9.77	0.003
Anthocyanidins (g/d)	55.3±49.4	46.8±54.8	43.4±63.4	23.5±20.03	0.001
Flavanones (g/d)	71.8±91.4	42.5±36.9	39.7±40.4	34.4±29.1	0.004

*ANOVA test, Data are expressed as mean ± SD.

sex, age, energy intake, and physical activity (28). The lack of a relationship between DII and BMI may be due to the inability of the BMI to differentiate between components of body composition, including fat mass, muscle, and bone. Studies show that BMI is not a good predictor of body fat, and it is better to use other indices such as WC (29). On the other hand, the findings indicate that inflammatory indices are more subordinate to body fat and its distribution than to BMI and general obesity, which confirms the findings of the present study (30). In another similar study on 198 women in Tehran, the relationship between DII and obesity was determined and it was found that the odds of abdominal obesity increased in higher DII scores. There was a significant association between DII and abdominal obesity (p=0.004), while there was no significant association between DII and general obesity (31). In confirmation of the aforementioned justification, we can

Table 4. Odds ratio (95% confidence interval) of general obesity and abdominal obesity according to the DII.

Characteristics	Quartiles Of DII				p *
	Q1 DII<5.11(n=49)	Q2 5.11≤DII<5.82 (n=47)	Q3 5.82≤DII<6.17 (n=53)	Q4 6.17≤DII (n= 0)	
Obesity (BMI ≥ 30 kg/m2)					
Unadjusted	1	1.36 (0.60-3.10)	2.25 (0.96-5.22)	1.33 (0.59-2.99)	0.16
Model 1	1	1.23 (0.52-2.94)	2.80 (1.09-7.15)	1.58 (0.61-4.05)	0.18
High WC (≥0.88)					
Unadjusted	1	1.50 (0.65-3.42)	1.68 (0.74-3.81)	1.12 (0.50-2.50)	0.01
Model 1	1	1.07 (0.43-2.66)	1.53 (0.60-3.89)	0.94 (0.35-2.49)	0.04
High WHR (≥0.8)					
Unadjusted	1	1.14 (0.37-3.44)	0.82 (0.29-2.28)	1.19 (0.39-3.60)	0.23
Model 1	1	1.04 (0.31-3.48)	0.70 (0.22-2.21)	1.04 (0.29-3.70)	0.36
High WHtR (≥0.5)					
Unadjusted	1	1.57 (0.51-4.82)	1.23 (0.43-3.51)	1.65 (0.53-5.04)	0.06
Model 1	1	1.12 (0.33-3.81)	1.13 (0.34-3.75)	1.58 (0.42-5.96)	0.08

Abbreviations: Q: Quartiles of the dietary diversity index; BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio.
Model 1: Adjusted for age, education level, smoking status, and physical activity.

refer to the study of Muhammad et al. in 2019 (28), which aimed to investigate the relationship of DII with weight and leptin level. It was found that with increasing DII score, plasma leptin increases significantly. This positive correlation indicates the important role of inflammatory properties of food in regulating adipose tissue inflammation (32). In the present study, an increase in the DII score was associated with a decrease in calorie intake, possibly due to an increase in leptin levels. A decrease in WC with an increase in DII score can be due to an increase in the lipolysis process resulting from an increase in leptin levels, regardless of the effect of energy intake. On the other hand, the levels of some inflammatory mediators, such as IL-6, TNF-α, and CRP, increase in obesity (33-35). TNF-α and other inflammatory factors, such as IL-1, increase leptin levels (36, 37). In a study by Shivappa et al. (38), it was found that pro-inflammatory foods were significantly associated with increased TNF-α levels. It seems that as the diet becomes more inflammatory, increased lipolysis due to increased TNF-α level is responsible for decreased WC.

5. Conclusion

One of the strengths of this study is the adjustment for potential confounders. Due to the cross-sectional nature of this study, causal relationship and the mechanism of this relationship cannot be expressed. Prospective studies will help to determine this mechanism and effect. The study found that increasing the DII score reduced the chances of developing abdominal obesity. However, there is no statistically significant relationship between the inflammatory index of diet and general obesity.

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