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ORIGINAL ARTICLE

The Association of Dietary Inflammatory Index with Risk of Depression, Anxiety, and Sleep Quality among Physically Active Adults

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ABSTRACT

Background: Limited data are available on association between dietary inflammatory index (DII) and mental health. So we evaluated the association between DII and risk of depression, anxiety, and sleep quality in physically active adults.

Methods: A total of 750 Iranian physically active adults were included in a cross-sectional study through stratified cluster sampling method. Food frequency questionnaire (FFQ) was used to evaluate dietary intake and to calculate DII scores. Pittsburg sleep quality index was used to assess sleep quality. Depression and anxiety were assessed by the Beck inventory measure. Odds Ratio (OR) and 95% Confidence Intervals (95%CIs) were estimated for depression, anxiety and sleep quality in relation to DII tertiles.

Results: After adjustment for energy, age, gender, marital status, and BMI, there was a significant association between a lower DII and an enhanced sleep quality (adjusted model: OR: 1.78; 95%CI: 1.24-2.57; $p<0.002$). However, no significant association was found between DII and odds of depression or anxiety.

Conclusion: Our review suggested a direct association between DII and the elevated risk of sleep disturbances among a group of physically active Iranian adults. No such an association was found for the risk of depression and anxiety. Further prospective studies help expanding current knowledge in this issue.

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Introduction

The prevalence of mental health disorders is increasing worldwide (1). Depression and anxiety are among the most prevalent types of mental health problems (1). Depression affects almost 350 million peoples throughout the world (2). The prevalence of depression in the Iranian population ≥18 years is estimated to be 8-20% (3, 4). Anxiety is an emotional, physiological, cognitive and behavioral state that may result from the perception of threat. People with anxiety disorders usually have frequent intrusive thoughts or worries, and they may avoid certain situations because of uneasiness (5). Environmental factors greatly affect mental health in a person (6). A novel hypothesis suggesting that inflammation is an etiological element for

mental disorders (4, 7). It has been shown that pro-inflammatory cytokines can increase risk of depression, anxiety and sleep disorders (8, 9). Adherence to an inflammatory potential diet can increase serum concentrations of pro-inflammatory cytokines in the body (10). Higher consumption of energy-dense, high-fat and high-sugar products, processed and red meats, and refined grains and alcohol has been associated to the increased levels of body inflammation (11). In contrast, high dietary intake of fruits, vegetables, whole grains, fish and lean meats can decrease levels of inflammatory markers in the blood (4, 10, 12, 13).

The association between pro- or anti-inflammatory food items and risk of mental disorders has been studied in an earlier investigation (4). However, it seems that the inflammatory potential of a diet should be measured as a whole (14). Therefore, dietary inflammatory index (DII) has been planned to quantify the potential inflammatory properties of a diet (14-16). To calculate DII, researchers measure the effect of each food item on serum levels of C reactive protein (CRP), interleukin 6 (IL-6), and tumor necrosis factor a (TNF-a) (15, 16). Although several studies have been done on the association of inflammatory potential of diet and risk of mental disorders, no similar study has been done among physically active persons. A cross-sectional study on 3363 adults showed significant relationship between consuming a pro-inflammatory diet and increased risk of stress (17). Another cross-sectional study of 249 female students in Iran, concluded that adherence to a high DII daily diet was significantly associated with poor sleep quality (SQ) (12). In another study conducted in 2019 in Iran among 7000 adults aged 35 to 65, there was a significant relationship between DII score and severe anxiety in women, but not among men (18). In a meta-analysis in China, DII was significantly associated with increased risk of mental health problems (19).

Mental health disorders increase can affect all populations worldwide and in particular in developing countries. Among different groups, physically active persons are susceptible to mental health problems due to changes in their usual daily life and dietary intake. One of the essential parameters of athletes that can increase the fitness and success in sport career is diet. There are risk factors that are more unique for athletes, such as the use of simple carbohydrates, red meat, and various sports supplements that increase the risk of depression in these people. We aimed to perform a cross-sectional study about association of DII and risk of depression, anxiety, and sleep disorders among a group of Iranian active adults.

Materials and Methods

This cross-sectional study was carried out among 750 adults aged 18-50 years in Kashan City in north of Isfahan province, Iran (Altitude of 1,600 m above sea level) from 2022 to 2023. The sample size was determined based on finding of Dehghan *et al.* (13) study using the formula of $n=[[(z1-\alpha/2)+(z1-\beta)]^2\times(p_1(1-p_1)+p_2(1-p_2))]/(p_2-p_1)^2$. Our study population consisted of active people of both genders with a BMI between 20 and 30 kg/m^2, who were exercising at least 1 hour and 3 times a week. We did not include subjects who were pregnant and lactating, or suffered from chronic diseases, those who had mental illness or took drugs affecting mental status or those who used dietary supplements that affected body inflammation and professional athletes with a history of participating in bodybuilding competitions. For participants' selection, gyms were first stratified based on 5 urban areas of Kashan city. Then, 2 gyms from each stratum (one male's club and one female's club) were randomly chosen. Finally, subjects were enrolled (75 persons from each selected gym) by cluster sampling method. A written informed consent was obtained from each participant in accordance with the Declaration of Helsinki. In the end, the obtained data from all 75 people from each fitness club remained confidential by the researcher and a copy of the results of this research was given to all participants. The study protocol was approved by Kashan University of Medical Sciences Ethics Committee, Kashan, Iran (IR.KAUMS.MEDNT.REC.1402.082).

A validated semi-quantitative food frequency questionnaire (FFQ) containing 168 food items that was modified according to Iranian dietary habits was used to assess dietary intake of the participants (20). They were asked to report the frequency of consumption of each food during the past year on daily, weekly, monthly, or annual basis. The frequency of intake of each food was then converted to grams/day using household measures. To calculate the energy and nutrient content of foods, we used NUTRITIONIST 4 software for Iranian foods (version 7.0; N-Squared Computing, Salem, OR, USA). DII score was calculated based on FFQ-derived dietary data for all participants by method introduced by Shivappa *et al.* (14). For this purpose, first we calculated the Z-score by subtracting the global standard mean from the amount reported and dividing the difference by the global standard deviation. Then, the Z-scores were converted to a centered percentiles (14) and those amounts were later multiplied by the food parameter effect score, to obtain a DII score for a subject. Finally, all individual foods' DII were summed up to obtain total DII (14).

In this research, 38 food items such as vitamins B1, B2, B3, B6, B9, B12, A, D, C, E as well as energy, carbohydrate, fat, protein, fiber, caffeine, cholesterol, iron, magnesium, zinc, selenium and omega-3, omega-9 and intake of pepper, ginger, turmeric, tea, onion, garlic, rosemary, oregano and various flavonoids were included.

To examine Sleep Quality, Pittsburgh SQ Index (PSQ-I) was utilized. The validity and reliability of this questionnaire was confirmed before (21). The quality of sleep, delay in falling asleep, length of useful sleep, sleep adequacy, difficulties in getting asleep, amount of hypnotic drug use and disturbances in daily functioning were assessed employing 7 questions with a score ranged from 0 to 3. A score of 3 in each scale indicated the maximum negative score (total score ranging from 0 to 21). Participants with a total score of ≥6 were classified to have poor sleep quality. Self-administrated Beck Depression Inventory (BDI) was used to assess participants' depression (22). This questionnaire contained 21 questions to assess symptoms of depression. Participants answered questions based on a four-choice scale ranging from 0 to 3. This questionnaire contained 2 questions about emotional issues, 11 questions for cognitive issues, 2 questions in relation to the behavior, 5 questions regarding the physical symptoms, and 1 question considering the interpersonal behaviors. The total score of each person ranged from a minimum of 0 to a maximum of 63. Patients with a depression score of >10 were considered to have moderate to severe depression.

Beck Anxiety Inventory (BAI) with 21-point scale was used as a self-reporting. The reliability and validity of the questionnaire was examined and confirmed by Poursadeghiya *et al.* (23). This questionnaire contained four-choose questions to indicate the intensity of anxiety. Each question described mental, physical and panic symptoms of anxiety. The total score ranged from 0 to 63. Patients with anxiety score of >8 were considered to have moderate to severe anxiety. Participants' weight to the nearest 0.1 kilogram was measured using a standard digital scale (Seca, Hamburg, Germany). Height was evaluated using a stadiometer in the standing position without their shoulders to the nearest 0.5 cm. Body mass index (BMI) was calculated as weight in kg divided by height in meters squared. Physical activity (PA) was assessed using a valid self-reported questionnaire (24). Furthermore, some general information, including participants' gender, age, marital status, educational level, and occupation status were collected for all subjects, by a general questionnaire.

Statistical analysis was done using Statistical Package for Social Sciences (SPSS, Inc., version 20, Chicago IL, USA). Continuous variables were expressed as mean±SD and categorical variables were expressed as percentages. DII scores were categorized into tertiles. Differences in variables across tertiles of DII were assessed using One-way ANOVA. To compare categorical variables across tertiles, the Chi-square test was applied. Odds ratio (OR) and 95% confidence intervals (95%CIs) of mental disorders in relation to DII were estimated using multivariable logistic regression in different models. Model a was adjusted for age, and energy intake. Model b was further adjusted for participants' gender and marital status as well as for smoking and Model c had additional adjustment for BMI. The lower tertile of DII score (T_1) was used as the reference category. $P<0.05$ was considered significant in all statistical analyses.

Results

Final analysis was undertaken on 750 participants (375 men and 375 women) who were selected from two gyms in Kashan City, Iran. The mean±standard deviation for age and BMI of all participants was 29.32±8.84 years and 23.88±3.75 kg/m^2, respectively. Socio-demographic characteristics and related covariates of participants across tertiles of DII were presented in Table 1. Significant differences were seen in physical activity ($p<0.03$), educational level ($p<0.01$), and gender ($p<0.001$) between tertiles of DII, while, no significant differences were found in terms of mean age and BMI between tertiles of DII. Percentage of different marital status ($p=0.81$) and occupation ($p<0.60$) had no significant differences between tertiles of DII. Table 2 shows energy adjusted dietary intake of study participants across tertiles of DII. No significant differences were visible in dietary intake of magnesium ($p=0.08$), selenium ($p=0.20$), zinc ($p=0.19$), and omega 3 fatty acids ($p=0.18$) between DII tertiles. However, those in T_3 category had significantly higher intake of energy, protein, carbohydrate and total fat compared with those in T_1 and T_2 ($p<0.001$). Furthermore, significant differences were seen for iron ($p<0.001$) and caffeine ($p=0.030$) consumption throughout the tertiles of DII.

Odds ratio and 95%CI of depression, anxiety, and sleep disorders across tertiles of DII was shown in Table 3. In the crude model, a significant association was observed between increasing tertile of DII and elevated risk of sleep disorders (OR=1.83, 95%CI: 1.28-2.61, p trend<0.01). In addition, by adjusting of age, energy intake, smoking, gender, marital status, and BMI, similar association was found (OR=1.78, 95%CI: 1.24-2.57, p trend<0.02), such that those with the highest DII had 78% higher risk of sleep disturbances than those with the lowest DII.

Table 1: General characteristic of participants across tertiles of dietary inflammatory index.

Variable	Dietary Inflammatory Index			P[a]
	T_1 (n=251)	T_2 (n=249)	T_3 (n=250)	
Age (years)	30.14±9.01	28.89±9.09	28.92±8.39	0.195*
BMI (kg/m^2)	23.78±3.86	23.60±3.60	24.27±3.76	0.120*
Gender				<0.001
Female	200 (79.7%)	159 (63.9%)	155 (62.0%)	
Male	51 (20.3%)	90 (36.1%)	95 (38.0%)	
Physical activity				0.038
Never	2 (0.8%)	4 (1.6%)	4 (1.6%)	
Little	42 (16.7%)	36 (14.5%)	36 (14.4%)	
Medium	149 (59.4%)	175 (70.3%)	176 (70.4%)	
Severe	58 (23.1%)	34 (13.7%)	34 (13.6%)	
Marital status				0.814
Single	134 (53.4%)	141 (56.6%)	133 (53.2%)	
Married	117 (46.6%)	108 (43.4%)	117 (46.8%)	
Education				0.014
Under diploma	15 (6.0%)	10 (4.0%)	15 (6.0%)	
Diploma	53 (21.1%)	63 (25.3%)	65 (26.0%)	
University	183 (73.0%)	176 (70.7%)	170 (68.0%)	
Job				0.607
Unemployed	62 (24.7%)	62 (24.9%)	58 (23.2%)	
Clerk	49 (19.5%)	43 (17.3%)	47 (18.8%)	
Self-employed	73 (29.1%)	74 (29.7%)	72 (28.8%)	
Non-specified	67 (26.7%)	70 (28.1%)	73 (29.2%)	

Data are mean±standard deviation unless indicated. [a]Obtained using one-way ANOVA for continuous variables and Chi-square test for categorical variable. *P* value<0.05 is significant.

Table 2: Nutrients intakes of participants across tertiles of dietary inflammatory index.

Variable	Dietary Inflammatory Index			P[a]
	T_1 (n=251)	T_2 (n=249)	T_3 (n=250)	
Energy (kcal)	2828.79±1812.73	3129.04±1689.69	4717.45±2795.37	<0.001
Protein (g)	202.93±57.93	204.76±47.36	231.74±61.86	<0.001
Carbohydrate (g)	914.30±273.01	949.95±252.19	1118.74±376.41	<0.001
Total fat (g)	243.19±82.95	258.57±87.57	352.60±188.49	<0.001
Magnesium (mg)	905.48±319.86	862.88±254.92	919.17±297.94	0.081
Caffeine (mg)	72.55±100.61	51.15±120.00	52.55±76.84	0.030
Selenium (µg)	1.02±2.32	5.30±73.31	1.42±3.63	0.200
Zinc (mg)	28.09±32.98	90.56±1087.64	10.85±55.01	0.191
PUFA (g)	1.22±0.88	2.63±24.66	0.31±1.77	0.188
Iron (mg)	32.44±14.04	28.11±11.53	24.67±10.94	<0.001

Data were presented as mean±standard deviation unless indicated. [a]Obtained using one-way ANOVA for continuous variables and Chi-square test for categorical variable. *P* value<0.05 was considered significant. PUFA: Polyunsaturated fatty acids.

No statistically significant association was found between DII tertiles and risk of depression (OR=1.04, 95%CI: 0.07-1.58, *p* trend=0.83) and anxiety (OR=1.62, 95%CI: 0.98-2.70, *p* trend=0.07) before adjustment for the confounders. These findings remained unchanged in different models of confounder adjustment and at the full-adjusted model (for depression: OR=1.09, 95%CI: 0.71-1.67, *p* trend=0.67 and for anxiety: OR=1.54, 95%CI: 0.92-2.58, *p* trend=0.12).

Discussion

Current study showed positive link between DII and the elevated risk of sleep disturbances. However, no significant association was observed between DII and risk of depression or anxiety among the participants. Different studies have been carried out to investigate association of diet with risk of mental disorders; however, no earlier study has been done among physically active persons for DII and mental health. Two cohort studies

reported significant association between dietary inflammatory potential and risk of depression and anxiety (25, 26), but it should be kept in mind that those studies were completed exclusively among females and dietary inflammatory potential was determined by not the same methods. In a longitudinal study of middle-aged individuals (mean age at follow-up=60 years), women with the highest DII score were almost 3 times more likely to develop persistent depressive symptoms, but no significant association was observed among the males (27). These results might be partially explain why women are more susceptible to inflammation than men; while dietary intake can influence this risk to be somehow more important in women than males (28, 29). In addition, the association between DII and depression and anxiety is affected partly at least by the food items of DII.

Based on present finding, a significant association was detected between DII and risk of sleep disorders. In line with our study, a cross-sectional study by Godos *et al.* (30) showed that participants at the highest quartile of DII score were more likely to have poor sleep (OR=0.49, 95%CI: 0.31-0.78). Furthermore, it has been shown that good adherence to the Mediterranean diet, as an anti-inflammatory dietary pattern, could improve SQ in adults (30, 31); while poor sleep is associated with chronic and low-grade inflammation (30). It has been suggested that inflammatory- or immune-mediated processes may reduce the number of hypocretin-containing neurons. Hypocretin cell loss is common among patients with sleep disorder narcolepsy (32-34).

The link between DII and mental health might be explored by understanding effects of diet on systemic inflammatory pathways, oxidative stress and gut microbiota (35). It has been shown that low intake of vegetables and unhealthy eating habits are related with pro-inflammatory responses and increases in oxidative stress (35). This pattern of daily dietary intake also can increase the population of pathogenic microbes at the gut lumina and reduces healthy microflora (36, 37). Reactive oxygen and nitrogen species interference with mitochondria function (38). In addition, oxidative stress results in DNA damage by the process of telomere shortening. Telomere shortening and mitochondria dysfunction consequently leads to mental health problems (39, 40).

Current study is the first investigation about association of DII and risk of depression, anxiety and sleep disturbances among physically active persons. We used validated questionnaires and considered a wide range of confounding variables in this study. All questionnaires were completed by trained nutritionists. However, the study had also some limitations. As the study had cross-sectional design, causal relationship could not be determined. In addition, lack of biochemical measurements including inflammation profile limited our ability to discuss mechanisms. As we all know, misclassification of participants in terms of dietary intakes is undeniable when using FFQ. In addition, it is possible that we missed some other food items with inflammatory potential in our FFQ. Furthermore, other mental health measures should be assessed for their possible association with DII. Finally, better clinical measurements of depression and anxiety are required to reach a firm conclusion.

Conclusion

In overall, findings of the present study showed that higher DII score was significantly associated with poor sleep quality. There was no significant association between DII score and risk of depression or anxiety. Future studies with prospective designs, considering more food parameters to compute DII score are required to reach a firm conclusion.

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Authors' Contribution

M.KH wrote the main text of the article and conducted data collection. A.M analyzed the data and re-checked the written text and A.Y performed secondary screening and rechecking of data analyzed.

Conflict of Interest

None declared.

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