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Dietary inflammatory index and healthy eating index-2015 are associated with rheumatoid arthritis

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Abstract

Objective: Many arthritic patients have the belief that dietary habits can worsen or ameliorate their symptoms. Whether diet quality can modify the risk of rheumatoid arthritis (RA) is an issue of continued scientific debate and interest. Therefore, we aimed to examine the association between both overall diet quality and the overall diet inflammatory potential on the risk of RA.

Design: Overall diet quality and the overall inflammatory potential of the diet were evaluated with the use of Dietary Inflammatory Index (DII) and the Healthy Eating Index (HEI)-2015, respectively. Both DII and HEI-2015 scores were calculated based on a validated semi-quantitative FFQ. Multivariable-adjusted odds of RA were calculated across tertiles of HEI, and energy-adjusted DII (E-DII) scores using binary logistic regression.

Setting: Mashhad, Iran.

Participants: Fifty newly diagnosed RA cases and 100 well-matched healthy people controls.

Results: Individuals in the highest tertile of DII scores, indicating the most pro-inflammatory diet, were about three times more likely to have RA than those in the lowest tertile (OR: 2·99; 95 % CI 1·08, 8·24; *P*-trend: 0·037), whereas individuals in the highest tertile of HEI scores, indicating more top dietary quality, had a significantly lower odds of RA than those in the lowest tertile (OR: 0·33; 95 % CI 0·12, 0·87; *P*-trend: 0·024).

Conclusions: Our findings show that E-DII and HEI-2015 are positively and negatively associated, respectively, with the odds of RA in a convenience sample of Iranians. These results highlight the importance of overall diet quality in modulating the risk of RA.

Keywords
Dietary Inflammatory Index
Healthy Eating Index-2015
rheumatoid Arthritis
Diet Quality

As a multisystem autoimmune inflammatory disease, rheumatoid arthritis (RA) is characterised by chronic synovial inflammation, joint and bone destruction or deformity,

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and pain[1]. RA may occur at any age but is most likely to appear between 30 and 55 years of age. Approximately 1 % of the world's population is affected by RA, and it is twice as common in women[2]. RA is also associated with cardiocerebrovascular diseases, which may ultimately lead to disability and premature death[3].

Although the precise aetiology of RA is not yet well understood, certain environmental exposures (e.g. smoking, diet and trauma), intestinal microbial changes and hormonal imbalances appear to affect the disease progression significantly. Diet is an important environmental factor that can have a major impact on the risk of RA and other chronic inflammatory diseases[4–7]. For example, fish has been found to reduce the risk of RA, while consuming sugary drinks rich in fructose and red meats have increased the RA risk. On closer inspection, diet makes a significant contribution in regulating inflammatory pathways. Multiple lines of evidence have shown that dietary components including moderate alcohol intake[8], fibre, *n*-3 PUFA, carotenoids, Mg[9], polyphenols[10] and specific nutrients like vitamins D[11] and E[12] are associated with the lower levels of chronic systemic inflammation.

The Dietary Inflammatory Index (DII®) is designed by Shivappa *et al.* in 2014, to specifically predict the overall inflammatory potential of an individual's diet. This index determines the inflammatory effects of forty-five nutritional parameters based on several inflammatory markers such as hs-CRP and IL-6, incorporating various inflammation-focused model systems (cell culture and animal models) and human studies[13]. Previous studies have shown the validity of the DII for predicting the relationship between the overall inflammatory potential of diet and common chronic diseases such as CVD and cancers[14,15]. However, so far, no attempt has been made to evaluate the relationship between pro- or anti-inflammatory effects of diet using DII and the risk of RA. In the present study, we also aimed to use a quick, reliable and compelling assessment of an individual's diet healthfulness in terms of its compliance with nutrition-based recommendations outlined by the 2015–2020 Dietary Guidelines for Americans: the Healthy Eating Index-2015 (HEI-2015)[16]. Therefore, the aim of this study was to evaluate the associations of DII and HEI-2015 with RA risk in a sample of Iranian adults. With the hypothesis of correlation, nutritional recommendations in these patients can be used to prevent the disease.

Materials and methods

Study design and participants

This observational study was conducted on a convenience sample of Iranians newly diagnosed with RA. Participants were recruited from patients who referred to the Rheumatology Referral Center at Mashhad city from January 2018 to February 2020. During this time, about 500 subjects have been newly diagnosed with RA by a rheumatologist, of whom fifty (1:10) patients were randomly selected for this study. The study included fifty patients with RA and 100 healthy individuals. The controls were matched with cases in a ratio of 2:1, according to sex and age (±5 years). The controls were selected among adults who did not have any connective tissue or joint disease, including RA.

Inclusion and exclusion criteria

The inclusion criteria for cases were as follows: adults ≥18 years old; having RA based on clinical diagnosis by a rheumatologist using the revised criteria for RA classification presented by the American Rheumatism Association in 1987; no evidence of any connective tissue or joints disease, except RA; being in the first 6 months of clinical diagnosis of RA and willingness to cooperate in the study. The inclusion criteria for controls were as follows: adult ≥18 years old; no evidence of any connective tissue or joints disease and willingness to cooperate in the study.

The exclusion criteria were as follows: a history of alcohol consumption or certain conditions that might affect nutritional status (e.g. taking certain medicines except for anti-inflammatory drugs) or any disease (e.g. severe endocrine disorders like diabetes, severe cardiovascular disorders like myocardial infarction, and stroke) that can significantly affect dietary intake or other dietary factors; following special diets, such as a vegetarian diet, weight gain diet, very-low-energy diet or ketogenic diet during the year prior to the interview, to avoid heterogeneity in dietary intake within groups, thus decreasing overall 'noise' in relation to the dietary 'signal' (e.g. the true difference associated with diet in relation to RA).

Dietary intake assessment

The habitual dietary intakes of participants during the previous year were assessed by completing a 168-item semi-quantitative FFQ through face-to-face interviews. Mirmiran *et al.* evaluated this questionnaire for validity and reliability with the use of twelve 24-h dietary recalls per month[17]. The prior study revealed the validity and reliability of this questionnaire for the extraction of food groups among the Iranian adult population[18]. Individuals were asked to report their daily, weekly, monthly or yearly intake frequency of each food item according to its standard size unit in the questionnaire. The data obtained from the questionnaire were analysed using Nutritionist IV software (First Databank Inc., Hearst Corp.), and the average daily energy and nutrient intake were calculated. Subjects who reported daily energy intake <3347·2 kJ (<800 kcal) or >17572·8 kJ (>4200 kcal), or zero consumption for more than 40 % of the items in the semi-quantitative FFQ, in the year preceding the interview were excluded from final analysis.

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Dietary inflammatory index

The DII is a scoring algorithm that evaluates the overall effect of a set of nutritional parameters including forty-five various macro- and micro-nutrients on inflammatory markers obtained from 1943 articles published from 1950 to 2010. This index is a valid tool for assessing the inflammatory potential of whole diets based on food groups[19]. The inflammatory effect of each food parameter is assessed by scoring in the range of –1 (maximally anti-inflammatory) to +1 (maximally pro-inflammatory) based on their effect on six well-known inflammatory markers (IL-1β, IL-4, IL-6, IL-10, CRP and TNFα). DII scores were calculated using the FFQ-derived dietary data and in the same way as previously described by Shivappa *et al.*[13] in detail. Energy-adjusted DII (E-DII) was created to control for the effect of total energy intake using the nutrient density approach. We calculated E-DII scores by converting the reported intake of dietary parameters to an amount per 4184 kJ (1000 kcal) of energy intake and using the energy-standardised version of the global reference database.

Healthy eating index

The HEI-2015 is constructed to reflect the overall diet quality in terms of adherence to the 2015–2020 Dietary Guidelines for Americans[16]. The HEI-2015 includes seven components (which count for ten points each) and six subcomponents (which count for five points each), which is how thirteen components have a total of 100 points. Subcomponents are scored proportionately from 0 to 5[20].

Physical activity assessment

Due to the prominent health-related role of physical activity, self-report International Physical Activity Questionnaire-Short Form was used to assess individuals' physical activity habits. The validity of this questionnaire was previously evaluated[21]. This questionnaire consists of four generic items to capture the duration and frequency of individuals' physical activity in a continuum of intensity levels between sedentary and vigorous over the past 7 d. Total physical activity was then estimated in metabolic equivalent hours per week.

Anthropometric measurements

The weight of each individual was measured with light clothing using a digital scale (Saca 831) to the nearest 100 g. The height was measured in a standing position, without shoes, leaning against the wall at a full-body stretch and a naturally straight spine using a wall-mount measuring tape with a 0·5-cm accuracy. BMI was then calculated by dividing the weight (in kg) by the height (in m) squared. Finally, to measure waist circumference, we positioned the measuring tape in the narrowest area between the lower rib and the iliac crest.

Other variables assessments

Other required variables such as age, gender, education level, employment status, vitamin/supplement use, NSAID use, tobacco use and family history of RA and female-specific variables including the number of deliveries, number of abortions and oral contraceptives pills used were collected by completing the General Information Questionnaire through a face-to-face interview.

Statistical analysis

All statistical analyses were performed using the software package IBM SPSS Statistics, version 16 (SPSS Inc.). The sample size was estimated to be at least eighty-two individuals in the control group and forty-one diseased individuals in case group (ratio 2:1) by assuming the prevalence of high DII scores to be 50 % among Iranian population (0·5) and OR of 30 % (OR = 0·3) with an alpha of 0·05 and power of 80 %[22]. The Kolmogorov–Smirnov test was used to ascertain whether continuous variables distributed normally or not. Between-group comparisons were made with an independent sample *t* test for quantitative variables and a χ^2 test for qualitative variables. The one-way ANOVA along with Tukey's test as a *post hoc* pairwise comparison was used to ascertain significant differences across tertiles of E-DII and HEI-2015 scores. The relationship between E-DII scores and HEI-2015 scores was indicated using Pearson's Correlation test. Similarly[23], OR (95 % CI) were obtained using binary logistic regression in the crude model and multivariable-adjusted models as follows: *Model 1* adjusted for continuous covariates including age, BMI, waist circumference, physical activity and sleep duration and *Model 2* adjusted for categorical covariates including gender, smoking, education, dietary supplementation and family history of RA. P values $< 0{\cdot}05$ were considered as statistically significant.

Results

The current study consisted of eighteen males (12 %) and 132 females (88 %). The mean age was 41·7 ± 10·5 years (range 19–68 years). The general characteristics of participants in both groups are compared in Table 1. Compared with controls, weight (+5·3 kg), BMI (+2·1 kg/m^2), waist circumference (+5·5 cm) and inactivity (+2·18 h/week) were significantly higher among cases. Both physical activity and sleep duration were significantly lower in cases than in controls. The number of smokers in the cases group was almost twice than in controls.

The distribution of participants' general characteristics across tertiles (T) of the E-DII and HEI-2015 scores is shown in Table 2. Individuals in the highest tertile (T_3) of E-DII scores had the lowest HEI scores, and those in the second tertile (T_2) had significantly lower HEI scores than individuals in the lowest tertile (T_1). Also, individuals in the lowest

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Table 1 Characteristics of study participants across case and control groups*

Variables	Case group (*n* 50)		Control group (*n* 100)		
	Mean	SD	Mean	SD	*P*
Male					1·00
n	6		12		
%	12		12		
Age (years)	41·70	10·29	41·67	10·70	0·99
Weight (kg)	67·41	10·03	62·10	8·56	< 0·001
BMI (kg/m^2)	26·02	3·47	23·89	2·81	< 0·001
Waist circumference (cm)	87·93	12·41	83·51	7·46	0·007
Smoker					0·007
n	17		15		
%	34		15		
University education					0·22
n	19		28		
%	38		28		
Physical activity (MET-h/week)	4·52	2·58	6·71	3·98	< 0·001
Sleep duration (h/d)	7·72	1·76	7·03	1·33	0·01
Time spent sitting (h/d)	5·96	2·56	5·01	1·75	0·008
Dietary supplementation					0·52
n	20		45		
%	40		45		
Family history of Arthritis					0·009
n	20		20		
%	40		20		

MET, metabolic equivalent.
*P values were obtained by the χ^2 test and independent samples t test for categorical and continuous variables, respectively.

tertile (T_1) of HEI scores had the highest E-DII scores, and those in the second tertile (T_2) had significantly higher E-DII scores than individuals in the highest tertiles (T_3). The result obtained from Pearson's correlation test revealed that the two indices were inversely correlated (Pearson Correlation coefficient = –0·34; *P*-value < 0·001).

The odds of RA across the tertiles of E-DII scores and HEI-2015 scores in the crude model and multivariable-adjusted models are shown in Table 3. The higher E-DII scores were observed in the subjects living with RA. This observation remained statistically significant after adjusting for potential confounders (model 2). Moreover, a significant increasing trend was observed in the odds of RA across the tertiles of E-DII scores. Conversely, the lower HEI-2015 scores were observed in the subjects living with RA. Also, a significant downward trend was observed in the odds of RA across the tertiles of HEI-2015 scores. This inverse relationship remained statistically significant after further adjustment for potentially confounding factors.

Discussion

The main finding of the current case–control study was a significant relationship between E-DII scores and RA, independent of potentially confounding lifestyle factors. Analyses revealed that the HEI-2015 scores had an inverse relationship with E-DII scores and RA. To our knowledge, data regarding the effect of the two dietary indices, DII/E-DII and HEI-2015, on the risk of RA are still limited.

Our results showed that adherence to a dietary regimen resulting in low DII/E-DII scores might reduce the odds of being RA. The onset of RA is influenced by unhealthy lifestyle behaviours and conditions, such as obesity, smoking, heavy alcohol consumption and sedentary behaviours. Nevertheless, this relation still remains statistically significant when potentially confounding factors were accounted for in different models. In line with our study, in a study conducted in 2018, an inflammatory dietary pattern was associated with increased seropositive RA risk with onset ≤55 years old[24]. In fact, higher DII or E-DII values represent a pro-inflammatory diet, rich in SFA and protein intake but poor in anti-inflammatory nutrients, including fibre, MUFA and PUFA[25,26].

Previous studies have reported several mechanistic pathways that may link dietary parameters to inflammatory diseases such as RA. Certain dietary ingredients, such as meat and butter, are pro-inflammatory based on the capacity to increase E-selectin, high-sensitivity C-reactive protein and soluble vascular cell adhesion molecule-1, which gradually leads to insulin resistance[27,28]. In a systematic review and meta-analysis of thirteen intervention trials, focusing on the effect of dietary sugar intake on biomarkers of subclinical inflammation, it has been suggested that the high dietary glycaemic index is linked to recurrent hyperglycaemic responses, increased free fatty acids, excessive production of free radicals and subsequently inducing systemic inflammation and chronic inflammatory diseases[29]. Moreover, in 2016, a cross-sectional study of 1209 US young adults aged from 20 to 30 years found that consumption of sugary drinks rich in fructose (sweetened soft drinks, high-fructose corn syrup and fruit drinks) at least five times a week has tripled the risk of RA (OR: 3·01, 95 % CI 1·20, 7·59, *P*: 0·021) even after further adjustment for potentially confounding factors including other dietary factors, physical activity, plasma glucose or smoking[30]. A high-fat diet turned out to be a potent factor in inflammation-related processes of developing RA. In a study conducted by Na *et al.* on mice with collagen-induced arthritis, a model of RA mice fed a high-fat diet showed elevated levels of inflammation-related T-cells (Th1 and Th17 cells) and M1 macrophages than in non-fat diet–collagen-induced arthritis mice. On the other hand, it has been observed that the number of α_2-glycoprotein 1, a soluble protein that stimulates lipolysis, increases, which in turn increases the Th-17 population as well as Il-17 secretion in high-fat diet-collagen-induced arthritis mice. IL-17, a prominent pro-inflammatory cytokine, is also known to have detrimental effects on lipid metabolism by accumulating fat droplets in THP-1 cells and stimulating lipolysis by reciprocally up-regulating the expression of α_2-glycoprotein 1 in adipose tissue in obese individuals, thereby causing severe inflammation and collagen-induced arthritis exacerbation[31].

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Table 2 Characteristics of study participants across tertiles of energy-adjusted Dietary Inflammatory Index (E-DII) and Healthy Eating Index (HEI)-2015 scores‡

	E-DII Score							HEI-2015 Score						
	$T_1 < -0{\cdot}922$ (n 49)		T_2 (n 50)		$T_3 \geq -0{\cdot}547$ (n 51)			$T_1 < 57$ (n 54)		T_2 (n 49)		$T_3 \geq 64$ (n 47)		
Variables	Mean	SD	Mean	SD	Mean	SD	P	Mean	SD	Mean	SD	Mean	SD	P
E-DII score								–0·44	0·53	–0·65	0·49*	–0·88	0·34*,†	<0·001
HEI-2015 Score	63·37	6·57	60·96	9·22*	57·15	5·75*,†	0·003							
Male							0·414							0·051
n	5		8		5			5		10		3		
%	10·2		16		11·8			9·3		20·4		6·4		
Age (years)	39·26	9·08	41·34	11·88	44·33	10·01	0·052	42·63	10·73	41·02	11·06	41·28	9·86	0·71
Weight (kg)	63·71	9·02	62·75	9·31	65·12	9·83	0·442	65·62	7·34	63·54	9·42	62·80	10·69	0·32
BMI (kg/m^2)	24·38	2·76	24·20	2·93	25·20	3·75	0·247	25·53	2·66	24·16	3·45	24·28	3·22	0·08
Waist circumference (cm)	84·51	6·73	84·17	8·31	86·25	12·67	0·511	86·6	8·36	83·9	12·24	84·27	7·50	0·30
Smoker							0·098							0·22
n	8		8		16			13		49		6		
%	16·3		16		31·4			24·1		26·5		12·8		
University education							0·516							0·50
n	16		18		13			14		18		15		
%	32·7		36		25·5			25·9		36·7		31·9		
Physical activity (MET-h/week)	6·53	3·80	5·15	2·21	6·27	4·63	0·141	6·65	5·50	6·14	2·92	5·29	2·36	0·19
Sleep duration (h/d)	7·12	1·36	7·49	1·50	7·11	1·63	0·378	7·26	1·70	7·04	1·49	7·40	1·26	0·51
Time spent sitting (h/d)	5·04	1·64	5·40	2·14	5·51	2·43	0·514	5·37	2·46	5·29	1·95	5·30	1·83	0·981
Dietary supplementation							0·747							0·50
n	20		24		21			25		18		22		
%	40·8		48		41·2			47·2		36·7		46·8		
Family history of Arthritis							0·692							0·097
n	11		15		14			19		8		13		
%	22·4		30		27·5			35·2		16·3		27·7		

MET, metabolic equivalents.
P values were obtained from ANOVA with Tukey's test as *post hoc* pairwise comparison for quantitative variables and χ^2 test for qualitative variables.
*$P < 0{\cdot}05$, significant difference from the first tertile (T_1).
†$P < 0{\cdot}05$, a significant difference from the second tertile (T_2).

Table 3 Rheumatoid arthritis risks across tertiles of energy-adjusted Dietary Inflammatory Index (E-DII) and Healthy Eating Index (HEI)-2015 scores*,†

	E-DII score						HEI-2015 score					
		T_2 (*n* 50)		$T_3 \geq -0{\cdot}547$ (*n* 51)				T_2 (*n* 49)		$T_3 \geq 64$ (*n* 47)		
Models	$T_1 < -0{\cdot}922$ (*n* 49)	OR	95 % CI	OR	95 % CI	*P*-trend	$T_1 < 57$ (*n* 54)	OR	95 % CI	OR	95 % CI	*P*-trend
Crude	Ref.	2·19	0·89, 5·41	2·96	1·22, 7·19	0·018	Ref.	0·43	0·19, 0·97	0·37	0·16, 0·86	0·027
Model 1	Ref.	1·84	0·81, 5·23	2·53	1·12, 6·65	0·039	Ref.	0·47	0·19, 1·03	0·41	0·19, 0·93	0·018
Model 2	Ref.	2·28	0·83, 6·29	2·99	1·08, 8·24	0·037	Ref.	0·46	0·18, 1·17	0·33	0·12, 0·87	0·024

*Rheumatoid arthritis risks across tertiles of E-DII and HEI-2015 scores were calculated using binary logistic regression models.
†Model 1 was adjusted for continuous covariates, including age, BMI, waist circumference, physical activity and sleep duration; model 2 was further adjusted for categorical covariates, including gender, smoking, education, dietary supplementation and family history of rheumatoid arthritis.

Our study also demonstrates that following diets with higher HEI scores, reflecting greater adherence to Dietary Guidelines recommendations, significantly reduces the odds of being RA. This association was independent of potential risk factors related to lifestyle behaviours and conditions. In addition to our study, few other studies have yielded similar results. A cross-sectional survey of women aged ≥55 years found that healthy controls had higher HEI than RA patients[32]. Similarly, in another cross-sectional study recently conducted in the USA, the HEI score was significantly different between individuals with RA (51·41 ± 0·37) and healthy subjects (53·50 ± 0·28)[33]. Analyses of data from the Nurses' Health Study and the Nurses' Health Study II with 3 678 104 person-years of observation revealed that lower HEI score was associated with the onset of RA in women aged ≤55 years, whereas no significant association observed in other women[31]. Our results also indicated that HEI was negatively linked to DII, which can also explain the HEI may alter the odds of RA. Diets with higher HEI scores will naturally tend to have lower DII scores[34,35]. As an integral part of healthy diets, fruits, vegetables, whole grains and fish are rich in a variety of biologically active substances that play a major role in modulating inflammatory responses in RA[36–38].

The lack of blood CRP, hs-CRP or IL-6 tests, sample size and limited population who match inclusion criteria were limitations of our study. Also, we could not exclude anti-inflammatory drug consumption as a confounder factor because most of the case group were taking the anti-inflammatory drug. However, the main weakness of the present study is inherent to its observational nature, which is uninformative on the temporal criterion for judging causality. However, this type of study provides a rationale for future clinical evaluations. The results of the present study are strengthened, however, by matching control group, adjusting for possible confounding factors, evaluating dietary quality in compliance with national dietary guidelines (HEI) and using FFQ as a validated instrument for the assessment of diet in long-term and habitual eating patterns compared with food records.

Conclusion

Greater adherence to diets low in DII scores and high in HEI scores is significantly associated with lower odds of having RA in a convenience sample of Iranians. Furthermore, we observed an inverse relationship between the two indices. These results suggest that dietary quality may influence the development of RA and clinicians should consider putting emphasis on the quality of individuals' diets as an effective strategy for implementing RA preventive programmes.

Significance and innovations

- To our knowledge, this study was the first study that simultaneously analysed the relation of both Dietary Inflammatory Index (DII) and Healthy Eating Index-2015 (HEI-2015) scores with rheumatoid arthritis among Iranians.
- Greater adherence to diets with low DII scores and high HEI-2015 scores was significantly associated with a lower risk of rheumatoid arthritis.
- This study shows that the energy-adjusted DII and HEI-2015 could be important tools for editing dietary guidelines for care and prevention of symptoms in rheumatoid arthritis.

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M.K., S.S.A. and N.M. Data validation and FFQ analysis: M.R.S.F.M. DII analysis: N.S.. Statistical analysis and interpretation of data: N.S. and D.S. Drafting of the manuscript: N.M. and D.S. Language revision: R.R. Editing of the manuscript: R.R. All authors gave final approval of the version to be published and agree to be accountable for all aspects of the work. *Ethics of human subject participation:* This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving study participants were approved by the research ethics committee at Mashhad University of Medical Sciences (ID: IR.MUMS.MEDICAL.REC.1397.327). Written informed consent was obtained from all subjects.

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