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Association between the Dietary Inflammatory Index and Sleep Quality among Lebanese University Students

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Abstract

Objective The association between sleep quality and overall health has been extensively examined. However, few studies have investigated the relationship between sleep and the inflammatory potential of the diet. Thus, the purpose of the present study was to explore the association between the scores on the Energy-Adjusted Dietary Inflammatory Index (E-DII) and sleep quality in Lebanese university students.

Materials and Methods We conducted a cross-sectional study with students attending the Tripoli campus of Beirut Arab University. A total of 270 students aged between 17 and 25 years were randomly selected. All students filled out a multicomponent questionnaire that included an assessment of their sleep quality using the Pittsburg Sleep Quality Index, and of their physical activity level using the short version of the International Physical Activity Questionnaire. The scores on the E-DII were calculated based on a validated food frequency questionnaire.

Results Individuals in the highest (most proinflammatory) quartile of the E-DII were at an increased risk of having poor overall sleep quality compared with the lowest quartile (odds ratio [OR] = 2.86; 95% confidence interval [95%CI]: 1.27–6.44). Regarding the individual domains of sleep quality, subjects in quartiles 3 and 4 of the E-DII were at an increased risk of having poor sleep efficiency compared with those in quartile 1 (OR = 2.49; 95%CI: 1.12–5.54; and OR = 2.52, 95%CI: 1.13–5.62 respectively).

Keywords
- sleep quality
- inflammation
- diet
- university students

Introduction

Sleep is a key factor that influences various metabolic and physiological processes, including functioning of the cardiovascular and immune systems, as well as cognitive and psychomotor activities.[1,2] Therefore, it is not surprising that about one-third of human life is spent sleeping.[3] In this regard, previous studies[4,5] have revealed that any disruption in sleep may have deleterious consequences on health, including a higher risk of developing obesity and chronic diseases such as diabetes and hypertension. Additionally, a recent meta-analysis[6] revealed that improving

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However, individuals in quartile 3 were at a reduced risk of having daytime dysfunction compared with those in the lowest quartile (OR = 0.44; 95%CI: 0.23–0.83).
Conclusion The inflammatory potential of the diet seems to be related to sleep quality in our sample of Lebanese university students. Future prospective studies are required to further explore this association.

sleep quality ameliorates many aspects of mental health, including depression, anxiety, and stress.

Considering the impact of sleep quality on overall quality of life, research efforts are directed toward elucidating the possible underlying causes of sleep disturbances, including changes in circadian rhythm and hormonal imbalances.[7,8] Furthermore, higher levels of inflammatory markers, such as C-reactive protein (CRP) and interleukin 6 (IL-6,) have been associated with poor sleep outcomes in previous studies,[9–11] and it has been suggested that an improved inflammatory profile is associated with good sleep outcomes. Therefore, the factors leading to an inflammatory state are potential risk factors for poor sleep quality.

The association between dietary patterns and systemic inflammation has been previously established with two main potential mechanisms: 1) by contributing to visceral obesity, which is associated with systemic inflammation; and 2) through the effects of individual nutrients on the levels of inflammatory markers.[12] Several studies have examined the impact of a proinflammatory diet on sleep quality. The Dietary Inflammatory Index (DII), which is a literature-derived score that evaluates the inflammatory potential of a diet, has been used in several studies,[13,14] which have shown that more proinflammatory diets are associated with worse objective and subjective sleep quality, longer sleep latency, more daytime dysfunction, self-reported sleep disturbances, and a higher risk of sleep apnea compared with anti-inflammatory diets.[15–20]

The likelihood of developing sleeping problems is highest among college students.[21] Sleep disturbances, irregular sleeping patterns, and poor sleep quality are experienced by 63% of American college students.[22] Additionally, due to stressors that affect their daily lives, such as overloaded schedules and demanding academic responsibilities, university students often adopt unhealthy eating and lifestyle patterns.[23] Therefore, compared with the population average, university students are at a higher risk of developing both unhealthy eating patterns and sleep disturbances. However, research focusing on the role of inflammatory diets on sleep outcomes has not been extensively conducted in this high-risk population.[24] In addition, this association has not been previously examined among Lebanese university students, who are more likely to eat a traditional Mediterranean diet (MD), which is known for its anti-inflammatory properties.[25] Hence, the objective of the present study is to examine the association between the dietary patterns of Lebanese university students, based on DII scores, and sleep quality.

Materials and Methods

Design and Study Population

A cross-sectional study was conducted between October 2018 and January 2019 among Beirut Arab University (BAU) undergraduate students attending the Tripoli campus. All students aged between 17 and 25 years and registered during the fall 2018-2019 semester in one of the 5 BAU faculties (Architecture, Business, Health Sciences, Engineering, and Science) were eligible to participate. The sample size was calculated based on a prevalence of bad sleep quality of 0.527 using the following formula: $n = z^2pq/d^2$ (in which n = sample size; z = 1.96, which corresponds to a 95% confidence level; p = 52.7%, corresponding to the prevalence of the primary outcome, which is sleep quality, taken from previous studies[26]; q = 0.473, which corresponds to 1 - p; and d = 0.06, corresponding to the margin of error). A minimum number of 266 students was needed. In total, data were collected from 300 students in the 5 BAU faculties using a stratified proportional sampling technique. After excluding participants who reported extreme intakes (> 5,000 kcal and < 800 kcal), the final number of participants included in the study was of 270.[27]

The study design was approved by the Review Board of Beirut Arab University, under protocol number 219H-0062-HS-M-0317. All study participants signed an informed consent form before being enrolled in the study.

Data Collection

Each participant was interviewed to collect data about sociodemographic characteristics, including age, gender, and family monthly income. Physical activity was evaluated using the short version of the International Physical Activity Questionnaire (IPAQ), which is a validated tool used to assess physical activity for research purposes.[28] Anthropometric measurements were performed for each participant in duplicate using standardized techniques, and the average of the two results was taken.[29] Height was assessed in a standing position without shoes to the nearest 0.1 cm using a wall-mounted height rod (Tanita Corporation of America, Inc, Arlington Heights, IL, United States). Weight was measured to the nearest 0.1 kg wearing light indoor clothing using an electronic digital scale HN286 Digital Personal Scale, Omron, Japan that was calibrated. Waist circumference (WC) was measured to the nearest 0.1 cm with a non-stretchable flexible tape with the participant in a standing position. For the WC, values > 80 cm and > 94 cm were considered as elevated for female and male subjects respectively.[30] The Body Mass Index (BMI) was calculated using the following formula: weight (kg)/height (m^2), and it was classified according to the World Health Organization (WHO) criteria for overweight and obesity classification.[31]

Dietary Assessment

A previously validated food frequency questionnaire (FFQ) consisting of 83 food items was used to assess dietary intake over the last 6 months.[32] The FFQ included three sections: food list, portion size, and frequency response. For each food item listed on the FFQ, a standard portion size was indicated, and nine frequency choices were given: "never or less than once per month," "one to three times per month," "once per week," "two to four times per week," "five to six times per week," "once per day," "two to three times per day," "four to five times per day," and "six or more times per day." The Nutritionist Pro software, version 7.3.0 (Axxya Systems, Woodinville, WA, United States), was used to calculate the daily intake of energy and nutrients.

Calculation of the Dietary Inflammatory Index

The DII was calculated based on a previously reported method using the daily intake of 28 out of possible 45 food parameters (carbohydrate, protein, fat, alcohol, total dietary fiber, cholesterol, saturated fat, monounsaturated fat, polyunsaturated fat, linolenic acid, linoleic acid, trans fatty acid, niacin, thiamin, riboflavin, cobalamin-vitamin B12, pyridoxine-vitamin B6, iron, zinc, selenium, vitamin A, vitamin C, vitamin D, vitamin E-α tocopherol, folate, β carotene, caffeine, and magnesium).[13,14] Briefly, at the individual level, the dietary intake of each food parameter was standardized to a global mean ± standard deviation (SD) value to generate a Z-score, which was converted to a proportion (with values from 0 to 1 and centered by doubling and subtracting 1). The centered proportions obtained were then multiplied by the corresponding literature-derived inflammatory scores and added to obtain the overall DII of each participant. The Energy-adjusted DII (E-DII) scores were computed using a similar procedure, but the dietary intake of each food parameter was first converted to per 1,000 kcal intake and standardized to an energy-adjusted global mean ± SD value.

Sleep Quality

The sleep quality of the participants was assessed through the Pittsburgh Sleep Quality Index (PSQI), which presents a high level of reliability and validity, and is a standardized, quantitative measure of sleep quality over the past month.[33,34] This tool consists of 19 self-reported questions, each with 7 domain scores. Each of the 7 components is evaluated equally on a scale ranging from 0 to 3, with a higher score reflecting progressively worsening problems, as follows: 1) subjective sleep quality (very good to very bad); 2) sleep latency (15 to > 60 minutes); 3) sleep duration (7 to < 5 hours); 4) sleep efficiency (≥ 85% to < 65% of hours slept/hours in bed); 5) sleep disturbances (not during the past month to 3 times per week); 6) use of sleeping medications (none to 3 times a week); and 7) daytime dysfunction (not a problem to a very big problem). These 7 components are then added to calculate a total score ranging from 0 to 21.[35] The final result is dichotomized by using a cutoff point of "5," with scores > 5 indicating poor sleep quality.

Statistical Analysis

The statistical analysis was performed using the IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, United States). The categorical variables are presented as frequencies (percentages), and the continuous variables, as mean ± SD values. The E-DII was treated as a categorical variable by breaking the data into four equal groups or quartiles. The first quartile (Q1) corresponds to the lowest 25% of the E-DII (the least inflammatory diets in our dataset). The next lowest 25% of the E-DII are categorized as the second quartile (Q2). The third quartile (Q3) includes the second highest 25% of the E-DII. Finally, the highest 25% of the E-DII (the most proinflammatory diets in our dataset) are included in the fourth quartile (Q4). The chi-squared and analysis of variance (ANOVA) tests were used, as appropriate, to examine the distribution of the baseline characteristics of the participants across the E-DII quartiles. The chi-squared test was used to explore the association between the sleep-related outcomes and the E-DII quartiles. In a later step, regression analysis was performed to consider the effect of other variables (age, gender, BMI, employment, family income, year of study, smoking, and physical activity level) on this association. For the association between the overall sleep quality and E-DII quartiles, odds ratios (ORs) with 95% confidence intervals (95%CIs) were estimated using binary logistic regression; and, for the association between the individual PSQI components and the E-DII, ORs with 95% CIs were estimated using ordinal regression.

Results

►**Table 1** illustrates the baseline characteristics of the participants according to the E-DII quartiles. There were no significant differences in the baseline characteristics of the participants according to the E-DII quartiles ($p > 0.05$).

Higher rates of poor overall sleep quality were found in the highest E-DII quartiles, with 66% and 78% of participants in Q3 and Q4 respectively, having poor sleep quality versus 52% in Q1 ($p = 0.02$). Despite the overall significant association between the E-DII and sleep quality, there were no significant differences in the sleep outcomes of the individual PSQI domains according to the E-DII quartiles ($p > 0.05$) (►**Table 2**).

The regression analysis presented in ►**Table 3** revealed an association between the E-DII and overall sleep quality. Individuals in Q4 were at an increased risk of having poor overall sleep quality compared with those in Q1 (OR =2.86; 95%CI: 1.27–6.44; $p = 0.01$). As for the individual domains, an association was found regarding sleep efficiency and daytime dysfunction and E-DII quartiles. Individuals in Q3 and Q4 of the E-DII were at an increased risk of having poor sleep efficiency compared with those in Q1 (OR = 2.40; 95%CI: 1.12–5.54; $p = 0.03$; and OR = 2.52; 95%CI: 1.13–5.62; $p = 0.02$ respectively). However, individuals in Q3 were at a reduced risk of having daytime dysfunction compared with those in Q1 (OR = 0.44; 95%CI: 0.23–0.83; $p = 0.01$). No

Table 1 Baseline characteristics of the study participants according to E-DII quartiles.

	E-DII quartiles (Q)				*p*-value
	Q1	Q2	Q3	Q4	
Age ($n = 270$)					
Mean(± SD)	20.12(± 1.87)	19.69(± 1.88)	19.79(± 1.65)	20.04(± 2.07)	0.49
Gender n (%) ($n = 270$)					
Male	38 (56.7%)	39 (57.4)	43 (63.2)	37 (55.2)	0.79
Female	29 (43.3)	29 (42.6)	25 (36.8)	30 (44.8)	
Employment n (%) ($n = 270$)					
Employed	5 (7.5)	4 (5.9)	7 (10.3)	4 (6.0)	0.81
Unemployed	62 (92.5)	64 (94.1)	61 (89.7)	63 (94.0)	
Smoking n (%) ($n = 270$)					
Yes	18 (26.9)	16 (23.5)	27 (39.7)	24 (35.8)	0.15
No	49 (73.1)	52 (76.5)	41 (60.3)	43 (64.2)	
Alcohol n (%) ($n = 269$)					
Yes	1 (1.5)	3 (4.4)	4 (5.9)	3 (4.5)	0.70
No	65 (98.5)	65 (95.6)	64 (94.1)	64 (95.5)	
Physical activity n (%) ($n = 270$)					
Inactive	24 (35.8)	25 (36.8)	23 (33.8)	22 (32.8)	0.18
Moderately active	25 (37.3)	35 (51.5)	31 (45.6)	37 (55.2)	
Vigorously active	18 (26.9)	8 (11.8)	14 (20.6)	8 (11.9)	
BMI ($n = 270$)					
Mean(± SD)	24.27(± 3.95)	23.88(± 3.65)	25.45(± 5.84)	24.59(± 3.50)	0.19

Abbreviations: BMI, Body Mass Index; E-DII, Energy-Adjusted Dietary Inflammatory Index; SD, standard deviation.
Note: The Chi-squared test was used for the categorical variables and the analysis of variance (ANOVA) test was used for the continuous variables.

significant association was found between the other PSQI individual domains and E-DII quartiles.

Discussion

The present cross-sectional study is the first to examine the association between sleep quality and the E-DII in a sample of Lebanese university students. The results indicate that the risk of having poor overall sleep quality was almost three times higher among students in the highest E-DII quartile compared with those in the lowest E-DII quartile after controlling for age, gender, BMI, employment, family income, year of study, smoking, and physical activity level. As for the individual PSQI components, high E-DIIs were positively associated with poor sleep efficacy; however, the risk of having daytime dysfunction was lowest among students in the third E-DII quartile compared with those in the lowest one. This anomalous result, which may have occurred by chance, should be explored and verified in future studies.

College students have overloaded academic schedules and often face or create unrealistic expectations, which can result in stress , poor sleep quality, and short sleep duration.[23] Thus, as in other countries and cultural contexts, poor sleep quality is very common among university students in Arab countries, with previous studies indicating that around 2/3 of college students attending the university of Sharjah, in United Arab Emirates (UAE), and 76% of medical students attending King Khaled University in Saudi Arabia have poor sleep quality.[17,36] In Lebanon, the quality of sleep among university students is better than in the Gulf region, but is far from optimal. A previous study[26] conducted on students from 6 universities across Lebanon, for example, revealed that more than half of them (52.7%) had poor sleep quality. Our results support these findings, as 64.2% of our population had poor sleep quality.

Due to the complexity of sorting out causal mechanisms, it is difficult to elucidate the exact cause of the sleep disturbance in a given person; however, in many instances, diet and other lifestyle factors are the primary factors.[37] In this regard, the findings of the current study revealed that students with higher E-DIIs had an increased risk of having poor overall sleep quality, which highlights the potential influence of diet on sleep patterns. Various individual dietary factors have already been implicated in sleep quality, and various mechanisms have been proposed to explain this association. These include the direct or indirect effect on the production of serotonin and melatonin for B1 and B6 vitamins, and stimulation of the nervous system for coffee and cola beverages.[37] Additionally, with the understanding of the role of inflammatory mediators and systemic inflammation in sleep quality, there is an increased interest in the

Table 2 Overall sleep quality and sleep-related characteristics of the participants by E-DII quartile.

	E-DII quartiles (Q)				
	Q1 ($n = 67$)	Q2 ($n = 68$)	Q3 ($n = 68$)	Q4 ($n = 67$)	*p*-value
Overall sleep quality, *n* (%) (*n* = 270)					
Poor sleep quality ≥ 5 PSQI	35 (52.2%)	40 (58.8%)	45 (66.2%)	52 (77.6%)	**0.02**
Good sleep quality <5 PSQI	32 (47.8%)	28 (41.2%)	23 (33.8%)	15 (22.4%)	
Subjective sleep, *n* (%) (*n* = 270)					
Very bad (3)	10 (14.9%)	7 (10.3%)	8 (11.8%)	8 (11.9%)	
Fairly bad (2)	9 (13.4%)	13 (19.1%)	14 (20.6%)	19 (28.4%)	0.23
Fairly good (1)	22 (32.8%)	26 (38.2%)	30 (44.1%)	28 (41.8%)	
Very good (0)	26 (38.8%)	22 (32.4%)	16 (23.5%)	12 (17.9%)	
Sleep latency, *n* (%) (*n* = 270)					
Long (> 60 minutes)	14 (20.9%)	10 (14.7%)	13 (19.1%)	14 (20.9%)	0.5
Medium (31–60 minutes)	9 (13.4%)	18 (26.5%)	16 (23.5%)	14 (20.9%)	
Short (16–30 minutes)	28 (41.8%)	21 (30.9%)	24 (35.3%)	29 (43.3%)	
Very short (< 15 minutes)	16 (23.9%)	19 (27.9%)	15 (22.1%)	10 (14.9%)	
Sleep duration, *n* (%) (*n* = 270)					
< 5 hours	8 (11.9%)	4 (5.9%)	8 (11.8%)	8 (11.9%)	0.5
5 hours	20 (29.9%)	23 (33.8%)	18 (26.5%)	26 (38.8%)	
6 hours	21 (31.3%)	23 (33.8%)	16 (23.5%)	18 (26.9%)	
≥ 7 hours	18 (26.9%)	18 (26.5%)	26 (38.2%)	15 (22.4%)	
Sleep efficiency, *n* (%) (*n* = 270)					
Very low (< 65%)	2 (3%)	0 (0%)	5 (7.4%)	5 (7.5%)	0.09
Low (65–74%)	5 (7.5%)	10 (14.7%)	7 (10.3%)	5 (7.5%)	
Medium (75–84%)	6 (9%)	10 (14.7%)	12 (17.6%)	15 (22.4%)	
High ≥ 85%	54 (80.6%)	48 (70.6%)	44 (64.7%)	42 (62.7%)	
Sleep disturbance, *n* (%) (*n* = 270)					
High (19–27)	0	0	0	0	0.85
Medium (10–18)	9 (13.4%)	12 (17.6%)	11 (16.2%)	12 (17.9%)	
Low (1–9)	53 (79.1%)	50 (73.5%)	54 (79.4%)	48 (71.6%)	
None (0)	5 (7.5%)	6 (8.8%)	3 (4.4%)	7 (10.4%)	
Use of sleep medication, *n* (%) (*n* = 270)					
≥ 3 times/week	3 (4.5%)	0 (0%)	1 (1.5%)	1 (1.5%)	0.66
1–2 times/week	0 (0%)	2 (2.9%)	2 (2.9%)	2 (3%)	
< 1 time/week	5 (7.5%)	4 (5.9%)	4 (5.9%)	7 (10.4%)	
Not in the past month	59 (88.1%)	62 (91.2%)	61 (89.7%)	57 (85.1%)	
Daytime dysfunction, *n* (%) (*n* = 270)					
High (5–6)	20 (29.9%)	15 (22.1%)	7 (10.3%)	18 (26.9%)	0.27
Medium (3–4)	17 (25.4%)	23 (33.8%)	25 (36.8%)	21 (31.3%)	
Low (1–2)	23 (34.3%)	23 (33.8)	24 (35.3%)	18 (26.9%)	
None (0)	7 (10.4%)	7 (10.3%)	12 (17.6%)	10 (14.9%)	

Abbreviations: E-DII, Energy-Adjusted Dietary Inflammatory Index; PSQI, Pittsburgh Sleep Quality Index.
Note: The Chi-squared test was used.

role of individual dietary components on inflammatory status and subsequently on sleep outcome. Indeed, various inflammatory mediators, such as IL-6 and tumor necrosis factor alpha (TNF-α), have been found to affect sleep-wake cycles, and both IL-1β and TNF-α have been shown to modulate non-rapid eye movement sleep.[38] Research indicates the role of individual dietary components in the disturbance of cytokine levels and subsequently sleep

Table 3 Associations regarding overall and individual domains of sleep quality and E-DII quartiles.

	E-DII quartiles (Q)							
	Q1 ($n = 67$) (Reference category)		Q2 ($n = 68$)		Q3 ($n = 68$)		Q4 ($n = 67$)	
	Odds ratio* Q1 versus Q1	*p*-value	Odds ratio* Q2 versus Q1	*p*-value	Odds ratio* Q3 versus Q1	*p*-value	Odds ratio* Q4 versus Q1	*p*-value
Overall sleep quality **	1	–	1.15 (0.55–2.39)	0.72	1.84 (0.864–3.901)	0.11	**2.87 (1.27–6.44)**	**0.01**
Subjective sleep quality **	1	–	1.05 (0.556–1.999)	0.87	1.49 (0.788–2.832)	0.22	1.72 (0.90–3.28)	0.1
Sleep latency **	1	–	0.891 (0.475–1.670)	0.72	1.202 (0.641–2.256)	0.57	1.164 (0.617–2.197)	0.64
Sleep duration **	1	–	0.874 (0.465–1.643)	0.68	0.777 (0.412–1.465)	0.44	1.255 (0.662–2.380)	0.49
Sleep efficiency **	1	–	1.700 (0.750–3.856)	0.2	**2.49 (1.12–5.54)**	**0.03**	**2.52 (1.13–5.62)**	**0.02**
Sleep disturbance **	1	–	1.237 (0.545–2.807)	0.61	1.414 (0.622–3.217)	0.41	1.072 (0.467–2.458)	0.87
Use of sleep medication **	1	–	0.609 (0.187–1.990)	0.41	0.797 (0.260–2.444)	0.69	1.190 (0.404–3.503)	0.75
Daytime dysfunction **	1	–	0.779 (0.415–1.465)	0.44	**0.44 (0.23–0.83)**	**0.01**	0.76 (0.40–1.44)	0.4

Abbreviation: E-DII, Energy-Adjusted Dietary Inflammatory Index.
Notes: Binary logistic regression and ordinal regression were used for the associations among the overall sleep quality and E-DII quartiles and for the associations involving the individual Pittsburg Sleep Quality Index domains and E-DII quartiles respectively.
*Adjusted for: age, gender, Body Mass Index, employment, family income, year of study, smoking, physical activity level.
**The best outcome category is the reference category.

problems. Christian et al.,[39] for example, found that suboptimal consumption of polyunsaturated fatty acids (PUFAs) among pregnant women can disturb IL-8 levels, which may lead to poor sleep quality. However, the authors[39] noted that this relationship is bidirectional, for poor sleep quality can also lead to increased serum IL-8 levels and inflammation. Similarly, Losso et al.[40] found that procyanidin B-2, which is present in tart cherry juice, improves sleep quality by inhibiting indoleamine 2,3-dioxygenase, increasing tryptophane availability, and reducing inflammation.

Clearly, diet represents a complex mixture of components with a potential for numerous interactions among various proinflammatory and anti-inflammatory components. Therefore, studying the overall inflammatory effect of diet rather than each individual component separately seems to be a prudent strategy. The MD, with its anti-inflammatory characteristics, has been studied in relation to sleep quality, and previous studies have revealed that the MD is associated with improved sleep quality among Spanish adolescents[41] and older adults after a 3-year follow-up.[42] Additionally, several studies have found that diets with high inflammatory potential, measured using the DII, were associated with overall poor sleep quality among various populations such as healthy adults,[15] pregnant women[18] and police officers.[19] However, few studies[17,43] have been undertaken to examine this association among university students, who are usually at a high risk of having poor sleep quality. Moreover, while most of the results obtained for other populations yielded similar results that confirm the role of a proinflammatory diet in sleep disturbances, the two studies conducted on university students yielded conflicting results.[17,43] Masaad et al.[17] found no association between the E-DII and overall sleep quality among students from the University of Sharjah (UOS), in the UAE. On the other hand, in a cross-sectional study conducted later on obese Iranian female students, Bazyar et al.[43] found that participants in the highest DII quartiles had a higher risk of sleep disturbances. Our results are in line with the findings of the latter study[43] concerning the association between the DII and overall sleep quality. These conflicting results highlight the fact that the association between the inflammatory potential of diet and sleep quality is not simple and straightforward, and that many factors can influence it. There are several explanations for this: first, the three studies were conducted on three different populations (Emirati,[17] Iranian,[43] and Lebanese [the present study]) with completely different dietary patterns. Second, the gender distribution in the three studies is different, with more males in the Emirati study, only females in the Iranian study, and a slightly higher proportion of females (compared with the Emirati study) in the current study. Third, the smoking levels were higher in our sample compared with the Emirati study (almost 31.5%; results not shown). Fourth, the use of regression models and the covariates included in these models differ between the three studies. Therefore, the inflammatory potential of the diets adopted by the three samples could be different. Additionally, as mentioned by Masaad et al.,[17] their sample might have an inherently lower dietary inflammatory status compared with other samples. However, the authors[17] found a trend of higher E-DIIs among poor sleepers. Although not significant, this may indicate that these associations can exist; however, it is masked in their sample by other factors. Additionally, the difference in gender distribution, smoking status, and possibly other factors can lead to differences in the inflammatory status of the studied populations, which may affect sleep patterns independent of the diet, especially if these factors are not included in the regression model.[44,45]

Regarding the individual sleep domains, we also found a strong association between sleep efficiency and E-DII quartiles: individuals with higher E-DIIs had an increased risk of poor sleep efficiency measured using the PSQI. A similar association was not detected among university students in the previous studies.[17,43] Still, these findings are consistent with the results of previous longitudinal studies, in which an increase in the DII was associated with longer, objectively measured, wake-after-sleep-onset (WASO) among European American obese and overweight pregnant women, police officers, and young adults from the United States.[18,19,46,47] Additionally, an increase in DII was associated with a decrease in sleep efficiency.[46,47] However, in the present study, we also found an unforeseen result that links higher E-DIIs with a reduced risk of daytime dysfunction, with individuals in the third E-DII quartile having less daytime dysfunction compared with those in the first E-DII quartile. This result also contradicts those of the study by Masaad et al.,[17] who found that high E-DIIs are positively associated with daytime dysfunction. This unexpected finding is hard to explain; however, it may be attributed to the confounding effect of excessive caffeine intake. In fact, previous studies have reported a high intake of sugar-sweetened beverages (SSBs) among university students in Arab countries.[48,49] The highest contribution was reported to be from coffee and coffee drinks such as sweetened American coffee, sweetened latte, cappuccino, instant coffee 3 in 1, sweetened instant coffee with milk, and hot chocolate, among others. Although to a lesser extent, however, soft drinks also add to the daily sugar and energy intake.[48,49] Being rich in caffeine, these SSBs also contribute significantly to the total daily caffeine intake. Indeed, higher intakes of caffeinated beverages have already been reported by college students.[49,50] Additionally, these beverages are packed with dietary components that increase the inflammatory potential of the diet, such as fat, saturated fat, and kilocalories. Therefore, an increased consumption of these beverages may increase the E-DIIs, but it also may help students stay awake during the day, due to their caffeine content, and decrease their daytime dysfunction. Indeed, in their review, O'Callaghan et al.[51] found a large body of literature that highlights the positive role of caffeine on physical and cognitive performance.

The present study has several limitations. First, it was conducted at BAU, a private university. Selection factors may be at play, and because public university students did not participate in the present study, the results may not be generalized to all Lebanese college students. Second, the study relied on self-reported data such as the FFQ to assess dietary intake and the PSQI to evaluate the sleep quality of the participants. Third, micro- and macronutrients were estimated using databases on nutrient content from sources from the United States, which may not apply to foods consumed in other parts of the world. Finally, the causal association cannot be established due to the cross-sectional design of the study. This is especially true in the light of the fact that the association between sleep quality and diet can be bidirectional, with evidence suggesting that sleep restriction can negatively affect our dietary choices.[52] In this regard, in their recent review article, Zuraikat et al.[52] emphasized the effect of sleep restriction on decreased diet quality, such as increased energy intake and increased intake of fats, including saturated fat. All of these dietary changes can increase the inflammatory potential of the diet.

On the other hand, the present study has several strengths. Although self-reports are subject to information bias, the participants were not aware of the hypothesized association between sleep and diet. The analyses took into consideration several possible confounding variables, such as age, gender, BMI, employment, family income, year of study, smoking, and physical activity level.

To our knowledge, the present is the first study to assess the association between sleep quality and the E-DII among Lebanese university students. The findings support our hypothesis that the inflammatory potential of the diet is related to sleep quality among university students in Lebanon. The association between sleep quality and the E-DIIs can be explored in future studies based in representative samples of Lebanese college students, which include various socioeconomic classes and regions across the country. Additionally, future cohort studies can be designed to elucidate the temporal association between sleep quality and the E-DII and to better understand the influence of various factors on this association and to further establish causality.

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Author's contribution
Zeina El-Ali and Rosy Mitri designed and conducted the study, performed the statistical analyses of study data, interpreted the results of the analyses and wrote the manuscript. James R. Hebert and Michael D. Wirth computed the DII and E-DII scores, contributed to the statistical analyses of study data, interpreting results of analyses, and writing the manuscript.

Conflict of Interests
Dr. James R. Hébert wishes to disclose that he owns controlling interest in Connecting Health Innovations LLC (CHI), a company that has licensed the right to his invention of the Dietary Inflammatory Index (DII) from the University of South Carolina to develop computer and smartphone applications for patient counseling and dietary intervention in clinical settings. Connecting Health Innovations LLC owns exclusive rights to the E-DIITM. The subject matter of the present paper will not have any direct bearing on that work, nor has that activity exerted any influence on this project. The authors have no other potential competing interests to disclose.

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