The Combined Association of Dietary Inflammatory Index and Resting Metabolic Rate on Cardiorespiratory Fitness in Iranian Adults

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Research

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Abstract

Background: It has been shown that inflammation may be related to obesity and cardiovascular diseases. No study has examined the combined association of dietary inflammatory index (DII) of the diet and resting metabolic rate (RMR) on cardiorespiratory fitness (CRF). Therefore, we investigated the combined association between DII and RMR on CRF.

Methods: This cross-sectional study was conducted on 270 adult subjects.The DII was calculated using a validated semi-quantified food frequency questionnaire. RMR was measured using an indirect calorimetric method. Socio-economic status, anthropometric measures, body composition and blood pressure were documented by a trained interviewer. CRF was assessed by using a graded exercise treadmill test.

Results: Those who were classified into low DII/high RMR compared with high DII/low RMR had significant higher VO_{2Max} (mL/kg/min) ($p=0.005$). Subjects in the low DII/low RMR category had significant lower VO_{2Max} (mL/kg/min) in comparison with low DII/high RMR ($p=0.001$) and high DII/high RMR ($p<0.001$) respectively. Participants with a high DII score and low RMR had lower VO_{2Max} (mL/kg/min) compared with those with a high DII score and high RMR ($p=0.002$). Moreover, we revealed that participants in the high DII/ high RMR group had lower odds of VO_{2max} (L.min) compared with the low DII/ low RMR group which was significant. (OR: 0.93, 95% CI: 0.30, 0.38, $p=0.009$).

Conclusions: Overall, consumption of a pro-inflammatory diet, is associated with 7% lower odds of VO2max among Iranian healthy adults. This study suggests that researchers should focus on combined relationships rather than single pair-wise associations for having a better judgment.

Introduction

Resting metabolic rate (RMR) is the least energy needed to keep up essential body function during a stable resting state and fasting status[1]. It is estimated that lean body mass is accounts for 60-85% of RMR. Previous studies have shown a significant association between RMR and body fat and weight in which obese people have a lower RMR. Additionally, inflammation may have a role in weight gain with increased fat mass that is described by the equilibrium between energy intake and energy expenditure[2, 3]. Indeed, increased body mass in obese individuals results in increasing C-reactive protein (CRP) and inflammatory cytokines[4]. Therefore, obesity is considered an inflammatory state[5]. Besides, this chronic inflammation in adipose tissue accelerates the complications and diseases caused by obesity[6]. The results of the study showed a positive association between the general indicator of C-reactive protein (CRP) and the risk of coronary heart disease with mortality from cardiovascular disease[7, 8]. Accumulating evidence also suggests that obesity reduces cardiorespiratory fitness (CRF)[9]. CRF is a modifiable and independent risk factor for mortality from cardiovascular disease (CVD)[10]. Previous studies have shown that high CRF, which is evaluated by the peak of oxygen uptake (VO_{2Max}), is associated with a reduced risk of cardiovascular disease and related mortality[11]. Therefore, inflammation and VO_{2Max} are significantly associated with other major cardiovascular risk factors[11]. Several important factors like diet are involved in reducing or increasing inflammation. Recently, increasing awareness of inflammation and health, as well as understanding the effective role of nutrition in modifying the inflammation process, led to the development of the dietary inflammatory index (DII), which is an essential tool to estimate the inflammatory potential of people's diet. The purpose of making this index is to classify people's diet from maximally anti-inflammatory to maximally pro-inflammatory[12]. Accumulating evidence confirms that a high DII diet is associated with an increased risk of many diseases like metabolic syndrome, diabetes, hypertension, and cancer[4, 9, 10, 13]. In previous studies association between the DII and anthropometric measures, such as BMI, waist circumference, and waist to height ratio (WHtR) was assessed[14]. As there is an association between less RMR and obesity and given the fact that CRF and obesity are two important risk factors for CVD mediating inflammation, this study aimed to investigate the relationship between the DII and RMR with CRF in a sample of Iranian adults. We hypothesized that the higher inflammatory index of the diet in our participants is associated with low RMR and CRF in Iranian adults.

Methods

Study design

In the current study, 276 adults (118 men and 152 women) have participated. Participants were recruited through a recruitment message placed in the social network. Subjects were chosen by convenience sampling. The research criteria included apparently healthy adults with age range of 18-50, having a desire to take part in the study, and being rsident in Tehran. We excluded those who had extreme values of dietary intake (less than 800 kcal/d or more than 4200 kcal/d, respectively), suffering from kidney, liver, and lung diseases and other conditions affecting the body composition status or infectious and active inflammatory diseases, pregnancy, lactation, routine supplement or drug use, such as weight loss, hormonal, sedative drugs, thermogenic supplements like caffeine and green tea, conjugated linoleic acid (CLA), etc. After removing 3 subjects due to the above-mentioned reasons, only 270 participants remained for statistical analysis. All necessary explanations about project were given to the participants. All procedures were in accord with the ethical standards of the Tehran University of Medical Sciences (Ethics Number: IR.TUMS.VCR.REC.1396.4085), which approved the protocol and informed consent form. All participants signed a written informed consent prior to the start of the study.

Anthropometric measures

The height of participants was measured without shoes by a wall stadiometer with precision close to of millimeter (Seca, Germany). We determined waist circumference (WC) by a non-elastic tape fixed in the middle of the iliac crest and the lowest rib on the exhale. Body composition including weight, fat mass (FM), fat free mass (FFM), lean body mass (LBM) and body mass index (BMI) was measured by InBody (InBody720, Biospace, Tokyo, Japan) with following protocol: avoid food ingestion for at least 4 hours, minimum intake of 2 liters of water the day before, no coffee or alcoholic beverage consumption during at least 12 hours. Subjects were asked to empty their bladder immediately before the test [15].

Assessment of other variables

Subjects completed a self-administered questionnaire to assess the participants' demographic including age, gender (male/female), smoking (not smoking/quit smoking/smoking) and education (under diploma/diploma/educated). Physical activity was assessed using the international physical activity questionnaire (IPAQ)[16]. Subjects were quantified into three categories including very low (<600 MET-minute/week), low (600-3000 MET-minute/week), moderate and high (>3000 MET-minute/week) calculated based on Metabolic Equivalents (METs)[17].

Dietary intakes

A validated 147-item semi-quantitative food frequency questionnaire was utilized to evaluate habitual food intake [18]. Nutritional data was gathered by experienced and trained nutritionists through duly interviews. Participants reported their intake frequency for each food item during the past year on a daily, weekly, monthly, or yearly basis. Portion sizes of consumed foods that were reported in household measures were converted to grams. The food items were analyzed for their energy content using the Nutritionist 4 software (version 7.0; N-Squared Computing, Salem, OR, USA), modified for Iranian foods.

Resting metabolic rate

An indirect calorimetric method (Cortex Metalyser 3B, Leipzig, Germany) was used to estimate resting metabolic rate (RMR). It is based on calculating the amount of oxygen consumed by the body. First, a ventilated hood was given to individuals, to inhale the respiratory air into the lungs, then the device determines the amount of oxygen consumed by the body according to the amount of metabolism using the volume of oxygen concentration. The calculation of RMR was under the following conditions:1) fasting over the past 12 hours 2) abstention from alcohol, caffeine, for at least 4 hours although. It is considered an ideal period of 12 hours to ensure that the body is resting and after digestion and absorption. 3) Subjects trained that rested in a supine position for 15 min also 5 minutes added to time [19].

Cardiorespiratory fitness testing

VO_{2max} by the treadmill and the respiratory gas analyzer (Cortex Metabolizer 3B) was measured according to the Bruce protocol [20]. This protocol is divided into successive 3-minute stages, that starts at a speed of 2.7 $km \cdot h^{-1}$ and an incline of 10% gradient for 3 minutes and becomes faster based on the participant’s tolerance.

Indications for terminating the test include if the patient request to stop due to chest pain, shortness of breath, or fatigue, when participants had more than 90% maximum heart rate predicted for age, a respiratory exchange ratio ≥ 1.10, and when a plateau is identified (<150 ml x min^{-1} increase) in $\dot{V}O_{2max}$ contrary to an increment in speed. Two of the three criteria should meet. After that individuals cool down with 3 minutes-4 km/h walk and stretching exercises.

DII development

DII score was determined by multiplying the dietary inflammatory weights [21] of 29-item nutrients or food. Afterward, these values were summed. First, the daily intake of macro-and micronutrients (carbohydrate, protein, total fat, cholesterol, saturated fatty acids, monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-3 fatty acids, n-6 fatty acids, β-carotene, vitamin A, vitamin C, vitamin D, vitamin E, vitaminB6, vitaminB12, fiber, folic acid, niacin, riboflavin, thiamin, iron, zinc, selenium, magnesium, onion, caffeine) were computed to lessen the between-person variation in dietary intake; due to lack of some nutrients in our documents (trans FAs, flavan-3-ol, flavones, flavonols, flavanones, anthocyanidins, isoflavones, pepper, thyme/oregano, rosemary, garlic, ginger, saffron, and turmeric and tea), we excluded these items. Adjusted intake of food parameters for each individual was standardized to its corresponding global mean and standard deviation. The derived Z score values were converted to percentile and centered, by doubling the values and subtracting one, to normalize the scoring system and to avoid skewness. The centered percentile value for each food parameter is then multiplied by its respective overall food parameter score to obtain the food parameter-specific DII score. Finally, the DII score was determined by summing all of the food parameter-specific DII score. The greater the DII score, the more pro-inflammatory diet, and more negative scores demonstrate a more anti-inflammatory diet.

Statistical analysis

The normality of distributions was checked using Kolmogorov-Smirnov and Shapiro-Wilk statistical test. All variables had normal distributions. Then subjects were categorized based on median values of DII score and RMR both separately. In the next step, we merged these dichotomized groups of DII and RMR to compute four independent groups (low DII/ low RMR, low DII/ high RMR, high DII/ low RMR and high DII/ high RMR). To compare general characteristics across the four groups, we used one-way analysis of variance (ANOVA) and chi-square tests for quantitative and qualitative variables, respectively. To compare participants' dietary intakes within four groups, analysis of covariance (ANCOVA) to adjust for energy intake. We used ANOVA to examine significant differences across the four above mention groups. Post hoc Tukey test was used to compare pairwise mean differences. Analysis of covariance test was performed to compare the mean of CRF among DII/RMR groups after adjusting for potential confounders such as age, sex, smoking status, energy intake, physical activity, and BMI. CRF values were then transformed into binary variables according to their median values. Binary logistic regression was performed to find the association of CRF with DII/RMR categories in various models. First, we adjusted age and sex. Then we additionally controlled for smoking and physical activity status. In the final model, we moreover adjusted BMI. To obtain the overall trend of odds ratios across the combined effect of DII and RMR, we considered these classifications as an ordinal variable in the logistic regression models and the first tertiles regarded as the reference group. All statistical analysis was performed with the SPSS (Statistical Package for Social Sciences) for Windows 25.0 software package (SPSS, Chicago, IL). The level of statistical significance was pre-set at $p < 0.05$.

Results

The general characteristics of participants are shown in Table 1. This research included a total of 270 participants (118 men and 152 women) with an age range of 20-59 years old. The mean of age, height, weight, BMI, WC, FFM and systolic blood pressure had significant differences across study groups. For other variables, we did not see any significant difference. The distribution of sex among the four groups was significantly different.

Table 1
General characteristics of the participants in the study

	Low DII / Low RMR	Low DII / High RMR	High DII / Low RMR	High DII / High RMR	P-value
n	67	67	68	68	
	Mean ± SD				
Age (year)	39.8 ± 12.5	35.4 ± 12.7	39.3 ± 14.8	32.4 ± 11.6	0.004
Height (cm)	163 ± 9.29	173 ± 9.15	162 ± 7.85	172 ± 9.06	<0.001
Weight (Kg)	67.8 ± 13.8	79.3 ± 14.3	64.4 ± 12.3	77.6 ± 17.8	<0.001
BMI (kg/m^2)	25.1 ± 4.21	26.5 ± 5.00	24.2 ± 4.03	26.1 ± 5.22	0.022
WC (cm)	87.8 ± 10.8	93.5 ± 12.5	84.1 ± 10.0	91.8 ± 14.2	<0.001
FFM (kg)	45.2 ± 10.3	55.1 ± 12.6	43.3 ± 9.43	55.1 ± 12.4	<0.001
FM (kg)	22.5 ± 7.57	23.56 ± 11.3	21.0 ± 7.24	22.6 ± 10.9	0.526
LBM (kg)	47.1 ± 9.74	46.2 ± 11.0	45.3 ± 10.6	49.0 ± 12.9	0.299
Systolic blood pressure (mmHg)	109 ± 19.5	118 ± 12.6	109 ± 18.1	107 ± 24.0	0.007
Diastolic blood pressure (mmHg)	70.3 ± 8.26	73.5 ± 10.5	69.1 ± 14.5	69.6 ± 8.77	0.102
	Percentage				
Sex, (%)					<0.001
Male	11.3	35.8	15.1	37.7	
Female	34.7	17	32	16.3	
Smoking, (%)					0.231
Not smoking	26.1	23.9	25.2	24.8	
Quit smoking	8.3	50	33.3	8.3	
Smoking	25	12.5	12.5	50	
Physical activity, (%)					0.238
Low	26.3	17.2	28.3	28.3	
Moderate	25.2	26.2	23.3	25.2	
High	20	38	22	20	
Education (%)					0.241
Under diploma	16.7	22.2	38.9	22.2	
Diploma	40	20	17.8	22.2	

	Low DII / Low RMR	Low DII / High RMR	High DII / Low RMR	High DII / High RMR	P-value
Educated	21.8	26.1	25.5	26.6	

P value less than 0.05 was considered significant.

Values are based on mean ± standard deviation or reported percentage.

One-way ANOVA for quantitative data and Chi-2 test for qualitative data have been used.

DII, Dietary inflammatory index; RMR, Resting metabolic rate; WC, Waist circumference; FFM, fat free mass; FM, fat mass; BMI, body mass index; mmHg, millimeter of mercury; Kg, kilogram; kg/m^2,kilogram per $meter^2$

Table 2 indicates the dietary intake of study participants by DII/RMR categories. There were significant differences in intake of protein, fiber, energy, vitamins (B12, B6, C) and total cholesterol between DII/RMR groups. Other dietary intakes had no significant differences.

Table 2
Dietary intake of study participants

	Low DII / Low RMR	Low DII / High RMR	High DII / Low RMR	High DII / High RMR	P_{value}†
Participants, (n)	67	67	68	68	
Carbohydrate, g/d	306 ± 114	376 ± 152	327 ± 129	319 ± 163	0.151
Protein, g/d	78.8 ± 28.9	104 ± 44.2	80.1 ±28.8	89.1 ± 38.6	0.017
Fat, g/d	71.5 ± 29.9	84.8 ± 34.4	71.7 ± 31.5	77.6 ± 29.6	0.752
Fiber, g/d	15.1 ± 6.67	18.2 ± 7.60	15.9 ± 7.32	13.7 ± 4.96	0.007
Energy†, Kcal/d	2134 ± 689	2634 ± 969	2222 ± 772	2289 ± 929	0.007
Vitamin B12, μg/d	3.72 ± 1.98	5.49 ± 3.46	3.93 ± 2.23	4.66 ± 2.25	0.025
Vitamin B6, mg/d	1.34 ± 0.64	1.73 ± 0.75	1.36 ± 0.65	1.32 ± 0.49	0.044
Vitamin A, μg/d	1249 ± 803	1624 ± 1261	1313 ± 782	1177 ± 815	0.272
Vitamin C, mg/d	138 ± 69.4	152 ± 78.2	140 ± 86.5	114 ± 47.5	0.032
Vitamin D, IU/d	1.81 ± 1.41	2.50 ± 2.20	2.27 ± 2.19	2.47 ± 2.46	0.477
Vitamin E, mg/d	3.95 ± 2.48	4.97 ± 3.01	4.49 ± 4.50	3.91 ± 1.48	0.522
Beta-carotene, μg/d	771 ± 689	1011 ± 1179	771 ± 659	660 ± 754	0.340
Caffeine, g/d	156 ± 129	269 ± 753	161 ± 116	179 ± 132	0.820
Total Cholesterol, mg/d	254 ± 181	381 ± 280	233 ± 99.2	267 ± 131	0.003
Folate, mg/d	282 ± 117	345 ± 156	301 ± 129	293 ± 125	0.776
Iron, mg/d	19.7 ± 11.1	25.3 ± 12.8	19.9 ± 7.70	20.2 ± 10.3	0.458
Zinc, mg/d	8.52 ± 3.38	10.9 ± 5.03	8.69 ± 3.21	9.64 ± 4.10	0.271
Magnesium, mg/d	260 ± 101	309 ± 111	277 ± 101	274 ± 102	0.753
MUFA, g/d	21.3 ± 11.2	24.8 ± 11.3	21.3 ± 10.9	23.7 ± 10.3	0.773
PUFA, g/d	15.3 ± 8.12	17.7 ± 10.0	14.5 ± 7.59	16.3 ± 8.23	0.701
Niacin, mg/d	19.2 ± 6.92	25.9 ± 11.1	20.4 ± 8.03	21.6 ± 12.9	0.346
Omega3, g/d	0.33 ± 0.23	0.32 ± 0.24	0.17 ± 0.13	0.20 ± 0.13	<0.001
Omega6, g/d	13.1 ± 7.73	14.8 ± 9.31	12.4 ± 6.98	13.9 ± 7.87	0.713
Riboflavin, μg/d	1.50 ± 0.62	1.88 ± 0.87	1.59 ± 0.63	1.83 ± 1.07	0.063
SFA, g/d	21.4 ± 9.43	25.6 ± 11.5	22.1 ± 11.1	24.4 ± 10.6	0.595
Selenium, mg/d	0.03 ± 0.02	0.05 ± 0.04	0.04 ± 0.03	0.04 ± 0.03	0.642
Thiamin, mg/d	1.68 ± 0.68	2.15 ± 0.91	1.74 ± 0.68	1.78 ± 1.30	0.938

	Low DII / Low RMR	Low DII / High RMR	High DII / Low RMR	High DII / High RMR	P_{value}†

P value less than 0.05 was considered significant.

Values are based on mean ± standard deviation.

† based on ANCOVA test adjusted for energy intake

DII: Dietary Inflammatory Index; RMR: Resting Metabolic Rate; MUFA: Mono Unsaturated Fatty Acids; PUFA: Poly Unsaturated Fatty Acids; SFA: Saturated Fatty Acids

The mean of VO_{2Max} (mL/kg/min) was higher in participants that were classified as high DII/ high RMR (p-value <0.001), this significant association was remained significant after controlling for confounders (p-value= 0.04). Post hoc Tukey test revealed those who classified into low DII/high RMR in compared with high DII/low RMR had significant higher VO_{2Max} (mL/kg/min). Also, subjects in the low DII/low RMR category had significant lower VO_{2Max} (mL/kg/min) in comparison with low DII/high RMR and high DII/high RMR respectively. Participants with a high DII score and low RMR had lower VO_{2Max} (mL/kg/min) compared with those with high DII score and high RMR. However, the mean of VO_{2max} (L.min) and VO_{2max} (LBM) before and after adjustment for confounders, had no significant differences in any classification (Table 3).

Table 3

Mean of cardiorespiratory fitness by combined effect of dietary inflammatory index and resting metabolic rate

	Interaction of DII and RMR								
	Low DII / Low RMR(1)	Low DII / High RMR(2)	High DII / Low RMR(3)	High DII / High RMR(4)	P*	P†	Comparison group	Post hoc (P)	P‡
VO_{2max} (ml/kg/min)	28.2 ± 6.00	33.5 ± 9.11	29.0 ± 6.05	33.8 ± 8.1	<0.001	0.004	(1) versus (2) (1) versus (4) (2) versus (3) (3) versus (4)	0.001 <0.001 0.005 0.002	0.04
VO_{2max} (L. min)	2.232 ± 0.70	2.238 ± 0.78	2.11 ± 0.66	2.35 ± 0.74	0.37	0.56	(1) versus (2) (1) versus (4) (2) versus (3) (3) versus (4)	0.99 0.80 0.81 0.29	0.14
VO_{2max} (LBM)	46.7 ± 8.35	47.8 ± 8.79	46.7 ± 8.14	47.7 ± 8.14	0.81	0.68	(1) versus (2) (1) versus (4) (2) versus (3) (3) versus (4)	0.88 0.91 0.89 0.92	0.89

DII, Dietary inflammatory index; RMR, Resting metabolic rate; CRF, Cardiorespiratory fitness, LBM, Lean body mass; VO_{2max}, Maximal oxygen consumption

P* obtained from One-way analysis of variance (ANOVA) was used to compare DII/RMR classifications

Values are based on mean ± standard deviation

P value less than 0.05 was considered significant.

P‡= Adjusted for Age, Sex, Energy intake, Smoking, Physical Activity, Body Mass Index

P† obtained from polynomial linear regression

P‡ obtained from analysis of covariance (ANCOVA)

Multivariate adjusted odds ratios and 95% confidence intervals for CRF by the combined effect of DII and RMR are presented in Table 4. In the crude model, those who were in the high DII/ high RMR group, compared to the other classifications were more likely to have higher VO_{2max} (ml/kg/min) (OR=3.21; CI95%:1.55-665, p=0.001), there was no association after adjusting for confounding variables. Moreover, we found that participants in high DII/ high RMR group, had lower odds of VO_{2max} (L.min) which was significant (OR: 0.78, 95% CI: 0.37-1.65, p=0.045). When potential confounders were taken into account, such association remained signiﬁcant (OR: 0.93, 95% CI: 0.38-0.38, p=0.009).

Table 4
Odd ratios and 95% CIs for cardiorespiratory fitness by combined effect of dietary inflammatory index and resting metabolic rate

	Interaction of DII and RMR				**P value***
	Low DII / Low RMR	**Low DII/ High RMR**	**High DII/ Low RMR**	**High DII/ High RMR**	
	OR(CI)				
VO_{2max} (ml/kg/min)					
Crude	1	2.92 (1.41, 6.02)	1.20 (0.59, 2.43)	3.21 (1.55, 6.65)	0.001
Model1	1	0.78 (0.29, 2.09)	0.84 (0.36, 1.97)	0.73 (0.28, 1.86)	0.82
Model2	1	0.76 (0.28, 2.07)	0.90 (0.38, 2.12)	0.81 (0.31, 2.11)	0.75
Model3	1	1.28 (0.43, 3.77)	0.72 (0.29, 1.82)	1.31 (0.47, 3.65)	0.67
VO_{2max} (L.min)					
Crude	1	0.47 (0.22, 0.98)	0.39 (0.18, 0.85)	0.78 (0.37, 1.65)	0.045
Model1	1	0.48 (0.20, 1.14)	0.30 (0.13, 0.68)	0.93 (0.40, 2.20)	0.01
Model2	1	0.46 (0.19, 1.10)	0.29 (0.13, 0.68)	0.97 (0.41, 2.30)	0.007
Model3	1	0.44 (0.18, 1.08)	0.29 (0.13, 0.68)	0.93 (0.30-0.38)	0.009
VO_{2max} (LBM)					
Crude	1	1.46 (0.70, 3.04)	1.12 (0.53, 2.37)	1.56 (0.75, 3.24)	0.58
Model1	1	1.18 (0.51, 2.70)	1.11 (0.50, 2.44)	1.29 (0.57, 2.94)	0.94
Model2	1	1.13 (0.49, 2.61)	1.10 (0.50, 2.42)	1.26 (0.55, 2.90)	0.95
Model3	1	1.21 (0.51, 2.85)	1.09 (0.49, 2.40)	1.35 (0.57, 3.17)	0.91

Data are presented as odds ratio (95% CI).

*Obtained by binary logistic regression.

Abbreviations: DII, Dietary inflammatory index; RMR, Resting metabolic rate

Model $1_=$ Adjusted for Age, Sex, Education Status, Smoking

Model $2_=$ Adjusted for Age, Sex, Education Status, Smoking, Physical Activity

Model $3_=$ Adjusted for Age, Sex, Education Status, Smoking, Physical Activity, Body Mass Index

Discussion

The results of our study demonstrated that the mean of VO_{2Max} (mL/kg/min) was higher in participants that were classified as high DII/ high RMR. Also, we found that those who were classified into low DII/high RMR compared with high DII/low RMR had significant higher VO_{2Max} (mL/kg/min). subjects in the low DII/low RMR category had significant lower VO_{2Max} (mL/kg/min) in comparison with low DII/high RMR and high DII/high RMR respectively. Participants with a high DII score and low RMR had lower VO_{2Max} (mL/kg/min) compared with those with a high DII score and high RMR. Moreover, we revealed that participants in the high DII/ high RMR group had lower odds of VO_{2max} (L.min) which was significant.

In line with our results, a study by Potteiqer et al[22]. Showed that participants lost 5 kg of body weight and about 4% of their adipose tissue during a 16-month exercise program. Also, after nine months, it was associated with a significant increase in VO_{2max} and a significant increase in RMR in both sexes. Eventually, the results showed that following a moderate-intensity aerobic exercise program along with reduced caloric intake from foods lead to an increased RMR and weight loss and body fat in obese people[22]. Another study by Poehlman et al. indicated a high correlation between aerobic capacity and RMR in men. They also showed that RMR was higher in strong men with high physical fitness[23]. On the other hand, positive stepwise gradient in RMR according to tertiles of CRF in a cross-sectional study by shook et al. indicate the key role of aerobic capacity on resting metabolic rate. In this study, participants with moderate to high CRF had higher RMR than those with low CRF[24]. Previous results by Kim and colleges have also shown that a difference in measured RMR and predicted RMR in obese men and also shown that there is a significant difference between measured RMR and predicted RMR in Korean obese men. This study also reported a positive association between their aerobic capacity and RMR[25]. In addition, Ormsbee et al[26] showed that a period of 35–42 days of swim training such as light-moderate physical exercise after a competitive swim in healthy men and women leads to the following results: a)1.3%,12.2% increase in weight and body fat, respectively. b)7.7% decrease of VO_{2Max}, and c)7% decrease in RMR, without any change in blood lipids.

In contrast, previous results from a case-control study by Scott et al showed the DII score was associated with systemic inflammation increase and less lung function. They also reported that an increase by one unit of DII score can elevate the risk of asthma by 70%[27]. Another study by Smith et al. showed there is no significant relationship between aerobic capacity and RMR in healthy women in the age range of 19 to 30 years[28].

The reasons for these conflicting findings may be related to the various sample sizes of studies or also various studies design, even though lack of adjustment for different confounders such as individuals medical and family history.

Two possible mechanisms mentioned in studies regarding the effect of physical activity on RMR are as follows: physical activity can affect RMR by accelerating muscle growth and affecting physiological processes. Cardiorespiratory fitness also appears to be a key predictor of RMR, although it operates independently of skeletal muscle mass[29]. This difference in RMR according to CRF groups is probably due to physiological processes[24]. Other mechanisms for explaining how CRF and physical activity affect RMR levels may be related to sympathetic nervous system regulations[30–32], the function of neuroendocrine system[33, 34], structure changing of myocytes [35], and various immune responses[36].

Several limitations are better to be considered in the explanation of our findings. The main limitation of our study is its cross-sectional design which does not accurately state the cause-and-effect relationship. Another limitation is the low sample size of our study. Also, our estimates of the dietary inflammatory index were limited to the items in the standardized food frequency questionnaire in Iran and some food items are not consumed by the Iranian population.

However, some strengths of our study should be noted that the present study is the first study from Iran to examine the combined association of dietary inflammatory index and RMR on cardiorespiratory fitness. As well, we have used the standardized 168 items FFQ that has been collected for the Iranian eating habits assessment. Moreover, we adjusted several important confounders which could affect our main results. Therefore, the results of the present study can be a positive step in the direction of anti-inflammatory diet recommendations by physicians.

Conclusion

In conclusion, consumption of a pro-inflammatory diet, as indicated by High DII/ High RMR, is associated with 7% lessen odds of VO_{2max} among Iranian healthy men and women. However, more studies on this area are needed to confirm the veracity of our results. This study suggests that researchers should focus on dietary indexes rather than single antioxidant nutrients for having a better judgment.

Abbreviations

DII
dietary inflammatory index
BMI
body mass index
FFQ
food frequency questionnaire
RMR
resting metabolic rate
ANOVA
analysis of variance
ANCOVA
analysis of covariance
MUFA
monounsaturated fatty acids
PUFA
polyunsaturated fatty acids
WHtR
waist to height ratio
CRF
cardiorespiratory fitness
WC
waist circumference
FM
fat mass
FFM

fat free mass
LBM
lean body mass
CRP
C-reactive protein
CVD
cardiovascular disease
VO_{2Max}
maximum (max) rate (V) of oxygen (O_2) consumption
CLA
conjugated linoleic acid

Declarations

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Author's contributions

HSH and SS-b contributed to conception/design of the research; NP, SM, NB and ME contributed to acquisition, analysis, or interpretation of the data; HSH and NP drafted the manuscript; KD and SS-b critically revised the manuscript; and SS-b agrees to be fully accountable for ensuring the integrity and accuracy of the work. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the ethics committee of Tehran University of Medical Sciences (Ethics Number: IR.TUMS.VCR.REC.1396.4058). Written informed consent was obtained from all subjects/patients.

Consent for publication

Participants were provided a study overview and verbal consent was attained.

Competing interests

The authors declare that they have no competing interests.

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