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The Impact of Unhealthy Eating Behaviors on Sleep Quality Among University Students: A Cross-Sectional Study

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Abstract

Background: This study examined the impact of specific unhealthy eating behaviors on sleep quality (SQ) among university students. Understanding how dietary habits affect sleep during the significant lifestyle transitions that students experience during university life can inform health promotion strategies. **Methods**: A cross-sectional study was conducted among international university students using a self-administered questionnaire assessing dietary habits, meal timing, and sleep-related behaviors. The Pittsburgh Sleep Quality Index (PSQI) was utilized to assess sleep quality. Statistical analyses were performed to examine the relationship between eating patterns and overall sleep quality and its components. **Results**: More than half of the 385 students (51.7%) had poor sleep quality, as defined by the PSQI criteria. Daytime dysfunction was significantly more common among females than males (27.9% vs. 8.3%, respectively; p<0.001). Conversely, poor sleep efficiency was more prevalent among males than females (27.5% vs. 15.8%; p=0.008). Multivariate logistic regression revealed that, compared to students who did not frequently consume heavy evening meals, those who did were more likely to experience poor sleep quality (OR = 2.73, 95% CI: 1.575-4.731). Similarly, those who frequently replaced regular meals with snacks were more likely to experience poor sleep quality than those who did not (OR = 2.68, 95% CI: 1.465-4.895). Finally, students who ate within three hours of bedtime had higher odds of poor sleep quality compared to those who had their last meal more than three hours before bedtime (OR = 2.06, 95% CI: 1.173-3.629). **Conclusion**: Unhealthy dietary habits, such as consuming heavy evening meals, replacing meals with snacks, and a short meal-to-bedtime interval are significantly associated with poor sleep quality. Interventions promoting healthier dietary patterns and appropriate meal timing could help improve sleep and overall well-being in this population.

Keywords: sleep quality; chrono-nutrition; dietary habits; meal timing; university students

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1. Introduction

Poor sleep quality (SQ) is a significant public health concern associated with increased risk of morbidity and mortality [1]. Research indicates that it negatively impacts cognitive functions such as concentration and memory, exacerbates physical and mental health problems, and ultimately raises healthcare system costs [2,3].

Sleep disturbance, including insomnia, is more prevalent in young adults, especially university students, than in the general population [4–6]. Good SQ is defined as the individual's overall evaluation of their sleep based on factors, such as sleep efficiency, latency, duration, and the amount of wakefulness after sleep inception [7]. Validated tools such as the Pittsburgh Sleep Quality Index (PSQI) are available to measure these characteristics [7,8].

Research has increasingly focused on the complex relationship between nutrition and sleep, highlighting how dietary patterns can impact sleep quality and duration [9]. For instance, Melo et al. reported that higher evening food intake was associated with lower sleep efficiency, increased nocturnal alertness, and a higher apnea-hypopnea index (AHI) [10,11]. Another study divided participants based on food intake timing into early eaters, late eaters, and meal skippers. The results showed that late eaters had significantly poorer SQ and greater daytime drowsiness than early eaters [12].

Choi et al. also reported that skipping breakfast regularly and late-night eating were correlated with poorer sleep quality and an increased incidence of obstructive sleep apnea [13]. This confirms the significant influence of mealtimes on sleep health.

The notion of chrono-nutrition includes three principal elements of human dietary habits: food consumption's timing, regularity, and frequency [14, 17]. In 1986, Dr Alain Delabos presented chrononutrition, the idea that emphasize that eating patterns should align with the circadian rhythms of the body, which are influenced by daily fluctuations in metabolism [18]. Delayed meals and irregular eating patterns can disrupt these rhythms, which can cause negative health outcomes, including cardiometabolic diseases, elevated risk of developing type 2 diabetes mellitus, obesity, and reduced sleep quality [10,11,19, 21].

Due to the global population of international students having substantially increased, going from 2 million in 2000 to over 6 million in 2021, as the World Migration Report indicates, it is critical to investigate how the distinct dietary and lifestyle habits of this group may have an impact on their sleep quality [22,23,24]. These habits include skipping breakfast, late-night snacking, irregular meal timings, and substituting snacks for meals.

This study seeks to explore how detrimental dietary behaviors impact sleep quality among international university students. Specifically, eating close to bedtime, substituting meals with snacks, late-night snacking, skipping breakfast, consuming heavy evening meals, and irregular eating schedules. We hypothesize that the aforementioned dietary patterns are associated with poorer sleep quality among international university students.

2. Materials and Methods

2.1. Methodology

The research design, performance, and writing adhered to the guiding principles introduced in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [25].

2.2. Study Design

This cross-sectional quantitative study was conducted between September and November 2024 at the University of Pécs, Hungary, using a self-administered questionnaire that included the validated Pittsburgh Sleep Quality Index (PSQI).

2.3. Participants

All international students (approximately 5,000), aged 18 years or older and enrolled in the fall semester of the 2024/2025 academic year at the University of Pécs, were considered eligible for participation [26]. Those who did not meet these criteria were deemed ineligible. Students were invited to participate through convenience sampling, a technique selected for its practicality, cost-effectiveness, and suitability for research within relatively homogeneous populations such as university student cohorts [27].

A total of 422 students were approached; of those, 32 declined participation, and 390 initially completed the survey. Following data screening, 385 fully completed questionnaires were included in the final analysis, while five responses were excluded due to missing data.

2.4. Data Collection

Data collection involved direct visits to the various University of Pécs campuses, where students were approached. Following a detailed description of the research objective, questionnaires were distributed directly in paper-based form to participants upon obtaining their informed consent. Participation was voluntary.

2.5. Sample Size

The required sample size for the analysis was calculated based on World Health Organization (WHO) guidelines for the minimum sample size for prevalence studies. [28,29]. The following formula was used:

$$n = \frac{\mathbf{Z}^2 \times p(1-p)}{d^2}$$

For this calculation, a 95% confidence level, a 5% margin of error (d), a Z-score of 1.96, and an assumed population proportion (p) of 0.5 were used. Based on these parameters, a minimum sample size of 385 participants was determined.

2.6. Questionnaire Tool

The study utilized a self-administered questionnaire, available in English, comprising 41 items divided into two main sections. The first section (22 items) collected baseline information, including sociodemographic characteristics, lifestyle factors, physical characteristics, and dietary behaviors. Sociodemographic characteristics included (age, sex, marital status, nationality, residential setting, academic faculty, academic level and year of study), lifestyle factors included (alcohol and coffee consumption, smoking status, perceived stress levels, physical activity, and napping habits). Participants also self-reported their height and weight. Dietary behaviors assessed usual mealtime regularity, breakfast skipping, consumption of late-night snacks (defined as after 10 PM), replacement of meals with snacks, tendency to consume heavier evening meals compared to daytime, and the typical time interval between the last meal and bedtime.

The second section (19 items) consisted of the validated tool Pittsburgh Sleep Quality Index (PSQI), which was used to assess overall sleep quality and its components [8]. Dietary habit questions and categorization methods for sleep components were informed by and adapted from the previous research by Faris et al. (2022), as discussed in the sections below [30]. A detailed classification of all questionnaire items is provided in Supplemental File S1.

2.6.1. Anthropometric Assessment

Students self-reported their height (cm) and weight (kg), from which Body Mass Index (BMI) was calculated and categorized according to the standard classifications: underweight (BMI < 18.5 kg/m^2), normal weight (BMI: 18.5–24.9 kg/m^2), overweight (BMI: 25–29.9 kg/m^2), obesity class I (BMI: 30–34.9 kg/m^2), obesity class II (BMI: 35–39.9 kg/m^2), and obesity class III (BMI > 40 kg/m^2) [31].

Given known differences in body composition, specific BMI classifications were applied to Asian students: underweight (BMI < 18.5 kg/m^2), normal weight (BMI: 18.5–22.9 kg/m^2), overweight (BMI: 23–24.9 kg/m^2), obesity class I (BMI: 25–29.9 kg/m^2), obesity class II (BMI: 30–34.9 kg/m^2), and obesity class III (BMI ≥ 35 kg/m^2) [32,33].

2.6.2. Sleep Quality Assessment

The Pittsburgh Sleep Quality Index (PSQI) was used to assess participants' sleep quality and patterns over the preceding month. The reliability and validity of the PSQI are well-established [8]. The PSQI comprises 19 questions categorized into seven distinct components of sleep: subjective sleep quality, sleep duration, sleep latency, sleep efficiency, sleep disturbances, daytime dysfunction, and the use of sleep medications.

Students rated each component on a scale ranging from 0 to 3, where 0 indicated the best sleep quality and 3 represented the poorest. Individual component scores were then calculated and summed to yield a global PSQI score, ranging from 0 to 21. A higher global score represents worse sleep quality; a score of 0 indicates the absence of sleep problems, while a score of 21 represents severe difficulties across all sleep domains [8].

2.6.3. Eating Habits Assessment

Participants responded to a series of questions assessing various aspects of their eating patterns during the previous month. These included inquiries about frequent breakfast skipping, late-night snack consumption (defined as snack intake after 10:00 PM), and substituting snacks for main meals (breakfast, lunch, and dinner). Participants were also asked about the tendency to consume heavier meals in the evening, and the consistency of mealtime patterns, referring to the regular consumption of main meals at fixed times.

To clarify, participants were informed that snacks included calorie-rich items such as chips, sweets, baked goods, processed meats, cheeses, and beverages, excluding water, diet drinks, tea, and plain coffee. Participants responded with either a "yes" or "no" from the available options. In addition, they were asked to report the interval between their last meal of the day and bedtime, selecting from predefined categories: 0–2 hours, or ≥3 hours.

2.6.4. Coding and Categorization of Variables

To transform the sleep quality from ordinal scores (ranging from 0 to 21 for the global PSQI and from 0 to 3 for each sleep sub-component) into categorical variables, the global PSQI score was dichotomized: a score greater than 5 was defined as poor overall sleep quality, and a score of 5 or less as good overall sleep quality [8].

The PSQI sub-components scores were categorized as either adequate or inadequate. For subjective sleep quality, scores of 0 or 1 were classified as adequate (representing high and medium quality), and scores of 2 or 3 were considered inadequate (representing low and very low quality). Similarly, sleep latency was categorized as adequate for scores of 0 or 1 (indicating a duration of 30 minutes or less to fall asleep), and inadequate for scores of 2 or 3 (indicating a duration of more than 30 minutes). For sleep efficiency (defined as the % of actual time spent asleep in bed), an efficiency of 75% or more (scores of 0 or 1) was classified as adequate, while an efficiency of 74% or less (scores of 2 or 3) was deemed inadequate. Sleep duration was considered adequate for six hours or more (scores of 0 or 1) and inadequate for less than six hours (scores of 2 or 3).

Sleep disturbance (assessed by the frequency of various sleep-related problems such as waking up at night, breathing issues, or experiencing bad dreams that interfere with sleep quality) was categorized as adequate when the sum of scores was less than 10 out of 27 on PSQI's sleep disturbance component score (representing no or low levels of disturbance), and inadequate when the sum of scores was 10 or more (representing medium or high levels). The need for sleep medication was deemed adequate with no or low usage (scores of 0 or 1) if participants reported using it less than once per week, and inadequate with medium or high usage (scores of 2 or 3) if used once per week or more.

Daytime dysfunction was classified as adequate for no or low levels of dysfunction, scores of 0 or 1 (indicating a lack of or only a slight problem with remaining alert during daily activities and maintaining sufficient motivation to complete tasks), and inadequate for scores of 2 or 3 for medium or high levels (indicating the problem was sometimes or very frequently an issue). Finally, the time

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interval between the last meal and bedtime was considered adequate if it was three hours or more, and inadequate if it was less than three hours [30].

2.7. Ethical Approval

Ethical approval for this study was obtained from the Institutional Review Board of the University of Pécs (No.9568-PTE 2023).

2.8. Statistical Analysis

Statistical analyses were conducted using SPSS software (version 27). Categorical variables were presented as frequencies and percentages, while quantitative data were summarized using means and standard deviations (SD). Descriptive statistics were generated to characterize the sociodemographic data and overall sleep quality. Sleep components and sex were compared using the Pearson Chi-squared test.

Cross-tabulation and an assessment of the strength of association were conducted between sleep components and eating habits, with results presented as odds ratios (OR), 95% confidence intervals (CI), and p-values. Furthermore, multiple logistic regression analysis was performed to calculate the odds ratio (OR), 95% confidence intervals (CI), and p-value, thereby assessing the impact of dietary habits on overall sleep quality (as measured by the PSQI). The results were adjusted for the following demographic and lifestyle factors: age, sex, marital status, residential setting, academic faculty, academic level, year of study, nationality, BMI, smoking, physical activity, stress level, napping frequency, alcohol and coffee consumption. Statistical significance was defined as a p-value <0.05.

3. Results

A total of 385 students were included in the present study, drawn from a population of approximately 5,000 international students. The participants' sociodemographic profiles are summarized in Table 1. The majority of the students (68.8%) were females, and most students (71.7%) were between 18 and 24 years of age. These participants originated from one of four broad regions: the Middle East and North Africa (MENA), Europe/Americas, Central, Eastern and South Asia, and Sub-Saharan Africa. A significant proportion (82.3%) of the students were single. Regarding academic enrollment, 68.6% were in faculties related to medicine, health sciences, or pharmacy. Another 19.5% were enrolled in engineering and sciences faculties, with the remaining 11.9% in business, humanities, law, music, or visual arts.

The majority of the students (70.1%) were pursuing undergraduate degrees, while 15.6% were in master's programs and 14.3% in doctoral programs. A large proportion (70.4%) were in their first or second year of study. In terms of residential status, 79.7% lived off-campus. Smoking was reported by a minority (13.8%), while regular alcohol consumption (54.8%) and coffee or caffeinated beverage intake (50.6%) were common. Regular physical activity was reported by a smaller group (39.7%). Regarding body weight, (60.3%) had a normal BMI, while (30.1%) were classified as overweight or obese. Severe stress was reported by one-quarter of participants (25.7%). Additionally, a considerable proportion of participants reported poor sleep quality (51.7%), and the majority indicated daily napping (73.8%).

Table 1. General characteristics and sleep quality of the students (n = 385).

Characteristics	Frequency (n)	Percentage (%)
Sex		
Male	120	31.2
Female	265	68.8

Age group		
18-24	276	71.7
25-30	75	19.5
30-40	34	8.8
Year of study		
1st and 2nd Year	271	70.4
3rd and 4th year	100	26.0
5th and 6th year	14	3.6
Academic faculty		
Faculty of Engineering and	86	19.5
Sciences	265	68.6
Faculty of Medicine, Health		
Sciences and Pharmacy	34	11.9
Faculty of Business, Cultural		
Sciences, Humanities, Law, Music		
and Visual Arts		
Academic level		
Bachelor	270	70.1
Master	60	15.6
PhD	55	14.3
Marital status		
Single	317	82.3
Married	16	4.2
Other	52	13.5
Residential setting		
Dormitory	78	20.3
Apartment	307	79.7
Smoking status		
Smoker	53	13.8
Non-smoker	332	86.2
Alcohol consumption		
Irregular alcohol drinker	174	45.2
Regular alcohol drinker	211	54.8
Coffee consumption		
Irregular coffee drinker	190	49.4
Regular coffee drinker	195	50.6
Physical activity		
Irregular physical activity	232	60.3
exerciser	153	39.7
Regular physical activity exerciser		
Stress level		
Normal	78	20.3
Mild	71	18.4
Moderate	137	35.6
Severe	99	25.7
Napping frequency		
Do not nap	90	23.3
Once a day	284	73.8
More than once	11	2.9

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Nationality		
European and Americans	110	28.6
Middle Eastern & North African	134	34.8
Sub-Saharan African	52	13.5
Central, Eastern and South Asia	89	23.1
BMI (kg/m2)		
Underweight	37	9.6
Normal weight	232	60.3
Overweight & Obese class 1,2, and 3	116	30.1
Global sleep quality (PSQI)		
Poor sleep quality	199	51.7
Good sleep quality	186	48.3

BMI, body mass index; PSQI, Pittsburgh Sleep Quality Index.

Table 2 presents significant differences in sleep quality components based on sex.

For example, males reported poor sleep efficiency more often than females (27.5% vs. 15.8%, p=0.008). Conversely, females more frequently experienced daytime dysfunction compared to males (27.9% vs. 8.3%, p<0.001)

Table 2. Comparison of sleep quality and its components between male and female students.

Sleep behaviors	Male (n=120) n (%)	Female (n= 265) n (%)	Total (n=385) n (%)	X^2	*p*-value
Subjective sleep quality					
Adequate subjective sleep quality [1]	88 (73.3)	192 (72.5)	280 (72.7)	0.32	0.857
Inadequate subjective sleep quality [2]	32 (26.7)	73 (27.5)	105 (27.3)		
Sleep latency					
Adequate sleep latency [1]	79 (65.8)	169 (63.8)	248 (64.4)	0.153	0.696
Inadequate sleep latency[2]	41 (34.2)	96 (36.2)	137 (35.6)		
Sleep Duration					
Adequate sleep latency [1]	83 (69.2)	176 (66.4)	259 (67.3)	0.284	0.594
Inadequate sleep latency [2]	37 (30.8)	89 (33.6)	126 (32.7)		
Sleep efficiency					
Adequate sleep efficiency[1]	87 (72.5)	223 (84.2)	310 (80.5)	7.148	0.008
Inadequate sleep efficiency[2]	33 (27.5)	42 (15.8)	75 (19.5)		
Sleep disturbance					
Adequate sleep disturbance[1]	106 (88.3)	224 (84.5)	330 (85.7)	0.977	0.323
Inadequate sleep disturbance[2]	14 (11.7)	41 (15.5)	55 (14.3)		
Use of Sleep Medication					
Adequate use of sleep Medication [1]	113 (94.2)	237 (89.4)	350 (90.9)	2.239	0.135
	7 (5.8)	28 (10.6)	35 (9.1)		

Inadequate use of sleep Medication [2]					
Daytime dysfunction					
Adequate daytime dysfunction[1]	110 (91.7)	191 (72.1)	301 (78.2)	18.585	< 0.001*
Inadequate daytime dysfunction[2]	10 (8.3)	74 (27.9)	84 (21.8)		
Global PSQI Score					
Global score ≤5 (good overall sleep quality)[3]	66 (55.0)	120 (45.3)	186 (48.3)	3.123	0.077
Global score >5 (poor overall sleep quality)[4]	54 (45.0)	145 (54.7)	199 (51.7)		

* The *p*-value was obtained from Pearson's chi-square (sig. 2-sided), statistically significant at $p < 0.05$;[1] Adequate indicates relevant sleep component scores (0 or 1) on the Pittsburgh Sleep Quality Index (PSQI); [2] Inadequate indicates relevant sleep component scores (2 or 3) on the Pittsburgh Sleep Quality Index (PSQI);[3] A global score of ≤ 5 indicates good overall sleep quality according to the Pittsburgh Sleep Quality Index (PSQI);[4] A global score of > 5 indicates poor overall sleep quality according to the Pittsburgh Sleep Quality Index (PSQI).

Table 3 presents the associations between specific eating behaviors and the global Pittsburgh Sleep Quality Index (PSQI) score, as well as its components. The results revealed that several eating behaviors were significantly associated with poorer sleep outcomes among the students. Specifically, frequent breakfast skipping was associated with an increased likelihood of longer sleep latency (OR = 1.53, 95% CI (1.00, 2.33), *p* = 0.048), increased odds of sleep medication use (OR = 3.12, 95% CI (1.48, 6.57), *p* = 0.002), and daytime dysfunction (OR = 1.67, 95% CI (1.03, 2.72), *p* = 0.038) as compared to breakfast consumption. Similarly, late-night snacking showed greater odds of poor overall sleep quality (OR = 1.59, 95% CI (1.06, 2.38), *p* = 0.024), prolonged sleep latency (OR = 1.54, 95% CI (1.00, 2.35), *p* = 0.046), and reduced sleep efficiency (OR = 2.10, 95% CI (1.23, 3.58), *p* = 0.006) compared to no late-night snacking**.**

Students who substituted snacks for regular meals demonstrated significant associations with adverse sleep outcomes, including increased odds of poor overall sleep quality (OR = 3.00, 95% CI (1.97, 4.55), *p* < 0.001), poor subjective sleep quality (OR = 2.07, 95% CI (1.31, 3.26), *p* = 0.002), prolonged sleep latency (OR = 2.64, 95% CI (1.72, 4.06), *p* < 0.001), reduced sleep efficiency (OR = 2.17, 95% CI (1.29, 3.63), *p* = 0.003), and shorter sleep duration (OR = 2.50, 95% CI (1.61, 3.87), *p* < 0.001). The likelihood of sleep medication use (OR = 4.50, 95% CI (1.99, 10.19), *p* < 0.001) and daytime dysfunction (OR = 2.15, 95% CI (1.31, 3.52), *p* = 0.002) was also substantially higher in this group compared to students who did not.

Irregular meal timing was linked with adverse sleep parameters, including poor subjective sleep quality (OR = 2.68, 95% CI (1.17, 6.15), *p* = 0.016) and prolonged sleep latency (OR = 2.59, 95% CI (1.26, 5.34), *p* = 0.008) compared to regular meal timing. Furthermore, students who habitually consumed heavier evening meals showed significantly increased odds of poor overall sleep quality (OR = 2.10, 95% CI (1.39, 3.15), *p* < 0.001), poor subjective sleep quality (OR = 1.65, 95% CI (1.04, 2.61), *p* = 0.033), reduced sleep efficiency (OR = 2.23, 95% CI (1.30, 3.83), *p* = 0.003), and increased sleep medication use (OR = 3.15, 95% CI (1.39, 7.13), *p* = 0.004) compared to students who did not.

Finally, consuming a meal within three hours before bedtime was associated with poor overall sleep quality (OR = 2.38, 95% CI (1.58, 3.61), *p* < 0.001), poor subjective sleep quality (OR = 2.50, 95% CI (1.58, 3.96), *p* < 0.001), prolonged sleep latency (OR = 2.02, 95% CI (1.32, 3.08), *p* = 0.001), reduced sleep duration (OR = 1.61, 95% CI (1.05, 2.48), *p* = 0.028), and reduced sleep efficiency (OR = 1.99, 95% CI (1.19, 3.31), *p* = 0.008). This eating behavior was also linked with higher odds of sleep medication

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use (OR = 2.07, 95% CI (1.02, 4.21), *p* = 0.041) and daytime dysfunction (OR = 2.14, 95% CI (1.31, 3.50), *p* = 0.002) compared to consuming the last meal more than three hours before bedtime.

Table 3. Cross-tabulation and association measures of eating habit factors with poor overall sleep and its components (OR, and 95% CI).

Eating habits	Overall sleep quality	Subjective sleep quality	Sleep latency	Sleep duration	Sleep efficiency	Sleep disturbances	Use sleep medication	Daytime dysfunction
Skipping breakfast	1.24 (0.83-1.86)	1.46 (0.93-2.30)	**1.53 (1.00-2.33)**	1.47 (0.96-2.25)	1.33 (0.80-2.21)	1.67 (0.94-2.96)	**3.12 (1.48-6.57)**	**1.67 (1.03-2.72)**
Late-night snacking	**1.59 (1.06-2.38)**	1.58 (1.00-2.50)	**1.54 (1.00-2.35)**	1.35 (0.88-2.07)	**2.10 (1.23-3.58)**	1.61 (0.89-2.90)	0.79 (0.40-1.59)	1.53 (0.93-2.51)
Replacing meals with snacks	**3.00 (1.97-4.55)**	**2.07 (1.31-3.26)**	**2.64 (1.72-4.06)**	**2.50 (1.61-3.87)**	**2.17 (1.29-3.63)**	1.63 (0.92-2.89)	**4.50 (1.99-10.19)**	**2.15 (1.31-3.52)**
Eating heavy evening meals	**2.10 (1.39-3.15)**	**1.65 (1.04-2.61)**	1.20 (0.79-1.83)	0.75 (0.49-1.15)	**2.23 (1.30-3.83)**	1.03 (0.58-1.82)	**3.15 (1.39-7.13)**	1.42 (0.87-2.32)
Irregular mealtime	1.00 (0.55-1.78)	**2.68 (1.17-6.15)**	**2.59 (1.26-5.34)**	1.54 (0.79-3.00)	1.02 (0.49-2.14)	1.66 (0.63-4.38)	1.74 (0.51-5.89)	1.39 (0.65-2.98)
Short Meal-to-Bedtime Interval (<3h)	**2.38 (1.58-3.61)**	**2.50 (1.58-3.96)**	**2.02 (1.32-3.08)**	**1.61 (1.05-2.48)**	**1.99 (1.19-3.31)**	1.67 (0.94-2.96)	**2.07 (1.02-4.21)**	**2.14 (1.31-3.50)**

This table measures the association between specific dietary habits and the Pittsburgh Sleep Quality Index (PSQI) parameters Overall sleep quality categorized into: poor overall sleep quality (Global PSQI score > 5), and good overall sleep quality (Global PSQI score≤ 5) [8];Other sleep parameters were classified into two outcomes and analyzed as a categorical variable: adequate (component score 0 or 1) and inadequate (component score 2 or 3); Values presented in **bold** indicate statistical significance at a *p*-value less than 0.05;Risk assessment and crosstabs were conducted to calculate the odds ratio (OR) and its 95% confidence interval (CI), representing the strength of these associations

Table 4 presents the relationship between dietary habits and overall sleep quality (measured by the Pittsburgh Sleep Quality Index, PSQI).

These analyses were conducted while statistically accounting for the impact of multiple demographic and lifestyle confounders, including age, sex, marital status, nationality, residential setting, academic level, academic faculty, year of study, caffeine intake, smoking status, alcohol consumption, physical activity, stress levels, napping habits, and body mass index. Multiple logistic regression analysis identified heavy evening meals (OR = 2.73, 95% CI (1.58, 4.73), *p* < 0.001), replacing meals with snacks (OR = 2.68, 95% CI (1.47, 4.90), *p* = 0.001), and consuming the last meal within three hours before bedtime (OR = 2.06, 95% CI (1.17, 3.63), *p* = 0.012) as the strongest predictors of poor sleep quality.

Table 4. Adjusted multiple logistic regression showing eating habits associated with overall poor sleep quality.

Eating habit	Odds ratio	95% CI ()	*p*-value

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Replacing meals with snacks	**2.68**	(1.47-4.90)	**0.001***
Heavy evening meals	**2.73**	(1.58-4.73)	**<0.001**
Short Meal-to-Bedtime Interval (<3h)	**2.06**	(1.17-3.63)	**0.012**
Irregular mealtime	0.58	(0.27-1.26)	0.168
Skipping breakfast	0.67	(0.39-1.15)	0.144
Late-night snacking	0.82	(0.44-1.51)	0.517

Multiple logistic regression showing dietary habits that are associated with poor sleep quality among university students, adjusted for sociodemographic and lifestyle factors (age, sex, marital status, residential setting, academic faculty, year of study, nationality, BMI, academic level, smoking, alcohol and coffee consumption, physical activity, stress level and napping frequency); CI, confidence interval;Values presented in bold indicate statistical significance at a p-value less than 0.05 ($p<0.05$)

4. Discussion

This study investigated the impact of specific unhealthy dietary behaviors on sleep quality among international university students in Pécs, Hungary. According to the findings, over half of the students surveyed experienced poor sleep quality. This aligns with previous studies noting that university students are highly prone to poor sleep habits likely due to academic stress, social pressures, irregular schedules, and lifestyle changes [34–37]. For international students, cultural adaptation, language barriers, and isolation from support systems pose additional stressors.

Notably, sex-based variations in sleep quality were observed, with female students reporting poorer sleep in comparison to male students. This is consistent with prior research in Australia (65.1% vs. 49.8%), New Zealand (63.1% vs. 44.5%) and Spain (55.7% vs. 37.0%), where female university students reported poorer overall sleep quality than males [38-40]. This may be attributed to hormonal fluctuations, a higher prevalence of anxiety and depression, and higher psychosocial stressors among female students compared to male students [41].

Differences in sleep components based on sex were also evident, with lower sleep efficiency among male students, meanwhile, female students reported substantially higher levels of daytime dysfunction. These variations underscore the need for targeted strategies to address the distinct sleep quality gaps among these groups.

In addition, this study revealed a strong association between unhealthy eating patterns and overall poor sleep quality, as indicated by multiple aspects of sleep parameters, including sleep latency, efficiency, disturbances, duration, subjective sleep quality, use of sleep medication, and daytime dysfunction.

Key dietary behaviors identified were skipping breakfast, replacing meals with snacks, late-night snacking, consumption of heavy evening meals, irregular meal timing, and a short meal-to-bedtime interval.

4.1. Meal Timing and Sleep Quality

Growing evidence increasingly highlights the important impact of chrono-nutrition on sleep quality. The results of this study further support the established relationship. Our analysis identified three independent and robust predictors of poor sleep quality: short meal-to-bedtime interval, meal replacement with snacks, and heavy evening meals. These associations persisted after adjusting for potential confounding variables, revealing their powerful impact on sleep quality.

4.1.1. Short Meal-to-Bedtime Interval

Consuming meals within three hours before bedtime was significantly and independently associated with poor sleep. This finding is corroborated by numerous studies demonstrating a negative association between excessive late-night food intake before bedtime and various sleep quality parameters [42,43]. Beyond direct sleep disruption, late eating can elevate core body temperature, potentially causing a phase delay in the circadian rhythm, which may impair sleep initiation and continuity [44]. Furthermore, ingesting food shortly before sleep can cause digestive issues, most notably gastroesophageal reflux disease (GERD), eventually impacting sleep quality. A case-control study found that a dinner-to-bed time of less than three hours was significantly associated with a 7.45-fold higher odds ratio for GERD compared to individuals who maintained at least a four-hour interval [45,46]. Collectively, these findings advocate for a minimum three-hour digestion window between the last meal and sleep onset.

4.1.2. Meal Replacement with Snacks

Substituting structured meals with snacks exhibited a strong association with poor sleep quality. This is supported by a previous cross-sectional study of 498 university students, which found that frequent meal replacement with snacks was associated with a heightened risk of experiencing poor sleep quality [30]. This phenomenon may be attributed to the typically high energy content of snacks. Research in both animal and human models suggests that elevated caloric consumption, particularly from fats, can negatively impact the expression of circadian genes, thereby compromising sleep quality [47].

Furthermore, cohort data from 27,983 American women aged 35 to 74 revealed that a lower tendency for eating during conventional mealtimes and a greater reliance on snacks over meals correlated with a higher intake of fat and sweets for energy, coupled with a lower intake of fruits and vegetables [48]. This dietary pattern can lead to deficiencies in essential nutrients vital for sleep regulation, such as tryptophan, magnesium, and zinc [49].

4.1.3. Heavy Evening Meals

Consuming heavy evening meals significantly impacted poor sleep quality, aligning with prior research. For instance, Charlotte et al. (2024) demonstrated an association between increased evening food intake and poorer sleep quality parameters [50]. Meal timing plays a crucial role as a zeitgeber (time giver) for our intricate circadian rhythms. Heavy evening meals can disrupt the synchronization between the central pacemaker, located in the suprachiasmatic nucleus, and peripheral clocks, such as those in the liver. This desynchronization can lead to metabolic disturbances and, consequently, disrupt sleep-wake cycles [51].

4.2. Other Dietary Habits and Their Associations with Sleep Components

Some dietary behaviors might not emerge as statistically significant predictors in adjusted models for overall poor sleep quality; however, cross-tabulation analyses revealed meaningful associations with individual sleep components.

4.2.1. Skipping Breakfast

While skipping breakfast wasn't a significant independent predictor of overall poor sleep in multivariate analysis, it was associated with several negative sleep-related outcomes. In particular,

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our findings indicate that skipping breakfast correlates with longer sleep latency, a higher likelihood of sleep medication use, and increased daytime dysfunction. These results align with existing research. Previous studies consistently demonstrate a strong link between breakfast skipping and poorer sleep quality components among university students [52]. A randomized crossover-design study similarly observed shorter sleep latency when breakfast was consumed among participants, suggesting improved sleep onset compared to when breakfast was skipped [53].

Daytime dysfunction often manifests as reduced cognitive performance, altered mood, decreased energy, and lower overall productivity. Similarly, a review highlighted associations between breakfast skipping and midday fatigue and mood swings, often attributed to drops in blood sugar [54], which corroborates our findings. Furthermore, college students who skipped breakfast showed significantly lower scores on cognitive tests assessing overall performance, attentiveness, response time, and alertness compared to those who regularly consume breakfast [55]. Another intervention study found that consistent breakfast consumption improved sleep quality and reduced daytime dysfunction compared to individuals who habitually skipped their meals [56].

While a direct causal link between breakfast skipping and sleep medication use has not been extensively studied, persistent sleep disturbances associated with skipping breakfast can lead individuals to seek sleep aids, thereby increasing the likelihood of sleep medication use.

Breakfast skipping is defined as the intentional or unintentional omission of breakfast at least once a week. Despite the well-established benefits of regular breakfast consumption, the high prevalence of skipping this meal remains a significant public health concern. Estimates indicate that 10-30% of children and adolescents globally skip breakfast, with this figure rising dramatically to over 50% among university students; a study in Bangladesh reported that 52.8% of university students skipped breakfast, and those with poor sleep quality were threefold more likely to skip breakfast than their peers. Moreover, female students showed a greater tendency to skip breakfast than their male counterparts, a trend potentially linked to concerns about body image and weight control [57,58].

4.2.2. Late-Night Snacking

Although the multivariate model did not identify late-night snacking as an independent predictor of poor sleep, cross-tabulation analyses revealed its association with reduced sleep efficiency and increased sleep latency. These findings align with existing literature suggesting that consuming food, including snacks late at night, increases the risk of compromised sleep quality [30].

The mechanisms underpinning this association are likely multifactorial. University students often consume highly processed, energy-dense snacks, such as chips, sweets, and confectionery [59]. These foods are easily overconsumed, leading to increased caloric and fat intake. This dietary pattern has been directly linked to poorer sleep outcomes. For instance, a clinical investigation reported a negative correlation between the intake of total, trans, saturated, and polyunsaturated fats and actigraphy-measured sleep duration [60]. Carvalho et al. (2020) showed that higher fat and carbohydrate content in meals consumed before sleep in night-shift workers prolonged sleep onset latency [61]. On the other hand, research by Bravo et al. (2012) reported that consuming a specific type of pre-sleep snack (e.g., cereals containing a higher dose of tryptophan) can shorten sleep onset, a finding that contradicts our results [62]. This emphasizes that both the composition and timing of pre-sleep food intake are fundamental determinants of its effect on sleep.

In addition to these direct physiological effects, late-night snacking may also have an indirect effect by disrupting subsequent patterns of eating, as it could lead to increased likelihood of breakfast skipping, a behavior previously identified as being associated with diminished sleep quality [63-65]. A clinical trial of 16 adults showed that sleep restriction resulted in a substantial 42% increase in post-dinner caloric consumption, specially from snacks rich in protein, carbohydrates, and fiber [66]. This increased nocturnal consumption suggests a cycle where poor sleep could drive late-night eating, and vice versa, indicating a bidirectional association.

4.2.3. Irregular Meal Timing

No statistical significance was achieved for irregular meal timing in the regression analysis; however, the consistency of the observed associations with sleep components suggests further exploration. Irregular meal timing was particularly associated with longer sleep latency and worse subjective sleep quality, which is likely due to the role regular meal timing plays in circadian rhythm synchronization [67].

Irregular mealtime patterns can cause metabolic dysregulation and circadian misalignment [68]. Supporting this, research by Hatori et al. (2012) demonstrated that irregular patterns disrupt circadian rhythms while consistent feeding schedules help entrain them [69]. Later research demonstrated a strong association between irregular meal patterns and poorer sleep quality [70]. Similarly, a previous cross-sectional study reported a significant association between irregular meal timings and longer sleep latency [30].

Several key strengths support the findings drawn from this research. First, the use of the Pittsburgh Sleep Quality Index (PSQI), a well-validated tool that evaluates several sleep parameters [8]. Second, the sample size used in this study. The large sample size reinforced the statistical power of the findings and their generalizability to university student populations. Additionally, targeting international students, a demographic that frequently experiences extreme changes in lifestyle and eating patterns, adds strong insight into the sleep issues facing this vulnerable population. Lastly, controlling key potential lifestyle and demographic confounders in multivariate regression strengthened the validity of its findings.

However, several limitations should be acknowledged. A key weakness of this study is its cross-sectional methodology, which allowed for exploring the associations between unhealthy eating behaviors and poor sleep quality, but could not establish causality. Additionally, the restricted inclusion of university students as participants limits the findings' generalizability to non-student populations. Furthermore, the study did not examine other factors that could impact sleep quality, such as environmental factors, mental health assessments, nor provide a detailed analysis of diet quality or quantity. Finally, reliance on self-reported data could introduce the potential of response and recall bias, which could compromise the accuracy of the results.

Future longitudinal designs and randomized controlled trials should consider these variables to provide a more comprehensive assessment of factors influencing sleep quality outcomes.

5. Conclusions

Unhealthy dietary habits, particularly consuming heavy evening meals, replacing meals with snacks, and a short meal-to-bedtime interval, are significantly associated with poor sleep quality among international university students.

Interventions promoting meal timing and healthier eating patterns as part of comprehensive health promotion strategies could be an effective strategy to enhance sleep quality in this population.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Supplementary material 1; Questionnaire.

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Abbreviations

The following abbreviations are used in this manuscript:

SQ	Sleep Quality
PSQI	Pittsburgh Sleep Quality Index
OR	Odds Ratio
MENA	Middle Eastern & North African
AHI	Apnea-Hypopnea Index
STROBE	Strengthening the reporting of observational studies in epidemiology
WHO	World Health Organisation
P	Population Proportion
GERD	Gastroesophageal Reflux Disease

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