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Association of Dietary Insulin Index and Insulin Load with Sleep Quality among University Students: A Cross-Sectional Study

Hossein Nassaji-Jahromi[1], Sanaz Joekar[2], Akram Yazdani[3, 4], Azadeh Aminaianfar[1*]

1. Research Center for Biochemistry and Nutrition in Metabolic Diseases, Kashan University of Medical Sciences, Kashan, Iran.
2. Department of Clinical Psychology, School of Behavior Sciences, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.
3. Department of Biostatistics and Epidemiology, School of Public Health, Kashan University of Medical Sciences, Kashan, Iran.
4. Autoimmune Diseases Research Center, Kashan University of Medical Sciences, Kashan, Iran.

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ABSTRACT

Introduction: Inadequate sleep quality is a prevalent health concern worldwide. University students are at a particularly higher risk of experiencing poor sleep quality. Dietary factors can modulate sleep performance. To the best of our knowledge, no study has yet examined the relationship between the dietary insulin index (DII) and dietary insulin load (DIL) with sleep quality among university students. Therefore, this study aimed to investigate the association between DII and DIL and sleep quality among Iranian university students.

Methods: In 2023, this cross-sectional study was conducted among 330 students enrolled at Kashan University of Medical Sciences. Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI). Dietary intake was evaluated through a validated semi-quantitative food frequency questionnaire (FFQ) comprising 117 items. Multivariable regression models were applied to adjust for potential confounding factors, and a P-value of less than 0.05 was considered statistically significant.

Results: After adjusting for all potential confounders, participants in the highest quartile of DII had 64% lower odds of experiencing sleep disturbances compared with those in the lowest quartile (OR = 0.36, 95% CI: 0.14–0.88). Similarly, individuals in the fourth quartile of DIL had 65% lower odds of experiencing sleep disturbances compared to those in the first quartile (OR = 0.35, 95% CI: 0.14–0.84). However, no statistically significant associations were observed between DII or DIL and overall sleep quality or its subcomponents.

Conclusion: Higher DII and DIL were associated with lower odds of sleep disturbances among university students. These findings suggest a potential role of diet-induced insulin response in regulating sleep health. Further studies with larger sample sizes and more robust designs, such as prospective cohort studies, are warranted to confirm these results.

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Introduction

Sleep is an essential biological process that plays a crucial role in maintaining human health and overall well-being (1). Poor sleep quality is a primary global health concern (2-4) and has been associated with an increased risk of obesity (5), diabetes (6), cardiovascular diseases (7, 8), cancer (9-11), depression (12) as well as reduced concentration and memory impairment (13). Among university students, inadequate sleep may impair academic performance and negatively affect both psychological and physical well-being (14-18). A high prevalence of sleep disturbances has been reported among university students (19). For example, a meta-analysis conducted in 2024 estimated that the prevalence of sleep disturbances among Iranian medical students was 48% (20). Smoking, alcohol consumption, the use of electronic devices such as smartphones before bedtime, mental disorders, and unhealthy eating patterns (21-29) are recognized as risk factors for poor sleep quality. Previous evidence has also shown that the intake of specific dietary components, including processed foods (26, 30), milk and dairy products (31), and vegetables (32), as well as adherence to dietary patterns such as the DASH and Mediterranean diets, may be associated with sleep quality (33, 34). The dietary insulin index (DII) and dietary insulin load (DIL) are indices that represent the capacity of a diet to increase postprandial insulin levels (35). The food insulin index (FII)

* *Corresponding authors:* Azadeh Aminianfar, Ph.D, Research Center for Biochemistry and Nutrition in Metabolic Diseases, Kashan University of Medical Sciences, Kashan 8715981151, Iran. Phone: +98-21-88955805, Email: aaminianfar@gmail.com.

ranks foods according to their insulinogenic response. It is a valuable tool for investigating dietary effects on insulin regulation and the risk of insulin resistance–related disorders in nutritional research (35). The FII is determined by comparing the insulin response elicited by a test food with that of an isoenergetic portion of a reference food, such as glucose or white bread (35). Unlike the glycemic index (GI), which primarily reflects the carbohydrate content of foods, the FII also takes into account the amount and type of protein and fat consumed (35). DIL is calculated by summing the products of each food's FII, energy value, and consumption frequency (35). DII is then derived by dividing DIL by the total daily energy intake (35). Current evidence on the relationship between DII, DIL, and sleep quality—particularly among university students—remains very limited (36). A study by Sarsangi et al. (2023) reported a significant inverse association between DIL and sleep disorders in adults (36). Moreover, higher DII values were associated with a 39% reduction in the odds of experiencing sleep disorders in adults (36). To the best of our knowledge, this is the first study to examine the association between the dietary insulin index and insulin load and sleep quality among university students. Evidence regarding the relationship between DII, DIL, and sleep quality in other populations remains limited (36). Moreover, university students are particularly vulnerable to sleep disturbances (37, 38), and the prevalence of such disorders is notably high among Iranian students (20). Therefore, investigating modifiable risk factors associated with sleep quality is essential. Accordingly, the present study aimed to evaluate the associations between DII and DIL and sleep quality among university students in Iran.

Materials and Methods

Participants

This cross-sectional study was conducted among university students at Kashan University of Medical Sciences, Kashan, Iran, in 2023. The sample size was calculated based on findings from a previous study (39), resulting in a total of 330 participants. Eligible participants were those who: (1) were university students affiliated with Kashan University of Medical Sciences; (2) were not in their examination periods; (3) were free from chronic diseases, including mental disorders, cardiovascular diseases, diabetes, thyroid disorders, and other similar conditions; (4) were not taking medications for chronic illnesses, particularly psychiatric drugs; (5) had not experienced grief, emotional trauma, or divorce during the previous three months; (6) had not followed any special diet within the last three months; (7) were non-smokers; and (8) were not pregnant or breastfeeding. Exclusion criteria included: (1) failure to maintain cooperation with the researcher until study completion; (2) underreporting of daily energy intake (<800 kcal/day) or overreporting (>4200 kcal/day); and (3) alcohol consumption. Written informed consent was obtained from all participants, and the study protocol was approved by the Research Council of the Faculty of Medicine at Kashan University of Medical Sciences, Kashan, Iran (Ethical code: IR.KAUMS.MEDNT.REC.1402.115).

Dietary Assessment

A validated and reliable 117-item semi-quantitative food frequency questionnaire (FFQ) was used to assess dietary intake (40). This questionnaire was developed to capture commonly consumed foods in Iran, with standardized portion sizes (40). Participants reported the frequency and portion size of each food item consumed, with response options ranging from "never or less than once per month" to "six or more times per day." Reported frequencies were then converted to daily intake values (g/day). Energy, macronutrient, and micronutrient intakes were calculated using the United States Department of Agriculture (USDA) food composition database (41) and the Nutritionist IV software, which was modified to include Iranian foods.

Calculation of Dietary Insulin Index and Load

FII values for various food items were obtained from previously published research (35). The DIL was calculated by first determining the insulin load of each food item using the following formula: Insulin load = FII × energy content of food (kcal/day). The total DIL was then computed by summing the insulin loads of all consumed food items. Finally, the DII was computed as the ratio of total DIL to total daily energy intake.

Assessment of Sleep Quality

The Pittsburgh Sleep Quality Index (PSQI) is a widely recognized and standardized instrument for assessing sleep quality (42, 43). The validity and reliability of the Persian version of this questionnaire have been confirmed, with a Cronbach's alpha coefficient of 0.77 (44). The PSQI is designed to evaluate overall sleep quality and to distinguish individuals with and without

sleep disturbances. It consists of seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each component is scored on a Likert scale ranging from 0 to 3, resulting in a total global score ranging from 0 to 21. A total PSQI score greater than 6 indicates poor sleep quality (45).

Evaluation of Other Variables

Demographic and medical information of participants was collected through a structured questionnaire and face-to-face interviews. The questionnaire gathered demographic data, including age, college, academic semester, home ownership status, marital status, and place of residence (dormitory, native home, or living alone). It also obtained medical history data, such as family history of chronic diseases and psychological disorders, as well as information on medication and dietary supplement use. Body weight was measured using a Seca digital scale with an accuracy of 0.1 kg, while participants wore light clothing and no shoes. To ensure measurement precision, the scale was calibrated daily using standard weights of 1 kg and 2 kg. Height was measured using a wall-mounted stadiometer, with participants standing barefoot, heels against the wall, and head positioned in the Frankfurt horizontal plane. Height was recorded to the nearest 0.1 cm. Body mass index (BMI) was computed as weight (in kilograms) divided by height squared (in meters squared).

Physical activity levels were evaluated using the validated International Physical Activity Questionnaire–Short Form (IPAQ-SF) (46). The questionnaire measured the frequency and duration of light, moderate, and vigorous physical activities lasting at least 10 minutes, as well as sedentary behavior (sitting time). Moderate and vigorous activities were defined as those that induced an elevated heart rate and perspiration. Metabolic equivalent of task (MET) values were assigned to each activity level: 3.3 for light, 4.0 for moderate, and 8.0 for vigorous activities. Physical activity scores were calculated by multiplying the MET value by the duration (minutes) and frequency (days per week) of each activity. Participants' total weekly physical activity levels were then classified as low (<600 MET-min/week), moderate (600–1500 MET-min/week), or high (>1500 MET-min/week).

Statistical Analysis

The Kolmogorov–Smirnov test was used to assess the normality of the data distribution. To control for the effect of energy intake on DII and DIL scores, adjusted values were calculated using the residual method (47). Associations between DII, DIL, and sleep quality were examined after categorizing these indices into quartiles. The chi-square test was utilized to evaluate associations between categorical variables and DII or DIL, whereas analysis of variance (ANOVA) was used to compare continuous variables across quartiles. Analysis of covariance (ANCOVA) was performed to compare macronutrient and micronutrient intakes across DII and DIL quartiles, with adjustments for potential confounders. Binary logistic regression analysis was employed to examine the associations between DII and DIL scores and overall sleep quality. Additionally, ordinal logistic regression was used to investigate the relationships between DII and DIL scores and the component scores of sleep quality. Three models were designed for adjustment: Model 1 controlled for age and sex; Model 2 included additional adjustments for marital status, family history of psychological and chronic diseases, medication use, and physical activity (measured in METs); and Model 3, the fully adjusted model, further controlled for BMI. These covariates were selected based on previous evidence indicating potential associations with sleep quality. All statistical analyses were conducted using SPSS software, version 27.0 (IBM Corp., Armonk, NY, USA), and a two-sided P-value < 0.05 was considered statistically significant.

Results

Approximately 32% of the participants were male and 68% were female. The mean ± standard deviation (SD) values of DII and DIL among the participants were 41.9 ± 5.73 and 92,075 ± 31,923, respectively. The mean age of the participants was 21.4 years. In terms of BMI classification, 63.6% of the participants had normal weight, 11.2% were underweight, and 25.2% were overweight or obese. Table 1 presents the general characteristics of participants across DII and DIL quartiles. Participants in the highest quartile of both indices reported lower medication use compared with those in the lowest quartile. No other significant associations were observed between

DII or DIL and demographic or clinical variables, including age, weight, height, BMI, sex, academic term, physical activity status, place of residence, marital status, family history of chronic or psychological diseases, supplement use, home ownership status, and physical activity level (PAL).

Table 1. General characteristics of study participants across quartiles of DII (Dietary Insulin Index) and DIL (Dietary Insulin Load)

	DII					**DIL**				
	Q1	Q2	Q3	Q4	P-value	Q1	Q2	Q3	Q4	P-value
	Mean ± SD					Mean ± SD				
Age (year)	21.03 ± 2.44	21.6 ± 2.96	21.8 ± 3.07	21.09 ± 2.51	0.17	21.07 ± 2.48	21.8 ± 3.18	21.5 ± 2.94	21.07 ± 2.35	0.16
Weight (kg)	63.6 ± 11.7	64.3 ± 13.6	66.3 ± 17.2	66.5 ± 14.9	0.47	62.7 ± 11.6	64.8 ± 12.3	67.2 ± 17.4	66.03 ± 15.7	0.23
Height (meter)	1.68 ± 0.09	1.68 ± 0.1	1.68 ± 0.09	1.69 ± 0.09	0.86	1.67 ± 0.09	1.68 ± 0.09	1.68 ± 0.09	1.69 ± 0.1	0.81
METs (MET-min/Week)	1203 ± 1101	1183 ± 1071	1257 ± 1175	1168 ± 1012	0.95	1222 ± 1128	1111 ± 955	1381 ± 1277	1097 ± 950	0.30
	n (%)					n (%)				
Women	59 (72)	57 (68.7)	58 (69.9)	52 (63.4)	0.68	56 (68.3)	62 (74.7)	57 (68.7)	51 (62.2)	0.39
BMI categories					0.67					0.64
Underweight	9 (11)	13 (15.7)	6 (7.2)	9 (11)		12 (14.6)	8 (9.6)	8 (9.6)	9 (11)	
Normal	54 (65.9)	51 (61.4)	56 (67.5)	49 (59.8)		52 (63.4)	54 (65.1)	57 (68.7)	47 (57.3)	
Overweight and obese	19 (23.2)	19 (22.9)	21 (25.3)	24 (29.3)		18 (22)	21 (25.3)	18 (21.7)	26 (31.7)	
Semester five and up	35 (42.7)	39 (47)	32 (38.6)	28 (34.1)	0.37	34 (41.5)	38 (45.8)	31 (37.3)	31 (37.8)	0.66
College					0.78					0.22
Medicine	43 (52.4)	39 (47)	47 (56.6)	49 (59.8)		43 (52.4)	39 (47)	39 (47)	57 (69.5)	
Paramedic	11 (13.4)	9 (10.8)	7 (8.4)	12 (14.6)		11 (13.4)	9 (10.8)	12 (14.5)	7 (8.5)	
Nursing	18 (22)	21 (25.3)	19 (22.9)	16 (19.5)		17 (20.7)	24 (28.9)	19 (22.9)	14 (17.1)	
Health	7 (8.5)	9 (10.8)	6 (7.2)	3 (3.7)		8 (9.8)	6 (7.2)	9 (10.8)	2 (2.4)	
Dentistry	3 (3.7)	5 (6)	4 (4.8)	2 (2.4)		3 (3.7)	5 (6)	4 (4.8)	2 (2.4)	
Single or widowed or divorced	72 (87.8)	78 (94)	76 (91.6)	75 (91.5)	0.57	73 (89)	75 (90.4)	79 (95.2)	74 (90.2)	0.51
Native and living alone	27 (32.9)	26 (31.3)	32 (38.6)	35 (42.7)	0.40	26 (31.7)	26 (31.3)	28 (33.7)	40 (48.8)	0.06
Family history of psychological illness (No)	79 (96.3)	81 (97.6)	75 (90.4)	79 (96.3)	0.12	79 (96.3)	80 (96.4)	77 (92.8)	78 (95.1)	0.67
Family history of chronic disease (No)	71 (86.6)	65 (78.3)	66 (79.5)	70 (85.4)	0.40	71 (86.6)	65 (78.3)	63 (75.9)	73 (89)	0.07
History of drug usage (No)	74 (90.2)	77 (92.8)	82 (98.8)	80 (97.6)	0.04	74 (90.2)	77 (92.8)	82 (98.8)	80 (97.6)	0.04
History of dietary supplement usage (No)	57 (69.5)	66 (79.5)	58 (69.9)	60 (73.2)	0.43	58 (70.7)	66 (79.5)	64 (77.1)	53 (64.6)	0.13
home ownership status (Tenant)	5 (6.1)	6 (7.2)	12 (14.5)	5 (6.1)	0.15	4 (4.9)	7 (8.4)	12 (14.5)	5 (6.1)	0.12
PAL					0.98					0.50
Low	36 (43.9)	31 (37.3)	35 (42.2)	32 (39)		35 (42.7)	38 (45.8)	31 (37.3)	30 (36.6)	
Average	34 (41.5)	37 (44.6)	36 (43.4)	36 (43.9)		34 (41.5)	33 (39.8)	34 (41)	42 (51.2)	
a lot	12 (14.6)	15 (18.1)	12 (14.5)	14 (17.1)		13 (15.9)	12 (14.5)	18 (21.7)	10 (12.2)	
Classification of sleep quality					0.32					0.27
Good	32 (39)	41 (49.4)	44 (53)	38 (46.3)		32 (39)	45 (54.2)	39 (47)	39 (47.6)	
Bad	50 (61)	42 (50.6)	39 (47)	44 (53.7)		50 (61)	38 (45.8)	44 (53)	43 (52.4)	

DII: Dietary Insulin Index, DIL: Dietary Insulin Load, METs: Metabolic equivalents, PAL: Physical Activity Level
* Obtained from ANOVA test for quantitative variables and Cross-tab test for qualitative variables

Table 2 presents the dietary intakes of participants across quartiles of DII and DIL. University students in the highest quartiles of both indices had significantly higher intakes of several macro- and micronutrients, while their fat intake was lower compared with those in the lowest quartiles. After adjusting for age, sex, and energy intake, participants in the highest quartile

of DII had significantly higher intakes of fiber; percentage of energy from carbohydrates and protein; iron, calcium, zinc, magnesium, β-carotene; and vitamins A, ascorbic acid, thiamine, riboflavin, niacin, pyridoxine, and folate compared with those in the lowest quartile ($P < 0.05$). Conversely, they reported significantly lower intakes of percentage of energy from fat, saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) ($P < 0.05$). No other significant associations were observed between DII and energy intake, vitamin D, or cobalamin ($P > 0.05$). For DIL, participants in the highest quartile also reported significantly higher intakes of energy, fiber, percentage of energy from carbohydrates and protein, iron, calcium, zinc, magnesium, β-carotene, and vitamins A, ascorbic acid, thiamine, riboflavin, niacin, pyridoxine, and folate compared with those in the lowest quartile ($P < 0.05$). They also had significantly lower intakes of energy from fat, as well as from saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) ($P < 0.05$). No other significant associations were observed between DIL and vitamin D or cobalamin ($P > 0.05$).

Table 2. Dietary intakes of study participants across quartiles of DII and DIL

	DII					DIL				
	Q1	Q2	Q3	Q4		Q1	Q2	Q3	Q4	
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	P-value	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	P-value
Energy	2343 ± 92.07	2120 ± 91.3	2188 ± 91.4	2301 ± 92.05	0.30	2460 ± 85.4	1902 ± 85.2	1950 ± 84.8	2645 ± 85.6	< 0.001
Fiber	14.7 ± 0.70	18.4 ± 0.70	18.2 ± 0.70	18.8 ± 0.70	< 0.001	14.7 ± 0.71	18.01 ± 0.72	18.7 ± 0.71	18.7 ± 0.73	< 0.001
% calorie from CHO	45.1 ± 0.65	53.2 ± 0.64	56.6 ± 0.64	62.05 ± 0.65	< 0.001	45.6 ± 0.70	53.3 ± 0.71	57.1 ± 0.70	61 ± 0.72	< 0.001
% calorie from Pro	12.4 ± 0.29	12.8 ± 0.29	14.08 ± 0.29	12.8 ± 0.29	0.001	12.2 ± 0.29	12.7 ± 0.30	13.9 ± 0.29	13.2 ± 0.30	0.001
% calorie from Fat	44.2 ± 0.65	36.2 ± 0.64	31.2 ± 0.64	27.04 ± 0.65	< 0.001	44 ± 0.68	36 ± 0.69	31 ± 0.68	27.7 ± 0.70	< 0.001
SFA	22.2 ± 0.54	21.4 ± 0.54	19.7 ± 0.53	17.6 ± 0.54	< 0.001	22.5 ± 0.54	21.1 ± 0.55	19.7 ± 0.54	17.6 ± 0.56	< 0.001
MUFA	42.1 ± 1.31	30.06 ± 1.3	25.06 ± 1.3	19.6 ± 1.3	< 0.001	41.6 ± 1.3	31.1 ± 1.31	25.7 ± 1.3	18.2 ± 1.33	< 0.001
PUFA	41.7 ± 1.09	30.7 ± 1.08	24.2 ± 1.08	19.6 ± 1.09	< 0.001	42.2 ± 1.05	30.5 ± 1.07	25.1 ± 1.05	18.3 ± 1.08	< 0.001
Calcium	691 ± 31.9	865 ± 31.7	918 ± 31.7	950 ± 31.9	< 0.001	697 ± 32.1	838 ± 32.4	936 ± 32.1	953 ± 32.9	< 0.001
Fe	15.19 ± 0.56	18.55 ± 0.56	18.71 ± 0.56	18.77 ± 0.56	< 0.001	15.3 ± 0.57	17.9 ± 0.58	19.1 ± 0.57	18.7 ± 0.58	< 0.001
Zn	7.09 ± 0.22	8.02 ± 0.22	8.39 ± 0.22	7.91 ± 0.22	< 0.001	7.12 ± 0.22	7.82 ± 0.22	8.33 ± 0.22	8.15 ± 0.23	0.001
Mg	232 ± 7.04	269 ± 6.99	278 ± 6.99	279 ± 7.03	< 0.001	232 ± 7.07	267 ± 7.15	279 ± 7.07	281 ± 7.26	< 0.001
Beta carotene	345 ± 34.3	466 ± 34.1	467 ± 34.1	445 ± 34.3	0.03	352 ± 34.6	442 ± 35	487 ± 34.6	444 ± 35.5	0.04
Vitamin A	687 ± 47.8	911 ± 47.4	911 ± 47.4	948 ± 47.7	< 0.001	702 ± 48.1	853 ± 48.6	967 ± 48.1	936 ± 49.4	< 0.001
Vitamin D	1.66 ± 0.13	1.83 ± 0.13	1.89 ± 0.13	1.75 ± 0.13	0.64	1.6 ± 0.13	1.83 ± 0.13	1.89 ± 0.13	1.81 ± 0.14	0.47
Thiamine	1.49 ± 0.04	1.69 ± 0.04	1.81 ± 0.04	1.93 ± 0.04	< 0.001	1.47 ± 0.04	1.7 ± 0.04	1.82 ± 0.04	1.91 ± 0.04	< 0.001
Riboflavin	1.3 ± 0.05	1.55 ± 0.05	1.66 ± 0.05	1.66 ± 0.05	< 0.001	1.3 ± 0.05	1.52 ± 0.05	1.66 ± 0.05	1.7 ± 0.05	< 0.001

	DII					DIL				
	Q1	Q2	Q3	Q4	P-value	Q1	Q2	Q3	Q4	P-value
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	
Niacin	17.1 ± 0.49	18.02 ± 0.49	19.7 ± 0.49	19.5 ± 0.49	< 0.001	16.7 ± 0.49	18.2 ± 0.5	19.4 ± 0.49	19.9 ± 0.5	< 0.001
Pyridoxine	1.12 ± 0.06	1.33 ± 0.06	1.34 ± 0.06	1.29 ± 0.06	0.03	1.12 ± 0.06	1.3 ± 0.06	1.33 ± 0.06	1.33 ± 0.06	0.04
Folate	296 ± 14.04	346 ± 13.9	359 ± 13.9	353 ± 14.02	0.007	299 ± 14.1	337 ± 14.2	369 ± 14.1	349 ± 14.4	0.005
Cobalamin	2.88 ± 0.19	3.07 ± 0.19	3.44 ± 0.19	2.89 ± 0.19	0.15	2.61 ± 0.19	3.17 ± 0.19	3.33 ± 0.19	3.17 ± 0.2	0.05
Ascorbic acid	132 ± 11.1	165 ± 11.07	163 ± 11.06	178 ± 11.1	0.02	130 ± 11.2	161 ± 11.3	173 ± 11.2	174 ± 11.5	0.01

*) Obtained from the ANCOVA test, adjusted for age, gender and daily energy intake, except for the energy variable, which was only adjusted for age and gender.
CHO: Carbohydrate; Pro: Protein; Fat: Fatty acid; SFA: Saturated fatty acid; PUFA: Polyunsaturated fatty acid; MUFA: Monounsaturated fatty acid; Fe: Iron; Zn: Zinc; Mg: magnesium

Findings from the binary and ordinal logistic regression analyses examining the associations between DII and DIL and overall sleep quality, as well as its components, are presented in Table 3. Higher quartiles of both indices were generally associated with lower odds of sleep disturbances. After adjustment for potential confounders, university students in the highest quartile of DII had 22% lower—but not statistically significant—odds of poor overall sleep quality (OR = 0.78, 95% CI: 0.41–1.49; P-trend = 0.44). However, they had significantly lower odds (by 64%) of experiencing sleep disturbances (OR = 0.36, 95% CI: 0.14–0.88) compared with those in the lowest quartile of DII. Other components of sleep quality, including subjective sleep quality, sleep latency, sleep efficiency, use of sleep medication, and daytime dysfunction, showed inverse but non-significant associations with DII. A non-significant positive association was observed between sleep duration and DII (OR for highest vs. lowest quartile = 1.30, 95% CI: 0.74–2.30).

Table 3. Multivariable-adjusted ORs (and 95% CIs) for sleep quality and its components across quartiles of DII and DIL

	DII					DIL				
	Q1	Q2	Q3	Q4	P-trend	Q1	Q2	Q3	Q4	P-trend
	OR (95% CI)					OR (95% CI)				
Overall sleep quality*										
Crude	1	0.65 (0.35, 1.21)	0.56 (0.3, 1.05)	0.74 (0.39, 1.37)	0.30	1	0.54 (0.29, 1.004)	0.72 (0.38, 1.34)	0.70 (0.38, 1.31)	0.45
Model 1	1	0.67 (0.36, 1.25)	0.58 (0.31, 1.08)	0.77 (0.41, 1.44)	0.36	1	0.52 (0.28, 0.98)	0.72 (0.38, 1.35)	0.72 (0.38, 1.35)	0.53
Model 2	1	0.64 (0.34, 1.22)	0.58 (0.3, 1.1)	0.8 (0.42, 1.51)	0.48	1	0.51 (0.26, 0.97)	0.73 (0.38, 1.4)	0.76 (0.4, 1.44)	0.68
Model 3	1	0.64 (0.33, 1.22)	0.56 (0.29, 1.08)	0.78 (0.41, 1.49)	0.44	1	0.49 (0.26, 0.95)	0.71 (0.37, 1.36)	0.74 (0.39, 1.41)	0.63
Subjective sleep quality**										
Crude	1	0.58 (0.3, 1.11)	0.61 (0.32, 1.17)	0.67 (0.35, 1.28)	-	1	0.48 (0.25, 0.92)	0.70 (0.36, 1.33)	0.70 (0.36, 1.33)	-
Model 1	1	0.59 (0.31, 1.14)	0.63 (0.33, 1.21)	0.68 (0.35, 1.3)	-	1	0.48 (0.25, 0.93)	0.70 (0.37, 1.35)	0.70 (0.37, 1.34)	-
Model 2	1	0.58 (0.3, 1.12)	0.67 (0.34, 1.3)	0.75 (0.38, 1.45)	-	1	0.46 (0.24, 0.9)	0.75 (0.38, 1.46)	0.79 (0.41, 1.54)	-
Model 3	1	0.57 (0.29, 1.11)	0.63 (0.32, 1.23)	0.59 (0.33, 1.04)	-	1	0.44 (0.22, 0.86)	0.69 (0.35, 1.35)	0.75 (0.39, 1.46)	-
Sleep latency**										
Crude	1	0.76 (0.43, 1.33)	0.63 (0.36, 1.1)	0.59 (0.33, 1.04)	-	1	0.81 (0.47, 1.42)	0.64 (0.36, 1.11)	0.65 (0.37, 1.14)	-
Model 1	1	0.75 (0.43, 1.32)	0.62 (0.35, 1.08)	0.61 (0.34, 1.07)	-	1	0.76 (0.43, 1.34)	0.62 (0.35, 1.08)	0.67 (0.38, 1.18)	-
Model 2	1	0.76 (0.43, 1.33)	0.65 (0.36, 1.15)	0.64 (0.36, 1.12)	-	1	0.76 (0.43, 1.35)	0.66 (0.37, 1.17)	0.69 (0.39, 1.22)	-
Model 3	1	0.76 (0.43, 1.34)	0.64 (0.36, 1.14)	0.63 (0.36, 1.12)	-	1	0.76 (0.43, 1.33)	0.64 (0.36, 1.14)	0.68 (0.38, 1.2)	-
Sleep duration**										

Crude	1	0.95 (0.54, 1.65)	0.77 (0.44, 1.34)	1.28 (0.74, 2.24)	-	1	1.11 (0.64, 1.93)	0.89 (0.51, 1.55)	1.5 (0.86, 2.62)	-
Model 1	1	0.99 (0.56, 1.73)	0.82 (0.47, 1.44)	1.28 (0.73, 2.24)	-	1	1.21 (0.69, 2.12)	0.93 (0.53, 1.63)	1.51 (0.86, 2.64)	-
Model 2	1	0.96 (0.54, 1.68)	0.8 (0.45, 1.43)	1.34 (0.76, 2.35)	-	1	1.21 (0.69, 2.13)	0.92 (0.51, 1.63)	1.62 (0.92, 2.85)	-
Model 3	1	0.95 (0.54, 1.68)	0.79 (0.44, 1.4)	1.3 (0.74, 2.3)	-	1	1.18 (0.67, 2.09)	0.87 (0.49, 1.56)	1.59 (0.9, 2.8)	-
Sleep efficiency**										
Crude	1	0.89 (0.42, 1.87)	0.48 (0.21, 1.11)	0.73 (0.34, 1.58)	-	1	1.01 (0.47, 2.16)	0.70 (0.31, 1.58)	0.84 (0.38, 1.85)	-
Model 1	1	0.94 (0.44, 2.001)	0.52 (0.22, 1.21)	0.76 (0.35, 1.65)	-	1	1.06 (0.49, 2.29)	0.74 (0.32, 1.67)	0.87 (0.39, 1.91)	-
Model 2	1	0.99 (0.46, 2.13)	0.57 (0.24, 1.34)	0.78 (0.35, 1.73)	-	1	1.14 (0.52, 2.5)	0.84 (0.36, 1.94)	0.88 (0.39, 1.97)	-
Model 3	1	0.99 (0.46, 2.13)	0.55 (0.23, 1.3)	0.76 (0.34, 1.68)	-	1	1.11 (0.5, 2.44)	0.80 (0.34, 1.85)	0.85 (0.38, 1.92)	-
Sleep disturbances**										
Crude	1	0.35 (0.14, 0.84)	0.35 (0.14, 0.83)	0.34 (0.14, 0.83)	-	1	0.46 (0.19, 1.08)	0.54 (0.23, 1.28)	0.35 (0.15, 0.84)	-
Model 1	1	0.36 (0.15, 0.86)	0.35 (0.15, 0.85)	0.36 (0.15, 0.87)	-	1	0.45 (0.19, 1.08)	0.55 (0.23, 1.3)	0.36 (0.15, 0.86)	-
Model 2	1	0.37 (0.15, 0.91)	0.34 (0.13, 0.84)	0.38 (0.15, 0.93)	-	1	0.46 (0.19, 1.1)	0.59 (0.24, 1.45)	0.37 (0.15, 0.89)	-
Model 3	1	0.37 (0.15, 0.9)	0.32 (0.13, 0.79)	0.36 (0.14, 0.88)	-	1	0.43 (0.18, 1.05)	0.55 (0.22, 1.34)	0.35 (0.14, 0.84)	-
Use of sleep medication**										
Crude	1	0.89 (0.34, 2.31)	0.95 (0.37, 2.44)	0.67 (0.24, 1.86)	-	1	1.15 (0.44, 2.98)	1.11 (0.42, 2.89)	0.75 (0.26, 2.14)	-
Model 1	1	0.9 (0.34, 2.36)	0.93 (0.35, 2.41)	0.72 (0.25, 2.009)	-	1	1.05 (0.4, 2.76)	1.07 (0.4, 2.83)	0.79 (0.27, 2.28)	-
Model 2	1	1.03 (0.38, 2.79)	1.15 (0.42, 3.15)	0.9 (0.31, 2.63)	-	1	1.15 (0.42, 3.13)	1.40 (0.49, 3.97)	1.01 (0.33, 3.01)	-
Model 3	1	1.03 (0.38, 2.78)	1.15 (0.42, 3.15)	0.9 (0.31, 2.64)	-	1	1.16 (0.42, 3.14)	1.40 (0.49, 3.99)	1.01 (0.33, 3.01)	-
Daytime dysfunction**										
Crude	1	0.91 (0.52, 1.58)	0.72 (0.41, 1.26)	0.9 (0.51, 1.57)	-	1	0.62 (0.35, 1.08)	0.88 (0.51, 1.54)	0.70 (0.4, 1.22)	-
Model 1	1	0.92 (0.52, 1.61)	0.74 (0.42, 1.29)	0.92 (0.53, 1.62)	-	1	0.61 (0.34, 1.07)	0.88 (0.5, 1.55)	0.71 (0.41, 1.25)	-
Model 2	1	0.82 (0.47, 1.45)	0.7 (0.39, 1.24)	0.91 (0.52, 1.6)	-	1	0.55 (0.31, 0.97)	0.83 (0.47, 1.48)	0.72 (0.41, 1.26)	-
Model 3	1	0.82 (0.47, 1.45)	0.7 (0.39, 1.24)	0.91 (0.51, 1.6)	-	1	0.55 (0.31, 0.97)	0.83 (0.46, 1.47)	0.71 (0.4, 1.26)	-

* Obtained from Binary regression test
** Obtained from the Ordinal regression test
Model 1: Adjusted for age and sex
Model 2: further adjustment was made for marital status, family history of psychological illness, family history of chronic illness, history of medication use, and METs
Model 3: further adjustment was made for body mass index

With respect to DIL, participants in the highest quartile had 26% lower—but not statistically significant—odds of poor overall sleep quality (OR = 0.74, 95% CI: 0.39–1.41; P-trend = 0.63). However, they had significantly lower odds (by 65%) of experiencing sleep disturbances (OR = 0.35, 95% CI: 0.14–0.84) compared with those in the lowest quartile of DIL. Other components of sleep quality, including subjective sleep quality, sleep latency, sleep efficiency, and daytime dysfunction, showed inverse but non-significant associations with DIL. Non-significant positive associations were also observed between DIL and the components of sleep duration and use of sleep medication.

Discussion

The present study demonstrated a significant inverse association between DII and DIL and the component of sleep disturbances. To the best of our knowledge, this is the first study to examine the relationship between DII and DIL and sleep quality among university students.

Inadequate sleep quality represents a significant public health concern. It is particularly prevalent among university students, where it can impair academic performance, reduce quality of life, and increase symptoms of depression and anxiety (31, 48). In the present study, participants in the highest quartiles of DII and DIL had 64% and 65%, respectively, lower odds of experiencing sleep

disturbances compared with those with the lowest dietary insulin potential. However, no other significant associations were observed between these dietary factors and overall sleep quality or other sleep components. Evidence examining the relationship between DII, DIL, and sleep quality is minimal (36). Consistent with our findings, the only available study conducted by Sarsangi et al. found that participants in the third tertile of DIL had 62% significantly lower odds of sleep disturbances compared with those in the first tertile. Moreover, higher DII was significantly associated with a 39% reduction in the odds of sleep disturbances (36). Some mechanisms could elucidate the link between DII, DIL, and sleep disturbances. Insulin enhances the plasma tryptophan-to–large neutral amino acid (LNAA) ratio by promoting the uptake of LNAAs into skeletal muscles, excluding tryptophan. This process facilitates greater tryptophan transport across the blood–brain barrier, thereby enhancing serotonin synthesis (49, 50). Serotonin, a critical neurotransmitter involved in mood regulation, psychological well-being, and sleep quality, is subsequently converted into melatonin through two enzymatic steps (51). First, serotonin is acetylated by serotonin N-acetyltransferase (AANAT) to form N-acetylserotonin (NAS), which represents the rate-limiting step in melatonin synthesis. Then, NAS is methylated by acetylserotonin O-methyltransferase (ASMT) to produce melatonin—the principal hormone responsible for regulating the sleep–wake cycle (52). Furthermore, insulin has been shown to directly regulate circadian clocks in adipose tissue. Studies have demonstrated that postprandial insulin levels can entrain circadian rhythms in adipocytes, resulting in phase shifts in the expression of core clock genes, such as PER2 (Period Circadian Regulator 2). This regulation suggests that insulin contributes to the alignment of peripheral circadian clocks with external feeding cues, which in turn may influence sleep–wake patterns (53). Additionally, insulin may affect sleep quality by modulating the hypothalamic–pituitary–adrenal (HPA) axis, a key system involved in stress response and sleep regulation. The consumption of carbohydrate- and sugar-rich foods, which stimulate postprandial insulin release, has been shown to attenuate HPA axis activity and decrease cortisol secretion. This effect may help alleviate perceived stress—a common issue among university students—and thereby indirectly promote better sleep quality (54, 55).

This study had several notable strengths. To the best of our knowledge, it was the first to explore the relationship between DII and DIL and sleep quality among university students. Validated instruments were used to assess both sleep quality and dietary intake, thereby minimizing potential measurement errors. Comprehensive control for confounding variables—including age, sex, marital status, family history of mental or chronic diseases, medication use, physical activity, and BMI—was achieved. Data collection was conducted via interviews by trained nutritionists, which helped to reduce recall bias. Furthermore, the associations between the severity of each sleep quality component and both DII and DIL were examined. However, several limitations should be acknowledged. The cross-sectional design of the study precludes causal inference; therefore, the observed associations should be interpreted with caution. Although dietary intake was assessed using an FFQ, which is typically prone to recall bias (56), trained professionals assisted participants in completing the questionnaires to minimize this bias. Despite the use of a validated FFQ, the possibility of dietary intake misclassification or misreporting cannot be completely ruled out. To mitigate this concern, energy-adjusted DII and DIL indices were applied to reduce the likelihood of misclassification. Although a wide range of potential confounders was controlled for, residual confounding may still exist. Additionally, sleep quality was assessed through a self-reported questionnaire, which may be subject to measurement error and reporting bias, potentially affecting the accuracy of the observed associations.

In conclusion, the findings of this study suggest a significant inverse association between DII and DIL and sleep disturbances. These results may have important implications for dietary recommendations and the design of university health programs aimed at improving sleep quality through nutritional strategies. Further research—particularly longitudinal studies—is warranted to confirm these findings and clarify the underlying mechanisms.

Declarations

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Statement of Authorship

HN contributed to the conception, design, search, statistical analyses, data interpretation, and

manuscript drafting. AA contributed to the conception, design, and statistical analyses, as well as manuscript drafting, and supervised the study. SJ contributed to conception and design. AY contributed to the design and data interpretation.

Conflicts of Interest

There are no conflicts of interest.

Data Availability

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

References

1. Singh SR, Singh AB, Sarkar A. Review on sleep and its impact on health. 2023.
2. Hui S-kA, Grandner MA. Associations between poor sleep quality and stages of change of multiple health behaviors among participants of employee wellness program. Preventive Medicine Reports. 2015;2:292-9.
3. Kawyannejad R, Mirzaei M, Valinejadi A, Hemmatpour B, Karimpour HA, AminiSaman J, et al. General health of students of medical sciences and its relation to sleep quality, cell phone overuse, social networks and internet addiction. Bio Psycho Social Medicine. 2019;13:1-7.
4. Kataoka H, Miyatake N, Ichikawa H, Arakawa Y, Mori Y. Relationship of locomotive syndrome with health-related quality of life among patients with obstructive sleep apnea syndrome. Journal of Physical Therapy Science. 2017;29(7):1129-33.
5. Sun W, Huang Y, Wang Z, Yu Y, Lau A, Ali G, et al. Sleep duration associated with body mass index among Chinese adults. Sleep Medicine. 2015;16(5):612-6.
6. Sanchez C, Killgore W, Gehrels J, Alfonso-Miller P, Grandner M. 0127 nighttime snacking: prevalence and associations with poor sleep, health, obesity, and diabetes. Sleep. 2018;41:A49.
7. Xie D, Li W, Wang Y, Gu H, Teo K, Liu L, Yusuf S. Sleep duration, snoring habits and risk of acute myocardial infarction in China population: results of the INTERHEART study. BMC Public Health. 2014;14:1-10.
8. Hoevenaar-Blom MP, Spijkerman AM, Kromhout D, van den Berg JF, Verschuren WM. Sleep duration and sleep quality in relation to 12-year cardiovascular disease incidence: the MORGEN study. Sleep. 2011;34(11):1487-92.
9. Song C, Zhang R, Wang C, Fu R, Song W, Dou K, Wang S. Sleep quality and risk of cancer: findings from the English longitudinal study of aging. Sleep. 2021;44(3):zsaa192.
10. Kakizaki M, Kuriyama S, Sone T, Ohmori-Matsuda K, Hozawa A, Nakaya N, et al. Sleep duration and the risk of breast cancer: the Ohsaki Cohort Study. British Journal of Cancer. 2008;99(9):1502-5.
11. Jiao L, Duan Z, Sangi-Haghpeykar H, Hale L, White D, El-Serag H. Sleep duration and incidence of colorectal cancer in postmenopausal women. British Journal of Cancer. 2013;108(1):213-21.
12. Nakata A. Work hours, sleep sufficiency, and prevalence of depression among full-time employees: a community-based cross-sectional study. The Journal of Clinical Psychiatry. 2011;72(5):8355.
13. Kryger MH, Roth T, Dement WC. Principles and practice of sleep medicine E-book: Expert consult-online and print: Elsevier Health Sciences; 2010.
14. Wang J, Chen Y, Jin Y, Zhu L, Yao Y. Sleep quality is inversely related to body mass index among university students. Revista da Associação Médica Brasileira. 2019;65:845-50.
15. Alsaggaf MA, Wali SO, Merdad RA, Merdad LA. Sleep quantity, quality, and insomnia symptoms of medical students during clinical years: relationship with stress and academic performance. Saudi Medical Journal. 2016;37(2):173.
16. Maheshwari G, Shaukat F. Impact of poor sleep quality on the academic performance of medical students. Cureus. 2019;11(4).
17. Franquelo-Morales P, Sánchez-López M, Notario-Pacheco B, Miota-Ibarra J, Lahoz-García N, Gómez-Marcos MÁ, Martínez-Vizcaíno V. Association between health-related quality of life, obesity, fitness, and sleep quality in young adults: The Cuenca adult study. Behavioral Sleep Medicine. 2018;16(4):347-55.
18. Hernandez R, Vu T-HT, Kershaw KN, Boehm JK, Kubzansky LD, Carnethon M, et al. The association of optimism with sleep duration and quality: Findings from the coronary artery risk and development in young adults (CARDIA) study. Behavioral Medicine. 2020;46(2):100-11.
19. Azad MC, Fraser K, Rumana N, Abdullah AF, Shahana N, Hanly PJ, Turin TC. Sleep disturbances among medical students: a global perspective. Journal of Clinical Sleep Medicine. 2015;11(1):69-74.
20. Shafiee A, Teymouri Athar MM, Seighali N, Amini MJ, Hajishah H, Arabazadeh Bahri R, et al. The prevalence of depression, anxiety, and sleep disturbances among medical students and resident physicians in Iran: A systematic review and meta-analysis. Plos One. 2024;19(8):e0307117.
21. Kaneita Y, Ohida T, Osaki Y, Tanihata T, Minowa M, Suzuki K, et al. Insomnia among Japanese adolescents: a nationwide representative survey. Sleep. 2006;29(12):1543-50.
22. Chakravorty S, Chaudhary NS, Brower KJ. Alcohol dependence and its relationship with insomnia and other sleep disorders. Alcoholism: Clinical and Experimental Research. 2016;40(11):2271-82.
23. Nakade M, Takeuchi H, Kurotani M, Harada T. Effects of meal habits and alcohol/cigarette consumption on morningness-eveningness preference and sleep habits by Japanese female students aged 18–29. Journal of Physiological Anthropology. 2009;28(2):83-90.

24. Munezawa T, Kaneita Y, Osaki Y, Kanda H, Minowa M, Suzuki K, et al. The association between use of mobile phones after lights out and sleep disturbances among Japanese adolescents: a nationwide cross-sectional survey. Sleep. 2011;34(8):1013-20.
25. Al-Khani AM, Sarhandi MI, Zaghloul MS, Ewid M, Saquib N. A cross-sectional survey on sleep quality, mental health, and academic performance among medical students in Saudi Arabia. BMC Research Notes. 2019;12(1):665.
26. Godos J, Grosso G, Castellano S, Galvano F, Caraci F, Ferri R. Association between diet and sleep quality: A systematic review. Sleep Medicine Reviews. 2021;57:101430.
27. Tao Y, Liu Z, Huang L, Liu H, Tian H, Wu J, et al. The impact of smartphone dependence on college students' sleep quality: the chain-mediated role of negative emotions and health-promoting behaviors. Frontiers in Public Health. 2024;12:1454217.
28. Esubalew D, Delie AM, Limenh LW, Worku NK, Fenta ET, Hailu M, et al. Poor sleep quality among bedtime smartphone user medical students in Ethiopia, 2024. Sleep Medicine: X. 2024;8:100134.
29. Corrado A, Scidà G, Vitale M, Caprio B, Costabile G, Annuzzi E, et al. Eating habits and sleep quality in individuals with type 1 diabetes on continuous glucose monitoring and insulin pump. Nutrition, Metabolism and Cardiovascular Diseases. 2024;34(7):1703-11.
30. Sousa Gomes M, Martins J, Duarte A, Augusto C, Silva MJ, Padrão P, et al. Processed Food Consumption and Sleep Quality in School-Aged Children: Insights from a Cross-Sectional Study. Nutrients. 2025;17(2).
31. Komada Y, Okajima I, Kuwata T. The effects of milk and dairy products on sleep: a systematic review. International Journal of Environmental Research and Public Health. 2020;17(24):9440.
32. Jansen EC, She R, Rukstalis MM, Alexander GL. Sleep duration and quality in relation to fruit and vegetable intake of US young adults: a secondary analysis. International Journal of Behavioral Medicine. 2021;28:177-88.
33. Behbahani HB, Borazjani F, Sheikhi L, Amiri R, Angali KA, Nejad SB, Samadani M. The association between diet quality scores with sleep quality among employees: a cross-sectional study. Ethiopian Journal of Health Sciences. 2022;32(1).
34. Dakanalis A, Papadimitriou K, Alexatou O, Deligiannidou GE, Pappa M, Papadopoulou SK, et al. Mediterranean Diet Compliance Is Related with Lower Prevalence of Perceived Stress and Poor Sleep Quality in University Students: A Cross-Sectional Study in Greece. Nutrients. 2025;17(13).
35. Holt S, Miller J, Petocz P. An insulin index of foods: the insulin demand generated by 1000-kJ portions of common foods. The American Journal of Clinical Nutrition. 1997;66(5):1264-76.
36. Sarsangi P, Mohammadi M, Salehi-Abargouei A, Esmaillzadeh A, Mirzaei M. Dietary insulinemic potential, sleep quality and quantity in Iranian adults: Yazd health study and TAMYZ study. BMC Nutrition. 2023;9(1):92.
37. Ghafarzadeh J, Sadeghniiat-Haghighi K, Sadeghpour O, Akbarpour S, Amini-Behbahani F. Investigating the prevalence of sleep disorder and the impact of sweet almond on the quality of sleep in students of Tehran, Iran. Iranian Journal of Public Health. 2019;48(6):1149.
38. Monma T, Ando A, Asanuma T, Yoshitake Y, Yoshida G, Miyazawa T, et al. Sleep disorder risk factors among student athletes. Sleep Medicine. 2018;44:76-81.
39. Anjom-Shoae J, Keshteli AH, Afshar H, Esmaillzadeh A, Adibi P. Association between dietary insulin index and load and psychological disorders. British Journal of Nutrition. 2020;123(2):161-71.
40. Malekshah AF, Kimiagar M, Saadatian-Elahi M, Pourshams A, Nouraie M, Goglani G, et al. Validity and reliability of a new food frequency questionnaire compared to 24 h recalls and biochemical measurements: pilot phase of Golestan cohort study of esophageal cancer. European Journal of Clinical Nutrition. 2006;60(8):971-7.
41. Montville JB, Ahuja JK, Martin CL, Heendeniya KY, Omolewa-Tomobi G, Steinfeldt LC, et al. USDA food and nutrient database for dietary studies (FNDDS), 5.0. Procedia Food Science. 2013;2:99-112.
42. Khazaie H, Jalali A, Cheraghi K, Ahmadi SM, Khaledi-Paveh B. Sleep problems among intravenous and non-intravenous opioid-dependent patients: the role of modality of use. Heroin Addiction and Related Clinical Problems. 2018;20(6):27-34.
43. Khazaie H, Jalali A, Jozani Y, Moradi S, Heydarpour F, Khaledi-Paveh B. Comparative study on sleep quality and disorders in opiate and methamphetamine users. Heroin Addict Related Clinical Problems; 18 (6): 21. 2016;28.
44. Farrahi Moghaddam J, Nakhaee N, Sheibani V, Garrusi B, Amirkafi A. Reliability and validity of the Persian version of the Pittsburgh Sleep Quality Index (PSQI-P). Sleep and Breathing. 2012;16:79-82.
45. Buysse DJ, Reynolds III CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Research. 1989;28(2):193-213.
46. Moghaddam MB, Aghdam FB, Jafarabadi MA, Allahverdipour H, Nikookheslat SD, Safarpour S. The Iranian Version of International Physical Activity Questionnaire (IPAQ) in Iran: content and construct validity, factor structure, internal consistency and stability. World Appl Sci J. 2012;18(8):1073-80.
47. Willett W, Stampfer MJ. Total energy intake: implications for epidemiologic analyses. American Journal of Epidemiology. 1986;124(1):17-27.
48. Perotta B, Arantes-Costa FM, Enns SC, Figueiro-Filho EA, Paro H, Santos IS, et al. Sleepiness, sleep deprivation, quality of life, mental symptoms and perception of academic environment in medical students. BMC Medical Education. 2021;21:1-13.

49. Höglund E, Øverli Ø, Winberg S. Tryptophan metabolic pathways and brain serotonergic activity: a comparative review. Frontiers in Endocrinology. 2019;10:158.
50. Martin-Du Pan R, Mauron C, Glaeser B, Wurtman R. Effect of various oral glucose doses on plasma neutral amino acid levels. Metabolism. 1982;31(9):937-43.
51. Pagan C, Goubran-Botros H, Delorme R, Benabou M, Lemière N, Murray K, et al. Disruption of melatonin synthesis is associated with impaired 14-3-3 and miR-451 levels in patients with autism spectrum disorders. Scientific Reports. 2017;7(1):2096.
52. Pagan C, Delorme R, Callebert J, Goubran-Botros H, Amsellem F, Drouot X, et al. The serotonin-N-acetylserotonin–melatonin pathway as a biomarker for autism spectrum disorders. Translational psychiatry. 2014;4(11):e479-.
53. Tuvia N, Pivovarova-Ramich O, Murahovschi V, Lück S, Grudziecki A, Ost AC, et al. Insulin Directly Regulates the Circadian Clock in Adipose Tissue. Diabetes. 2021;70(9):1985-99.
54. Ulrich-Lai YM, Ostrander MM, Herman JP. HPA axis dampening by limited sucrose intake: reward frequency vs. caloric consumption. Physiology & Behavior. 2011;103(1):104-10.
55. Adam TC, Epel ES. Stress, eating and the reward system. Physiology & Behavior. 2007;91(4):449-58.
56. Naska A, Lagiou A, Lagiou P. Dietary assessment methods in epidemiological research: current state of the art and future prospects. F1000 Research. 2017;6:926.