



The negative relationship of dietary inflammatory index and sleeping quality in obese and overweight women

A cross-sectional study

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Abstract: *Background and aims:* Substantial evidence have linked low grade inflammation with the pathophysiology of chronic diseases and psychological impairment. An integral component underlying the link is pro-inflammatory diet. While sleeping is another significant contributor, few studies have addressed the relationship between the sleep quality and inflammatory cascade with the dietary quality as a moderator. The current study assesses the relation between inflammatory potential of the diet and sleep quality in Iranian obese and overweight women. *Method:* A total of 219 obese and overweight adult women were enrolled in this cross-sectional study. A standard 147-item food-frequency-questionnaire was used to record the dietary intakes; then, the dietary inflammatory index (DII) was derived from the result-consolidated questionnaires. Pittsburgh Sleep Quality Index (PSQI) was utilized to withdraw the sleep quality and quantity. *Results:* The mean ($\pm$ standard deviation) age, body mass index, and PSQI of individuals were 36.49 (8.38) years, 31.04 (4.31) kg/m², and 5.78(3.55), respectively. Patients in the highest DII quartile were the ones with the higher consumption of pro-inflammatory food, and, ~58% of participants who were in the higher quartile had a sleep disturbance status. Results revealed an inverse relationship between sleep quality and DII in the crude model ($\beta = -0.17$, $p = 0.01$) as well as full-adjusted model ($\beta = 0.24$, $p < 0.001$), such that women with higher DII had the poorest sleep quality. *Conclusion:* Based on the present observational study, obese and overweight females with higher adherence of the anti-inflammatory diet may have better sleeping status.

Keywords: sleep quality, dietary inflammatory index, obesity and overweight

Introduction

Approximately one-third of adults experience sleep disorder during their life time [1, 2], which is considered as a common health concern. The physiological effects of poor sleep hygiene, such as diabetes, cardiovascular disease, and obesity, has been well recognized [3] that result in serious poor health [4–9]. It is theorized that sleep disorders occur via altering circadian rhythm, hormonal disturbance, metabolic and inflammatory response [10–12], while their mechanistic pathways have yet remained

unclear. Update, there is not enough study to show the exact role of sleep disturbance with the pathophysiological mechanisms of some chronic diseases.

In order to offer an appropriate intervention and prevention guide, it is necessitated to well understand the mechanistic contribution of sleeping disorders in the physiologic response pathways. To date, most related studies have focused on the diet as a moderator for relating sleep quality with overall health status [13]. In order words, the dietary intake is considered as a modifiable risk factor associated with sleeping hygiene. The diets of whole grains, fish, fruits

and vegetables have anti-inflammatory effects; whereas the typical Western diet include high pro-inflammatory contents such as protein, total/saturated fats and simple carbohydrates [14], that induce gut dysbiosis [15].

Some reports have particularly allocated a significant role to dietary patterns with low-grade inflammation [16–18]. Based on scientific studies, Dietary Inflammatory Index (DII[®]) has been introduced for scoring the diet and inflammation measure. This scale evaluates the risk of diet that increases the inflammatory markers, i.e., tumor necrosis factor (TNF)- α , interleukin (IL)-1 β , IL-4, IL-6, IL-10, and C-reactive protein (CRP) [19]. In fact, the production of inflammatory markers was found to be acutely reduced during the sleep, while sleep restriction was associated with the increased circulation [20]. However, with an already existing a low-grade inflammation (e.g., in the obese state), an additive effect of inflammatory diet and poor sleeping hygiene is highly plausible. Additionally, several studies reported that the prevalence of obesity and overweight are increasing especially among Iranian women [21–23]. Iran is a multiethnic country, therefore, eating habits and lifestyle can be affected by the difference in socio-cultural, environmental, and genetic [24]. In the present study, the overall objective was to assess the association between the DII and sleeping pattern in Iranian obese and overweight adult women.

Material and methods

This cross-sectional study included healthy overweight and obese women ages 18 to 56 years randomly selected from the patients who referred to the health centers in Tehran (n=219). General characteristics of all health subjects were collected through a self-administered questionnaire. Exclusion criteria included the diagnoses of an acute or chronic inflammatory disease, the regular usage of oral contraceptives, a history of hypertension, cardiovascular disease, diabetes mellitus, impaired renal or liver function, intake of alcohol or drug abuse, smoking, thyroid disease, malignancy, pregnancy or any recent breastfeeding. Also, individuals with chronic diseases that affected their diet and those on any special dietary patterns or with any substantial body weight fluctuations over the past one year were excluded.

Biochemical assessment

Blood samples were collected following an overnight fasting. The obtained serums were stored at -80°C until the analyses were performed. According to the protocol from manufacturer, a single assay was used to analyze all samples. All measurements were taken at the laboratory

of the School of Nutritional Sciences and Dietetics of Tehran University of Medical Sciences (TUMS). The lipid profile was measured using commercial kits (Pars Azmoon, Iran).

Dietary assessment

A semi-quantitative food frequency questionnaire (FFQ) with 147 items was used for Iranian foods in accordance with Willett [25] to evaluate the average dietary intake over the past one year. Standard methods were used to transform portion sizes of the consumed foods into grams. An average daily intake of food parameters (including macro and micronutrients) was computed from the FFQ using NUTRITIONIST IV software (version 7.0; N-Squared Computing, Salem, OR).

Anthropometry measurements

An impedance fat analyzer (Inbody 770 scanner Co., Korea) was used to obtain the weight, body mass index (BMI), fat-free mass (FFM), body fat percentage (%), waist to hip ratio (WHR), and fat mass index (FMI) of the participants through a standardized procedure. In brief, a low-level electrical current was sent from the electrodes of hands and feet into the body, then, the impedance of current was measured with the aim of evaluating the body composition.

Assessment of sleep quality

The Pittsburgh sleep quality index (PSQI) is a self-reporting questionnaire to assess participants' sleep patterns and the quality six months before the analysis stage [26]. It consists 19 items that are rated on a four-point scale (0–3) and grouped into seven components (sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medications, and daytime dysfunction). Based on the questionnaire manual, the summation of item's scores in each component was summarized into component scores ranging from 0 (better) to 3 (worse). The total PSQI score was calculated as the summation of seven component scores ranging from 0 to 21. A low score (≤ 5) indicated normal sleep quality, while higher scores (> 5) of total PSQI were considered as disturbed sleep.

DII calculation

The complete description of the DII development and validation has been published elsewhere [19, 27]. In brief, several micronutrients, macronutrients, and other food parameters with inflammation plus food intake parameters of 11 populations around the world were aggregated to find

the evidence-based relationships among them. Data of these populations enabled the research team to adamantly calculate the “world mean value” and “world standard deviation” for each food parameter [28]. The z-scores were calculated via the subtraction of standard global mean from the actual dietary intake [27]. To obtain the food parameter-specific individual DII score, the respective food parameter effect score (inflammatory potential for each food parameter) was subsequently derived [29]. Afterward, the overall DII score for each participant was computed through the summation of all food parameter-specific DII scores. Higher DII scores were the indicator of more pro-inflammatory diets while lower values characterized more anti-inflammatory diets [19]. A total of 33 food parameters were obtained by the FFQ and used to compute DII, namely: energy, carbohydrate, protein, alcohol, fiber, omega 6, omega 3, total fat, monounsaturated fatty acid, polyunsaturated fatty acid, saturated fatty acid, cholesterol, vitamin B6, Folic acid, vitamin B12, vitamin C, vitamin D, vitamin E, vitamin A, Iron, Magnesium, Zinc, Selenium, Anthocyanidins, Flavan-3-ols, Flavones, Flavonols, Flavonones, Isoflavones, garlic, tea, and onion.

Statistical analysis

Descriptive statistics of study covariates and outcomes were performed. Kolmogorov-Smirnov test was used for evaluating the data distribution. The visually inspection was used for normality of relevant variables levels, and the extreme data outliers were excluded. Mean and standard deviation (SD) were used to present continuous variables; Chi-squared test or Student's t-test were applied to assess differences between groups. The DII was analyzed both as a categorical (quartile) and continuous variable. Linear regression (unadjusted) and multivariable logistic regression analyses were used to assess the association between the DII and sleep pattern. The logistic regression was adjusted for baseline characteristics (age, physical activity, energy and BMI) comparing individuals grouped into quartiles. The results were reported as percentage change (β) with 95% confidence intervals (95% CI). All reported p-values were based on two-sided tests and compared to a significance level of 0.05. All statistical outputs were analyzed by the SPSS®21 software (SPSS version 21, USA).

Results

In this study, the general characteristics of participants were presented in Table 1. The mean ($\pm$ SD) age, BMI, height, body weight and PSQI of individuals were 36.49 (8.38) years, 31.04 (4.31) kg/m², 161.38 (5.90) cm, 80.89 (12.45)

Table 1. Anthropometric and laboratory characteristics of studied population

Parameters	Minimum	Maximum	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	179	161.38	5.90
BMI (kg/m ²)	24.20	49.60	31.04	4.31
Body fat (%)	15.00	54.30	41.53	5.48
Waist hip ratio (cm)	.81	92	1.23	5.24
BMI (%)	19.40	74.20	34.04	8.69
Obesity degree (%)	29.40	231	143.69	21.51
WC (cm)	80.10	136.00	99.01	10.05
FFMI (kg/m ²)	14.60	147.80	18.37	7.64
FMI (kg/m ²)	6.90	26.90	13.15	3.37
FBS (mg/dL)	67	137	87.49	9.64
TC (mmol/L)	104	344	185.30	35.77
TG (mmol/L)	370	512	122.10	69.29
HDL-C (mg/dL)	18	87	46.58	10.86
LDL-C (mg/dL)	34	156	95.30	24.12
PSQI	0.00	21	5.76	3.55
DII score	−3.42	3.66	−0.003	1.70
Energy (kcal)	1028.98	4192.72	2613.03	751.74

BMI: body mass index; WC: waist circumference; FFMI: fat free mass index; FMI: fat mass index; FBS: fasting blood sugar; TC: total cholesterol; TG: Triglyceride; HDL: high density lipoprotein; LDL: low density lipoprotein; DII: dietary inflammatory index; PSQI: Pittsburgh sleep quality index. Data are presented as mean $\pm$ standard deviation (SD). n=219

kg and 5.78(3.55), respectively (Table 1). The characteristic data of target population is presented by quartiles of DII in Table 2. The individuals who were in the first quartile had lower DII scores, while in higher quartiles this relation was inverse. No clear trends were seen in the distribution of age, BMI, weight, percent body fat, or waist circumference across DII quartiles. Higher levels of HDL-C and LDL-C (Figure 1) were found in the higher quartiles of DII ($P<0.05$). Also, TG level was marginally related with DII, in the way that subjects with higher level of DII had higher level of TG in serum ($P<0.06$).

Based on the PSQI questionnaire, the number of people with adequate sleep quality was 92, whereas 127 suffered from sleep disturbances. There were no significant differences with regards to age, weight, BMI, percent body fat, or waist circumference in these two groups (Table 3).

Table 4 presents the data of multiple linear regression models with diet inflammatory index as independent and sleep quality as dependent variables. The DII parameter, as a dichotomous variable, was modelled in relation to the PSQI (sleep quality). The results showed that the sleep quality was inversely associated with DDI ($\beta=-0.17$, 95% CI (1.04 to 1.35), $p=0.01$), and after the adjustment of potential confounders (age, physical activity, energy and BMI), it remained significant ($\beta=-0.24$, 95% CI (1.09 to

Table 2. Characteristics of the studied sub-grouped in dietary inflammatory index (DII) quartiles

Variable	DII Quartiles				p-value
	Q1	Q2	Q3	Q4	
Age (year)	35.56 (8.29)	36.07 (8.38)	35.72 (8.08)	38.58 (8.73)	0.10
Weight (kg)	81.97 (13.39)	82.33 (14.35)	79.84 (11.56)	79.70 (10.17)	0.43
BMI (kg/m ²)	31.04 (4.33)	31.27 (4.95)	30.80 (4.25)	30.84 (3.79)	0.78
Body fat mass (%)	34.22 (8.99)	34.94 (9.90)	33.69 (8.32)	33.44 (7.55)	0.72
Body fat (%)	41.53 (5.62)	41.94 (5.22)	40.91 (5.83)	41.73 (5.36)	0.69
WC (cm)	99.68 (10.38)	99.51 (10.67)	98.94 (10.15)	98.21 (9.01)	0.80
PSQI	1.42 (0.49)	1.37 (0.48)	1.51 (0.50)	1.52 (0.50)	0.32
TG (mg/dL)	125.29 (66.55)	130.11 (88.59)	118.51 (65.76)	115.15 (53.57)	0.61
TC (mg/dL)	178.74 (35.03)	183.06 (30.24)	183.00 (36.19)	194.71 (39.87)	0.06
HDL-C (mg/dL)	45.09 (9.49)	42.87 (9.16)	46.53 (11.44)	51.15 (11.61)	<0.001
LDL-C (mg/dL)	92.85 (23.95)	92.64 (22.27)	92.50 (26.63)	102.34 (32.39)	0.05

BMI: body mass index; FFMI: fat free mass index; FMI: fat mass index; HDL: high density lipoprotein; LDL: low density lipoprotein; DII: dietary inflammatory index; TG: Triglyceride; CRP: high-sensitivity c-reactive protein; TC: total cholesterol; FBS: fasting blood sugar; PSQI: Pittsburgh sleep quality index; WC: waist circumference.

*p-value resulted from ANOVA analysis.

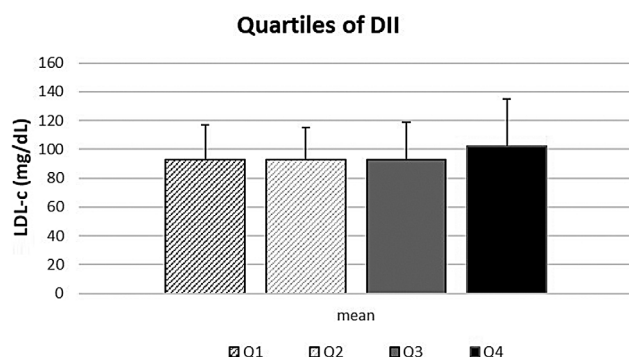


Figure 1. Level of LDL-c in serum across quartile of DII. LDL: low density lipoprotein; DII: dietary inflammatory index. The error bars represent the standard deviation (SD). Population was categorized based on dietary inflammatory index (DII) into four quartiles, such that the individuals in quartile 4 have the higher DII than others (Q1<Q2<Q3<Q4). It was seen that subjects who were in Q4 of DII, had greater levels of LDL-c (mg/dL) in the serum (102.34 (32.39), p=0.05) in compared to other quartiles.

1.49), p<0.001). Thus, the highest quartile of DII was less likely to provide the satisfying sleep quality. This trend also presented in Figure 2.

The association of dietary inflammatory index (DII) and sleep quality was shown in Figure 2. It was presented that individuals with increased DII score may have higher sleep disorder (p=0.011).

Discussion

Recent studies have demonstrated the adverse effect of sleep disturbances on health with particular salience among

Table 3. Characteristics of sleep pattern of studied sub-groups

Variable	PSQI N=92	PSQI N=127	p-value
Age (year)	36.04 (8.44)	36.54 (8.79)	0.39
Weight (kg)	80.46 (13.15)	79.96 (11.45)	0.23
BMI (kg/m ²)	30.87 (4.41)	30.85 (4.16)	0.22
Body fat mass (%)	33.60 (8.87)	33.79 (8.39)	0.44
Body fat (%)	41.39 (5.42)	41.63 (5.31)	0.49
Waist hip ratio (cm)	0.92 (0.05)	0.93 (0.05)	0.96
TG (mg/dL)	126.67 (66.55)	117.00 (61.35)	1.48
TC (mg/dL)	181.01 (28.64)	181.14 (34.54)	0.10
HDL-C (mg/dL)	47.70 (9.63)	46.57 (9.64)	0.68
LDL-C (mg/dL)	98.77 (20.76)	97.73 (23.98)	0.68

BMI: body mass index; FFMI: fat free mass index; FMI: fat mass index; HDL: high density lipoprotein; LDL: low density lipoprotein; DII: dietary inflammatory index; TG: Triglyceride; TC: total cholesterol; FBS: fasting blood sugar; PSQI: Pittsburgh sleep quality index; WC: waist circumference.

*Based on the PSQI questionnaire, the number of people with adequate sleep quality was 92 (less or equal than 5), whereas 127 suffered from sleep disturbances (>5). **p-value is result in independent sample T test.

overweight and obese individuals [30–34]. The objective of this study was to verify the observational relation of DII with sleep quality. An inverse association between DII, that is deemed to be low-grade inflammation-provoking [34], and sleep quality was observed in Iranian obese and overweight women; women with higher DII scores possessed poorer sleep quality. Adjusting the confounders statistically strengthened this trend.

The results of previous studies showed that adiposity promotes systematic low-grade inflammation in body [35]. The increasing rate of overweight and obesity among Iranian women may contribute to less physical activity and higher intake of calories, different type of dietary

Table 4. Association of DII with sleep quality

Variable	β	95% (CI)	p-value
DII*	-0.17	(1.04 to 1.35)	0.011
DII**	-0.24	(1.09 to 1.49)	0.001

DII: dietary inflammatory index.

Based on binary regression model in crude and adjustment models, the data was presented in Beta (β) and confidence interval (CI).

*Crude model.

**Adjusted model (after the adjustment of age, physical activity, energy and BMI).

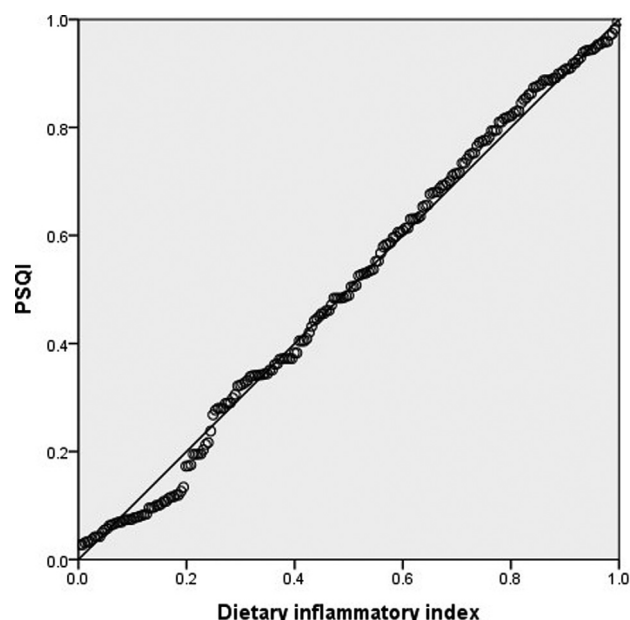


Figure 2. The association of DII on sleep quality among target population.

patterns. The assessment of dietary patterns among Iranian indicated that their diet is highly loaded with refined grains (bread and white rice), potatoes, and hydrogenated fat which can increase the grade of inflammation in body [36]. In addition, environmental factors such as education [37] and family history [23] may be related to adiposity. Studies also demonstrated that especial genotypes such as FTO [38], MC4R [39, 40] and Cry1 circadian gene polymorphisms [41] were tightly associated with general obesity in this area which may have possible association in this regard.

Recent study has shown that the change in the dietary inflammatory potential may result in the improvement of sleep quality, as the intervention can increase the sleep efficiency without increasing its duration. Similarly, in our study, we reached to the point that DII as the dietary inflammatory indicator was related to the sleep disturbance as the mediatory role of inflammatory factors [42]. Some other studies provided controversial results on separate foods and nutrients in relation with sleep. Those studies did not consider the multi effects of the foods and nutrients that

possibly could cause inconsistent results, therefore, probing the correlation of dietary pattern with sleep quality might be more useful and practical [43].

One of the major evaluation factors for the effect of the diet on inflammation is DII that was utilized here to categorize the target population based on the subsequent pro-inflammatory diet.

In few studies, the mediatory effect of inflammation was assessed on the role of nutrition and sleep quality through various methodologies and outcome measures. Cao et al. reported that a plant-based diet was inversely linked to CRP, with an increased effect among individuals with severe sleep apnea [44]. The plant-based dietary pattern resulted in lower inflammatory effect in body, so, in-line with that study, the present work proposed that the lower inflammation may contribute to better sleep.

Gordon-Dseagu et al. evaluated the connection between certain inflammatory factors, metabolic pathways and sleep. In fact, the inflammatory factors, such as $\text{TNF}\alpha$ and IL 1, are known as the sleep cytokines with strong roles in the initiation and promotion of sleep quality. Growth hormone discharge, that increases non-rapid eye movement sleep (NREM), is connected with IL1 levels. In addition, higher amount of IL1 in serum is associated with the lower concentration and abnormality of sleep pattern, as well as higher fatigue [45]. Therefore, any variation in the magnitude of inflammatory factors, which results in the pro-inflammatory dietary pattern, can be associated with the inadequate sleep pattern. The National Health and Nutrition Examination Survey (NHANES) [46] indicated that sleep quality was statistically related to the antioxidant level, oxidative stress and inflammation, whereas vitamins A and C and CPR were found to be the moderate mediator in cardio and metabolic health and sleep quality [47]. Based on these results, it might be concluded that the inflammation has a mediatory role in sleep-related disorders and other situations recognized to link to the subclinical, low-grade inflammatory status.

In addition, the inflammation and oxidative stress elevated [48–50] in clinical subjects with sleep disorders, while their levels of antioxidant molecules lessened [50, 51]. These results are in-line with the results obtained in the current study that higher DII may be associated with the sleep quality.

Strengths and weaknesses

The present study was the first to assess the association of DII and sleep quality among obese and overweight women in Iran. The results of this research may shed a light to the possible relationship among inflammation originated from diet and sleep statue in relation with abnormal weight.

Nevertheless, there were several limitations. First, because of the cross-sectional design of study, we did not have an exact cause-effect documentation, thus, the reverse-causation should be considered. As such, we were not able to determine whether the inflammatory potential of the diet affected the sleep quality or sleep features led to unhealthy dietary habits. And finally, we did not directly measure the inflammatory markers such as IL-1, or TNF- α and some genetic related factors.

Conclusions

The finding supported the hypothesis of that the higher inflammatory potential of a diet may be related to the poor sleep quality in Iranian obese and overweight women. Thus, there is the possibility that the improvement in sleep quality may be achieved via a dietary component which leads to lower chronic systemic inflammation. More studies with prospective designs with consideration of some genetic related factors can further confirm the exact effect and mechanism of DII on sleeping pattern.

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History

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Conflict of interest

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