Association Between the Dietary Inflammatory Index and Resting Metabolic Rate per Kilogram of Fat-Free Mass in Overweight and Obese Women

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Abstract

Background: A low Resting Metabolic Rate (RMR) as a risk factor for weight gain can be affected by many factors. However, the role of Dietary Inflammatory Index (DII) in RMR is still unknown. This study was designed to examine the association between resting metabolic rate per kilogram of fat-free mass and DII.

Methods: This cross-sectional study was conducted among 304 Iranian overweight and obese women aged 18-50 years. RMR was measured by indirect calorimetry. Bioelectrical Impedance Analysis (BIA) was used to determine Fat Free Mass (FFM) and other body composition parameters. A validated 147-item FFQ was used to compute dietary inflammatory index.

Results: Participants that consumed more pro-inflammatory foods, compared to those with lower intake had significantly a lower odds ratio for increased RMR/FFM (OR: 0.40; 95% CI: 0.16-0.91; p=0.01). Moreover, after adjusting for potential confounders, a significant inverse association between DII and RMR/FFM was observed in overweight women (OR: 0.31; 95% CI: 0.09-0.98; p=0.04).

Conclusion: In this study, an inverse association between DII score and RMR/FFM in overweight women was observed. Further studies, in particular prospective cohorts with long-term follow-up, are required to confirm these findings.

Keywords: Dietary inflammatory index, Female, Obesity, Overweight, Resting metabolic rate

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Introduction

Obesity is a major health problem in developed countries and a growing one in developing countries with prevalence of nearly 26% around the world. It may increase the risk of diabetes, heart disorders, fatty liver and many types of cancer (1). The understanding of the pathophysiology of excess adiposity and preventing obesity are of the utmost importance. Obesity can be induced by some risk factors such as high-energy food intake, low physical activity, sedentary behavior, genetics, and low resting metabolic rate (2).

Resting Metabolic Rate (RMR) is an important part of daily energy consumption and is accounted for 60~75% of total energy expenditure (3). A low RMR may lead to obesity or weight gain, and on the other hand, obesity may be associated with RMR via inflammation (4,5). Obesity is a chronic and systemic inflammatory disease, in which adipose tissue plays an important role through the production of numerous inflammatory cytokines, which regulate carbohydrate and lipid metabolism and immune function (6).

Alongside obesity, some foods such as red meat, high-fat dairy products, and refined grains have been shown to have inflammatory potential (7). Dietary Inflammatory Index (DII) was developed to characterize an individual's diet on a continuum from maximally anti- to pro-inflammatory to determine the effect of diet on inflammation (8). The current study was designed to examine the association between DII and RMR/Fat Free Mass (FFM) in overweight and obese participants.

Materials and Methods

Study population

This cross-sectional study included 304 overweight and obese adult women, aged 18 to 56 years, referred to health centres in Tehran, Iran. Participants were in good general health with Body Mass Index (BMI) ranged between 25 to 50 kg/m^2. The study protocol was approved by the Ethics Commission of Tehran University of Medical Sciences (IR.TUMS.VCR.REC.1395.1480), and all participants signed a written informed consent. In the current study, exclusion criteria were history of hypertension, kidney or liver disorders, cardiovascular diseases, diabetes mellitus, menopausal status, alcohol consumption, smoking, and pregnancy or lactation period. In addition, those women who had been following special diets were excluded.

Energy expenditure measurements

RMR was measured by indirect calorimetry (METALYZERR 3B-R3). An airtight mask covering nose and mouth was used for measuring respiratory gases with the spirometer MetaLyzer 3B-R3 (Cortex Biophysik GmbH, Leipzig, Germany). Participants were asked to refrain from alcohol or caffeine consumption and vigorous exercise for a day and 12 hour fasting before RMR measurements was required. The RMR was measured in the morning after a restful night's sleep in a silent room with an ambient temperature of 24-26 °C. After achieving steady state in the supine position in a quiet and darkened atmosphere, the RMR was measured for 30 *min*. Gas exchange and ventilation were recorded continuously via breath-by-breath gas analysis. The oxygen uptake (VO_2) and respiratory exchange ratio were analyzed within the last 20 *min* of the resting period and during a minimum of 5 consecutive minutes in steady-state conditions. The RMR was measured by calculating the amount of CO_2 produced and O_2 consumed through a one way valve between the subject and the analyzer (9).

Biochemical parameters

Fasting blood samples were taken and the serum was separated by centrifuge and stored at a temperature of -80°C until the analysis was carried out. Fasting plasma glucose and lipid was measured by using commercial kits (Pars Azmoon, Iran). Serum insulin concentrations were analyzed through the Enzyme-Linked Immunosorbent Assay (ELISA) (Human insulin ELISA kit, DRG Pharmaceuticals, GmbH, USA). Serum hypersensitive C-reactive protein (hs-CRP) was measured by an immunoturbidimetric assay. The International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) standardization for liver enzymes (SGOT, SGPT) was used. All measurements were done at the Endocrinology & Metabolism Research Institute (EMRI) of Bionanotechnology laboratory at Tehran University of Medical Sciences.

Dietary inflammatory index

The purpose of creating the DII is to provide a tool to measure the diet's inflammatory potential on a continuum from maximally anti-inflammatory to maximally pro-inflammatory. A higher DII score (more positive) presents a diet with more inflammation-causing food

and a lower DII score (more negative) presents a diet with less inflammation-causing food. Usual dietary intake was evaluated by using a 148-item semi-quantitative Food Frequency Questionnaire (FFQ) and its reliability and validity had been already approved in Iran (10). It was used to compute DII according to the method introduced by Shivappa *et al* and Esfahani *et al* (11,12). The FFQ included 147 foods commonly consumed by Iranians and standard serving sizes for each food item was defined. FFQ was collected through face-to-face interviews by trained interviewers at the health centers in Tehran. Software program Nutritionist IV was used for nutrient analysis which was modified for Iranian foods.

To calculate DII for all participants, first, the Z-score was computed by subtracting the global standard mean from the amount reported by participants and dividing the difference by the global standard deviation. Then, the Z-score was converted to a centered percentile score. The centered percentile score of participants for each food parameter was multiplied by the food parameter effect score, to obtain a DII score for an individual. After that, to create the overall DII score, all of the food parameter-specific DII scores were summed.

Finally, DII score was categorized into Tertile (T) including T1 (more anti-inflammatory foods), T2 (intermediate group) and T3 (more pro-inflammatory foods). Thirty food items of the theoretically possible list of 45 food parameters that were used in the present study were anti- inflammatory foods (dietary fiber, n-6 fatty acids, n-3 fatty acids, mono-unsaturated fatty acids, poly-unsaturated fatty acids, thiamin, riboflavin, niacin, vitamin B-6, folate, vitamin A, β-carotene, vitamin D, vitamin C, vitamin E, zinc, magnesium, selenium, onion, tea, and garlic) and pro- inflammatory foods (trans fatty acids, saturated fatty acids, protein, vitamin B-12, iron, total fat, energy intake, carbohydrate, and cholesterol).

Assessment of other variables

Physical activity level was measured by a validated International Physical Activity Questionnaire (IPAQ) including leisure, activities at work, commuting, and housework. The level of physical activity of participants was calculated as Met.h/d (13). Body composition including weight, BMI, body fat mass, body fat percentage, fat-free mass, visceral fat and waist to hip ratio was measured using a multi-frequency bioelectrical impedance analyzer InBody 770 scanner (Inbody Co., Seoul, Korea). According to the manufacturer's instructions, first, participants removed their shoes, coats, and sweaters, then they stood on the scale and kept the handles of the machines. Also, height was measured using a calibrated height gauge with a precision of 0.5 *cm* (in the standing position without shoes to the nearest 0.01 *m*). Obesity and overweight were defined as BMI≥30 kg/m^2 and 25≤BMI≤29.9 kg/m^2, respectively.

Statistical analyses

Descriptive analysis was used to describe the baseline characteristics of study population. The chi-square test and one way ANOVA were used to investigate categorical variables and continuous variables, respectively. In addition, to analyze the association between DII tertiles and RMR/FFM, logistic regression was utilized after adjusting for confounders including total energy intake, age, BMI, physical activity, and smoking. Also, p-values less than 0.05 were considered statistically significant. Statistical analyses of the present study were performed using IBM SPSS software (version 22.0; IBM Corp., Armonk, NY, USA).

Results

Study population characteristics

A total of 304 overweight and obese adult women, aged 18 to 56 years took part in the study. The mean and standard deviation of age, weight, and BMI among participants were 36.49±8.38 years, 80.89±2.45 *kg*, and 31.04±4.30 kg/m^2, respectively.

The mean and standard deviation of DII, RMR and RMR/ FFM were -0.003±152.36, 1720.38±1.70 and 33.76±4.47, respectively. The anthropometric and biochemical characteristics of participants are shown in table 1. In addition, participant's characteristics among DII tertiles are presented in table 2. Individuals with high DII score compared to those with low DII score had higher RMR /FFM, soft lean mass, basal metabolic rate and lower body fat. However, there were no significant differences in other characteristics of participants among DII tertiles.

Association between DII and RMR/FFM

The association between DII score and RMR/FFM was analyzed in the total population and also in sub-grouped population based on obesity degree in crude

Table 1. Characteristics of participants

	Min	Max	Mean	SD
Age (year)	17.00	56.00	36.49	8.38
Weight (*kg*)	59.50	136.60	80.89	12.45
Height (*cm*)	142.00	179.00	161.38	5.90
BMI (*kg/m²*)	24.20	49.60	31.04	4.30
RMR (*kcal/24h*)	1425.00	2548.00	1720.38	152.36
RMR/FFM (*kcal/24h/m²*)	21.50	45.86	33.76	4.47
Physical activity (Met.h/d)	29.12	42.50	38.05	7.87
FFMI (*kg/m²*)	14.60	147.80	18.37	7.64
FMI (*kg/m²*)	6.90	26.90	13.15	3.37
Soft lean mass (*kg*)	26.10	63.80	44.02	5.37
Body fat (%)	15.00	54.30	41.53	5.48
BMR (*kcal/24h*)	1132.00	1833.00	1381.08	121.97
TC (*mg/dl*)	104.00	344.00	185.30	35.77
TG (*mg/dl*)	37.00	512.00	122.10	69.29
HDL (*mg/dl*)	18.00	87.00	46.58	10.86
LDL (*mg/dl*)	34.00	156.00	95.30	24.12
SGOT(*µKat/L*)	6.00	60.00	18.05	7.75
SGPT(*µKat/L*)	4.00	98.00	19.49	13.83
hs-CRP(*mg/l*)	0.00	22.73	4.38	4.62
DII score	-3.42	3.66	-0.003	1.70
RQ	0.73	0.99	0.85	0.41

BMI-Body Mass Index, BMR-Basal Metabolic Rate, RMR-Resting Metabolic Rate, FFMI-Fat Free Mass Index, FMI-Fat Mass Index, SGOT-Serum Glutamic Oxaloacetic Transaminase, SGPT-Serum Glutamic Pyruvic Transaminase, HDL-High Density Lipoprotein, LDL-Low Density Lipoprotein, DII- Dietary Inflammatory Index, RQ-Respiratory Quotient, TG-Triglyceride, CRP-high–sensitivity c-reactive protein, TC-Total Cholesterol, RMR/FFM- Resting Metabolic Rate/Fat Free Mass

Table 2. Characteristics of study group sub-grouped by dietary inflammatory index

DII	T1 n = 96	T2 n=103	T3 n=97	* p-value
Age (year)	35.34 ±7.22	37.17 ± 8.60	36.69 ±9.15	0.291
Weight (*kg*)	80.32±13.14	80.24 ± 10.36	82.25 ± 13.57	0.431
Height (*cm*)	160.04±5.40	161.28±5.77	162.90± 6.27	0.003
BMI (*kg/m²*)	31.29±4.40	30.75±4.12	31.05±4.39	0.681
RMR (*kcal/24h*)	1721.18±170.40	1705.42±121.13	1735.48±162.90	0.373
RMR/ FFM (*kcal/24h/m²*)	33.72± 4.45	33.35± 4.20	34.40 ±4.80	< 0.001
FFMI (*kg/m²*)	17.68 ±1.45	19.16 ±13.01	18.19 ±1.45	0.393
FMI (*kg/m²*)	13.64± 3.39	12.99 ±3.31	12.85 ±3.39	0.223
Soft lean mass (*kg*)	42.79± 5.02	43.47± 4.89	45.69 ±5.68	< 0.001
Body fat (%)	42.98± 5.048	41.37 ±5.05	40.42± 6.05	0.004
Basal metabolic rate (*kcal/24h*)	1350.30± 114.86	1372.70 ±108.59	1417.20±130.36	<0.001
TC (*mg/dl*)	183.01 ±32.96	186.66 ±33.42	185.22 ±41.21	0.794
TG (*mg/dl*)	112.19 ±63.14	129.43 ± 70.74	124.13± 73.25	0.241
HDL (*mg/dl*)	46.79± 10.48	45.85 ±11.53	47.06± 10.87	0.750
LDL (*mg/dl*)	95.0624.56 ±	97.3923.05 ±	92.30± 24.32	0.401
SGOT (*µKat/L*)	16.26± 6.17	18.53± 7.98	19.21± 8.48	0.031
SGPT (*µKat/L*)	16.87 ±11.06	19.70 ±14.07	21.57± 14.50	0.077
CRP (*mg/l*)	4.62± 4.52	3.84± 4.48	4.64 ±4.91	0.445

*p-value resulted from ANOVA analysis

BMI-Body Mass Index, RMR-Resting Metabolic Rate, FFMI-Fat Free Mass Index, FMI-Fat Mass Index, SGOT-Serum Glutamic Oxaloacetic Transaminase, SGPT-Serum Glutamic Pyruvic Transaminase, HDL-High Density Lipoprotein, LDL-Low Density Lipoprotein, DII-Dietary Inflammatory Index, RQ-Respiratory Quotient, TG-Triglyceride, CRP-C-reactive protein , TC-Total Cholesterol

and adjusted binary regression model (Table 3). In total population, a marginally significant inverse association was observed between DII score and RMR/FFM in crude (OR $_{T3\ vs.\ T1}$= 0.58, 95% CI= 0.32-1.08, p-value=0.06) and adjusted models (OR $_{T3\ vs.\ T1}$= 0.63, 95% CI= 0.30-1.01, p-value =0.05).

It has been shown that overweight women with high DII score (T3) compared to low DII score (T1) had 60 and 69% lower odds of high RMR/FFM, respectively in crude (OR $_{T3\ vs.\ T1}$= 0.40, 95% CI= 0.16-0.98, p-value =0.01) and adjusted models (OR $_{T3\ vs.\ T1}$= 0.31, 95% CI= 0.09-0.98, p-value =0.04). However, women with obesity and morbid obesity had shown no statistically significant association between DII score and RMR/FFM.

Discussion

In the present study, a significant inverse association between DII score and RMR/FFM in overweight women and a marginally significant association in total participants were observed. However, no significant association was found between DII score and RMR/FFM in obese and morbidly obese women. Low resting metabolic rate, as one of the risk factors for obesity, was associated with high grade inflammation in the participants. There are controversial findings regarding the role of dietary intake in changing the energy expenditure. Some studies suggested that dietary macronutrient compositions or micronutrient can change the metabolic rate (14-16); however, other studies reported no change after dietary intervention (17,18). In addition, some studies revealed the effects of dietary supplements on energy expenditure. It has been shown that dietary supplements containing bioactive food ingredients such as green tea extract, L-tyrosine, caffeine, cayenne, and calcium may increase basal metabolic rate in obese participants (19,20). This may be due to the thermogenic effect of such ingredients._

Among dietary parameters which may influence the metabolic rate, the effect of inflammation-causing

Table 3. Association between DII and RMR/FFM in participants

Total participants				
	Crude model OR (95% CI)	p-value	Adjustment model OR (95% CI)	p-value
DII (T1) ¥				
DII (T2)	0.92 (0.52 - 1.65)	0.791	1.24 (0.49 - 3.14)	0.640
DII (T3)	0.58 (0.32 - 1.08)	0.062	0.63 (0.30 - 1.01)	0.054
***Based on obesity degree**				
	Crude model OR (95% CI)	p-value	Adjustment model OR (95% CI)	p-value
Overweight				
DII (T1) ¥				
DII (T2)	0.93 (0.39 - 2.19)	0.875	0.92 (0.22 - 3.81)	0.910
DII (T3)	0.40 (0.16 - 0.98)	0.010	0.31 (0.09 - 0.98)	0.045
Obesity				
DII (T1) ¥				
DII (T2)	0.68 (0.27 - 1.71)	0.422	1.31 (0.37 - 2.56)	0.661
DII (T3)	1.07 (0.41 - 2.77)	0.899	1.75 (0.58 - 3.09)	0.201
Morbid obesity				
DII (T1) ¥				
DII (T2)	1.11 (0.26 - 4.71)	0.883	1.67 (0.27 - 2.74)	0.399
DII (T3)	0.66 (0.15 - 2.90)	0.581	0.88 (0.08 - 1.47)	0.924

∞ based on binary regression model in crude and adjustment models

¥ Tertile 1 considered as reference group

* Overweight (BMI of 25-29.9 *kg/m²*), Obesity (BMI of *30-39.9 kg/m²*), Morbid obesity (BMI greater than or equal to 40 *kg/m²*)

foods is not well investigated. Dietary inflammatory index is associated with increased levels of various inflammatory markers which may aggravate the effect of inflammatory factors induced by adipose tissue in overweight and obese individuals. Adipose tissue is considered as a main determinant of inflammation in obesity (21), releases Free Fatty Acids (FFAs) and proinflammatory cytokines such as TNF-alpha (induced from adipose tissue as well as dietary inflammatory intake) and results in generation of Reactive Oxygen Species (ROS) in the mitochondria that may lead to mitochondrial loss and dysfunction (22).

Mitochondria have a central role in the energy metabolism. Energy is derived from the oxidation of food; NADH and FADH2 are formed in glycolysis, fatty-acid oxidation, and the citric acid cycle and they are energy-rich molecules that are eventually transformed to ATP inside mitochondria (23,24), but among this electron transfer process, generation of ROS is also probable. When mitochondria are impaired by ROS, utilization of oxygen, oxidation of food intake for production of energy-rich molecules as well as production of ATP (energy currency of the cell needed to run cellular processes) can be reduced and eventually metabolic rate may decrease (25,26).

To our knowledge, this is the first study that examined the association between DII and RMR/FFM. The strengths of the study were its fairly large same-sex population and its adjustment for some major confounders, and also utilization of advanced equipment for measuring RMR.

Limitations

One of the limitations was the cross-sectional design of the study; certainly further randomized clinical trials and prospective observational studies are needed to confirm the effect of DII on resting metabolic rate.

Conclusion

The findings of this study show that adherence to the pro-inflammatory diet may lead to a reduction in RMR/FFM in overweight women.

Conflict of Interest

Not declared.

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