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Original Article

Investigating the Relationship between Caffeine Consumption Patterns and Depression, Anxiety, Stress and Sleep in Medical Students: A Structural Equation Model

Zahra Mohammadi[1*], Farzad Ebrahimzadeh[2], Fatemeh Abdoli[3], Ali Farhadi[4], Khatereh Anbari[5], Mojgan Azizi Rad[6]

[1]Social Determinants of Health Research Center, Lorestan University of Medical Science, Khorramabad, Iran
[2]Department of Biostatistics and Epidemiology, Nutritional Health Research Center, School of Health and Nutrition, Lorestan University of Medical Sciences, Khorramabad, Iran.
[3]Department of Clinical Psychology, Faculty of Psychology and Educational Science, Allameh Tabatabaei'i University, Tehran, Iran.
[4]Department of Social Medicine. School of Medicin, Lotestan University of Medical Sciences, Khorramabad, Iran
[5]Department of Social Medicine, Social Determinants of Health Research Center, Lorestan University of Medical Science, Khorramabad, Iran
[6]Department of Psychology, Kho, C., Islamic Azad University, Khorramabad, Iran.

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Abstract

Background and Aim: Many students turn to caffeine consumption to overcome drowsiness and depression. Moreover, caffeine intake can aggravate symptoms of anxiety, which is a predictor of depression. The present study was conducted to examine the effects of caffeine, anxiety, stress, sleep disturbance, and depression on medical students.

Materials and Methods: In this cross-sectional study, 278 medical students were selected using a multi-stage random sampling method. We collected and examined various types of information, including the consumption pattern, and amount of consumption, caffeine use and measurement of depression, anxiety and stress, using demographic information questionnaires, caffeine consumption checklist, caffeine consumption disorder, Petersburg sleep disorder and depression, and anxiety as well as stress questionnaires, from the participants. Chi-square test and structural equation model under 0.05 significance level as well as SPSS version 26 and AMOS version 21 software were used for data analysis.

Results: The findings of the present study indicated that 15.9% of the participants suffered from severe or extremely severe levels of depression, and 84.2% were dissatisfied with their sleep quality. Sleep disturbance had the strongest overall and direct effect on students' depression levels. Furthermore, caffeine consumption pattern affected depression both directly and indirectly through sleep disturbance, stress, and anxiety.

Conclusion: This study showed that depression among medical students is strongly associated with reduced sleep quality, which in turn might be influenced by excessive caffeine consumption.

Keywords: Caffeine consumption patterns, Depression, Anxiety, Stress, Sleep

***Corresponding Author:** Zahra Mohammadi, Master of Clinical Psychology, Social Determinants of Health Research Center, Lorestan University of Medical Science, Khorramabad, Iran. Email : zm65mohammadi@gmail.com.
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Introduction

Caffeine is one of the most widely consumed psychoactive substances in the world, with over 80% of people using it daily as part of their diet (1). For decades, there has been an ongoing debate about whether caffeine is beneficial or harmful to human health. According to reports, up to 400 mg of caffeine per day is considered safe for adults. However, excessive consumption of caffeine, which is sometimes reported, might adversely affect health (2). Vorster *et al*. (2018) noted that the use of these stimulants generally increases in environments with high levels of stress, e.g. before undergoing examinations (3). Furthermore, Alrakaf *et al*. (2020) found that the popularity of excessive caffeine use, particularly among students, probably stems from the belief that such stimulants enhance wakefulness, energy, concentration, and ultimately academic performance (4).

Research by Shadid *et al*. (2020) and Samaha (2020) showed that medical students experience higher stress levels compared with students in other fields (5,6), and nearly one-third of medical students worldwide suffer from depression (7). Samaha *et al*. (2020), and Karpushok *et al*. (2018) found that students often resort to caffeine to overcome drowsiness (8) and depression (6). Patterns of caffeine consumption refer to the amount, timing, and sources of caffeine intake. This pattern includes daily caffeine intake measured in milligrams, frequency of consumption, sources such as coffee, tea, energy drinks, chocolate, medications, and the timing of intake throughout the day. Such patterns might also relate to behavioral habits or caffeine dependence (9).

Epidemiological studies have indicated that caffeine might act as a protective factor against depressive states (10,11), improve motivational symptoms associated with depression, and enhance the efficacy of antidepressant treatments (11,12). Wang *et al*. (2016) reported that moderate caffeine intake might be associated with reduced risk of depression (13). Grosso *et al*. (2016) also demonstrated that a daily intake of at least 90 mg of caffeine is linked to a lower risk of depression in adults (14).

While depressive disorders are classified as mood and affective disorders, certain motivational symptoms, such as a lack of energy, lethargy, fatigue, and psychomotor slowing are common in individuals with depression (15). Kim SY *et al*. (2016) found that high caffeine intake is associated with increased depression, anxiety, insomnia, and stress (16).

Anxiety is another factor affecting the lives of students due to workload or individual as well as environmental factors. Evidence suggests that anxiety is a major predictor of depression, as approximately 90% of patients with anxiety disorders also experience comorbid depression (17). Developmentally, anxiety disorders almost always precede depression and typically begin in childhood or adolescence (18). Furthermore, caffeine consumption has a bidirectional relationship with anxiety symptoms. On the one hand, caffeine intake increases symptoms of anxiety (19); while on the other hand, individuals with anxiety disorders often exhibit heightened sensitivity or adverse reactions to caffeine (20). Liu *et al*. (2024) noted that caffeine intake is linked to an increased risk of anxiety even in otherwise healthy individuals without psychiatric disorders (19).

As mentioned above, students often use caffeine to combat drowsiness, but longitudinal studies have identified insomnia as an independent risk factor for the onset or recurrence of depression (21). Sleep disturbance is among the most prominent symptoms in patients with depression. This reciprocal relationship between sleep disorders and depression has led to a new perspective in which sleep issues are no longer considered merely an initial symptom of depression but rather a predictor (22, 23). In practice, students tend to rely on stimulants to maintain alertness and consequently increase their caffeine intake (24,25,26). Users might perceive fatigue as a sign of needing more stimulants, but evidence suggests that caffeine, rather than enhancing the performance, simply restores the function impaired due to drowsiness (27).

A review of the literature reveals inconsistencies. On the one hand, caffeine consumption appears to alleviate certain symptoms, particularly motivational symptoms of depression; while on the other hand, it might induce or exacerbate anxiety symptoms and negatively affect sleep quality as well as quantity. Many studies have shown that both anxiety and sleep disturbances are

significant predisposing factors for the development of depression. Therefore, the potential negative outcomes and side effects of stimulant use might outweigh its short-term benefits. Consequently, reduction of stimulant use might be a more sustainable approach to cognitive enhancement (24). Given the high prevalence of caffeine consumption among medical students and the existing contradictions in the literature on this topic, this study aimed to investigate and clarify the relationship between patterns of caffeine use and depression, anxiety, stress, and sleep among this population.

Materials and Methods

In this descriptive-analytical cross-sectional study, the statistical population consisted of all medical students of Lorestan University of Medical Sciences who were enrolled during the 2021-2022 academic year. According to the statistics provided by the university's education department, there were 1, 111 medical students actively studying at that time. The initial sample size was estimated at approximately 198 students, based on a pilot sample of 30 participants and the formula was:

$$n = \left| \frac{Z_{1-\alpha/2} + Z_{1-\beta}}{\frac{1}{2}\ln\frac{1+r}{1-r}} \right|^2 + 3$$

where $\alpha = 0.05$, $1-\beta = 0.80$, and **r** (the correlation coefficient between caffeine use disorder scores and depression scores on the DASS questionnaire) ≈ 0.196. Ultimately, taking into account the design effect, the final sample size was increased by 40%, resulting in a total of 278 participants.

Sampling Method

A multistage sampling method—combining stratified random sampling and cluster sampling—was employed in this study. First, strata were defined based on academic year. Within each stratum, several clusters (admission years) were identified. Then, two admission years from each stratum were randomly selected by systematic random sampling. Subsequently, a census approach was used within each selected admission year, enrolling all available students. Questionnaires were distributed in person by the research team, and the students were asked to complete them independently (self-administered).

Demographic Information Questionnaire

This researcher-developed questionnaire was designed to systematically collect individual demographic data, including age, gender, perceived economic status, employment status, years of study, and tobacco/hookah use.

Caffeine Consumption Checklist

The caffeine consumption checklist contained questions regarding patterns and amounts of caffeine use. It assessed the timing and frequency of consumption for 16 caffeinated products available in Iran (tea, green tea, Turkish coffee, French press coffee, mocha, espresso, instant coffee, Nescafé, hot chocolate, carbonated soft drinks, energy drinks, chocolate milk, chocolate-flavored milk, chocolate cookies, chocolate, and dark chocolate). This checklist was developed with input from a nutritionist, a university psychology faculty member, an addiction specialist, and a marketer in caffeinated products. Asgari *et al*. (2024) reported the checklist's validity and reliability coefficients as 0.85 and 0.77, respectively (16). In the present study, the checklist was administered to 287 participants, yielding a Cronbach's alpha of 0.88, which demonstrates good reliability (28).

Pittsburgh Sleep Quality Index (PSQI)

Developed by Buysse *et al*. in 1989 at the University of Pittsburgh, the PSQI is a self-report questionnaire that assesses sleep quality and disturbances over a 1-month interval, with total scores ranging from 0 to 21, where higher scores indicate more severe sleep problems. The PSQI evaluates seven components, i.e. subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, the use of sleep medication, and daytime dysfunction. Each component is scored on a 4-point Likert scale. The PSQI has demonstrated good internal consistency, validity, and reliability (29). In an international sample, Grandner *et al*. (2006) reported a Cronbach's alpha of 0.80 on a group of 112 participants (53 young and 59 older adults) (30). The scale's content validity has been confirmed, and in Iran, Kakouei *et al*. (2010) found a Cronbach's alpha of 0.83 in a sample of 110 professional drivers in Tehran (31).

Depression, Anxiety, and Stress Scale (DASS-21)

The DASS-21, developed by Antony *et al*. in 1998 (32), is a 21-item self-report measure in which respondents rate the frequency and severity of symptoms over the

past week using a 4-point Likert scale (0=did not apply to me at all; 3 = applied to me very much, or most of the time). The scale comprises three subscales, i.e. depression, anxiety, and stress. Psychometric evaluations have indicated high convergent and divergent validity and internal consistency (33). Correlations have been reported as follows: DASS depression with beck depression inventory = 0.70; DASS anxiety with zung anxiety scale = 0.67; DASS stress with the perceived stress scale = 0.49 (34). For Iranian samples, Cronbach's alpha coefficients have ranged from 0.85 to 0.94 (35).

Statistical Analysis

In the present study, a total of 278 participants were included, with a mean age of 23.10 ± 3.73 years (ranging from 18 to 41 years). Descriptive statistics were presented using frequency distribution tables, along with frequency and percentage indices. To examine the relationship between the dependent variable (level of depression) and demographic as well as contextual variables, the Chi-square test of independence was employed. Multivariate data modeling was conducted using structural equation modeling (SEM). To assess multivariate normality, Mardia's test was utilized, while Mahalanobis distances were employed to identify multivariate outliers. All the statistical analyses and description stages were performed using IBM SPSS Statistics version 26 and AMOS version 21, with a significance level set at 0.05.

This study was approved by the Ethics Committee of Lorestan University of Medical Sciences, Lorestan, Iran (Approval Code: IR.LUMS.REC.1402.002). The project identification code is 2837. Written informed consent was obtained from all the participants prior to their inclusion in the study.

Results and Discussion

In the present study, 278 individuals participated, with a mean age of 23.10 ± 3.73 years (ranging from18 to 41 years). The largest proportion of the participants belonged to the 18–24 age group (73.4%, n = 204). Regarding gender, females comprised the majority (n=145, 52.2%). In terms of marital status, most of the participants were single (n = 219, 78.8%). Concerning the use of anti-anxiety or antidepressant medications, the majority reported not using such medications (n=252, 90.6%). Similarly, in the subscale of cigarette or other substance use, most of the participants were non-users (n = 254, 91.4%).

Descriptive statistics were presented using frequency distribution tables, and frequency as well as percentage indices. The relationship between the dependent variable (level of depression) and demographic/background variables was assessed using the Chi-square test of independence. Multivariate data modeling was performed using structural equation modeling (SEM). Multivariate normality was evaluated with the Mardia test, and outliers were identified using Mahalanobis distance. All the statistical analyses and descriptions were conducted using IBM SPSS version 26 and AMOS version 21, with a significance level set at 0.05. As it has been indicated, detailed descriptive statistics for depression, anxiety, stress, and sleep disturbances have been provided separately in Table 1.

Table 1. Description of Depression, Anxiety, Stress, and Sleep Disorders.

Variable Name	Category	Frequency	Percentage
Depression	Normal	168	60.4%
	Mild	27	9.7%
	Moderate	39	14.0%
	Severe	23	8.3%
	Very Severe	21	7.6%
Anxiety	Normal	180	64.7%
	Mild	22	7.9%
	Moderate	36	12.9%
	Severe	16	5.8%
	Very Severe	24	8.6%
Stress	Normal	181	65.1%
	Mild	24	8.6%
	Moderate	32	11.5%
	Severe	25	9.0%
	Very Severe	16	5.8%
Sleep Quality Status	Adequate	44	15.8%
	Inadequate	234	84.2%

In the present study, the proportions of students with normal levels of depression, anxiety, and stress were 60.4% (n = 168), 64.7% (n = 180), and 65.1% (n = 181), respectively. However, 84.2% of students experienced poor sleep quality. The highest levels of sleep disturbance were observed in sleep duration (87.4%) as well as the participants' overall self-assessment of sleep quality (84.2%). In contrast, the lowest rates of sleep

Table 2. Description of Sleep Quality Status and Its Subscales in the Participants.

Variable	Category	Frequency	Percentage
Overall Sleep Quality Description	Normal Sleep	44	15.8%
	Mild Problems	169	60.8%
	Moderate Problems	57	20.5%
	Severe Problems	8	2.9%
Sleep Latency	Normal Sleep	62	22.3%
	Mild Problems	120	43.2%
	Moderate Problems	64	23.0%
	Severe Problems	32	11.5%
Sleep Duration	Normal Sleep	35	12.6%
	Mild Problems	124	44.6%
	Moderate Problems	70	25.2%
	Severe Problems	49	17.6%
Sleep Efficiency	Normal Sleep	217	78.1%
	Mild Problems	36	12.9%
	Moderate Problems	9	3.2%
	Severe Problems	16	5.8%
Sleep Disturbances	Normal Sleep	53	19.1%
	Mild Problems	192	69.1%
	Moderate Problems	30	10.8%
	Severe Problems	3	1.1%
Sleep Medication Use	Normal Sleep	242	87.1%
	Mild Problems	21	7.6%
	Moderate Problems	10	3.6%
	Severe Problems	5	1.8%
Daytime Dysfunction	Normal Sleep	105	37.8%
	Mild Problems	100	36.0%
	Moderate Problems	55	19.8%
	Severe Problems	18	6.5%
Sleep Quality Status	Adequate	44	15.8%
	Inadequate	234	84.2%

(12.9%), and sleep adequacy (21.9%). Each dimension of sleep quality has been detailed separately in Table 2.

Table 3 presents the results of the structural equation modeling (SEM) examining the relationships between depression, anxiety, stress, sleep disturbances, and the frequency of caffeine consumption. The mean frequency of caffeine consumption was 207.73 (SD=249.36). Notably, based on the Caffeine Withdrawal Symptoms Questionnaire, 16.2% of the participants (n=45) met the criteria for caffeine withdrawal symptoms in the absence of caffeine consumption. After identifying outliers according to the Mahalanobis distance, the sample size was reduced from 278 to 266. Moreover, multivariate normality was assessed and confirmed using the Mardia test (P<0.001, c.r. = 1.725). Table 4 includes model fit indices before and after removing the items (tea and green tea), demonstrating that overall model fit was acceptable, good, or in some cases, excellent (36).

Table 4 shows the standardized factor loadings for the items included in the structural equation model. Refer to Figure 1 for more details on the direct coefficients. According to the SEM, the predictor variables depicted in the conceptual model (Figure 1) accounted fgor approximately 94.6% of the variance in depression scores among the participants (R^2 = 0.946). The conceptual model and direct effects of each subcomponent have been illustrated in Figure 1.

Based on the Structural Equation Model (SEM) results, the predictor variables included in the conceptual model (Figure 1) accounted for approximately 94.6% of the variance in participants' depression scores (R^2 = 0.946). The conceptual model, illustrating the direct effects of each sub-construct within the model, has been presented in Figure 1.

According to Table 5, the largest indirect effect on depression was attributable to stress (0.684), followed by anxiety (0.190) and then sleep disturbances (0.174). The greatest direct effect on depression was associated with sleep disturbances (0.749), occurring primarily

Table 3. Model Fit Indices for Structural Equation Modeling of Various Constructs.

Condition	χ^2/df	p-value	RMR	GFI	NFI	CFI	PNFI	PCFI	RMSEA	p-close
Before Item Removal	1.451	<0.001	0.095	0.796	0.739	0.899	0.676	0.823	0.041	>0.999
After Item Removal	1.488	<0.001	0.090	0.803	0.753	0.901	0.706	0.820	0.043	0.998
Interpretation	Good		Acceptable	Good	Acceptable	Excellent	Acceptable	Good	Excellent	

Table 4. Standardized Factor Loadings in Structural Equations.

Path	Standardized β	p-value
Frequency of Use → Sleep Disorder	-0.144	0.058
Sleep Disorder → Stress	0.870	<0.001
Frequency of Use → Anxiety	-0.016	0.727
Stress → Anxiety	0.748	<0.001
Sleep Disorder → Anxiety	0.164	0.322
Anxiety → Depression	0.190	0.048
Sleep Disorder → Depression	0.174	0.197
Stress → Depression	0.684	<0.001
Frequency of Use → Depression	0.061	0.093

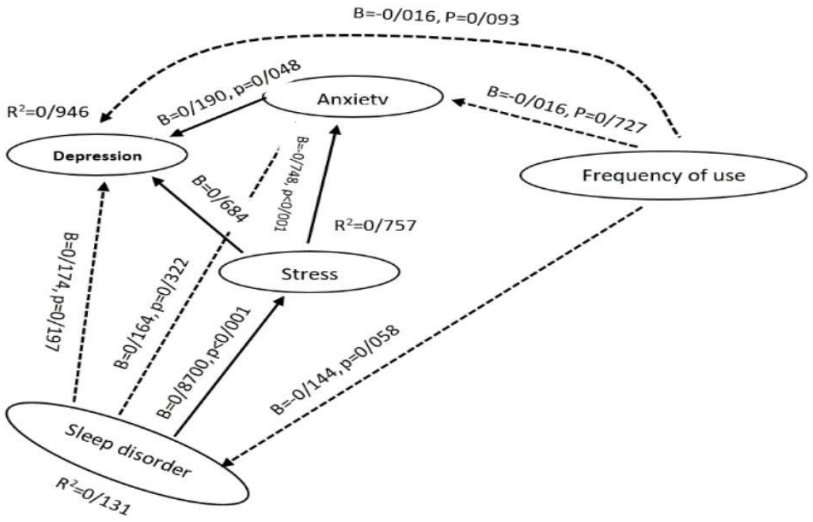

Figure 1. Conceptual Model with Estimated Path Coefficients from Structural Equations.

through the pathways of sleep disturbances → stress → depression or sleep disturbances → stress → anxiety → depression. The second most significant direct effect on depression was related to the frequency of caffeine consumption (0.061), which mainly influenced depression via the pathways of frequency of consumption → sleep disturbances → stress → depression, or frequency of consumption → sleep disturbances → stress → anxiety → depression. Overall, the largest total effects on depression were observed for sleep disturbances (0.924), followed by stress (0.826).

The present study was conducted to investigate the relationship between caffeine consumption patterns and depression, anxiety, stress, and sleep in medical students. The findings revealed that 15.9% of participating students suffered from severe or extremely severe levels of depression, with sleep disturbances (0.924) exerting the strongest overall and direct effect on depression among the students. After sleep disturbances, depression was indirectly influenced by stress (0.826). The frequency of caffeine consumption also indirectly affected depression, primarily through its impact on sleep disturbances.

Table 5. Model Fit Indices for Structural Equation Modeling of Various Constructs.

Variable	Direct Effect	Indirect Effect	Total Effect
Frequency of Use	0.061	0.136	0.075
Sleep Disorder	0.174	0.749	0.924
Stress	0.684	0.142	0.826
Anxiety	0.190	-	0.190

The results of this study indicated that the greatest indirect effects on depression were attributed to stress (0.684), followed by anxiety (0.190), and then sleep disturbances (0.174). The strongest direct effect on depression came from sleep disturbances (0.749), through the pathways of sleep disturbances → stress → depression or sleep disturbances → stress → anxiety → depression.

A significant proportion of the participants, i.e. 84.2% of the students, were dissatisfied with their sleep quality, and over 87% reported dissatisfaction with their sleep duration. A review of 57 studies on the sleep quality of medical students found that dissatisfaction with sleep quality was more common among medical students (65.13%) compared with students in other fields (23.9%) (37), making it the most prevalent sleep disturbance component (38). Poor sleep quality can stem from issues such as anxiety, depression, and stress (39), or be influenced by the demanding curriculum and heavy workload of medical studies. Importantly, poor sleep quality can negatively impact academic performance, mental health, and quality of life among these students (41). Sleep disturbances are also

associated with demographic characteristics, sociocultural factors, lifestyle, tobacco and alcohol use, and even students' GPA. Identification of these factors can inform more effective interventions and the allocation of appropriate health resources. To mitigate the adverse outcomes of poor sleep quality, education about the consequences, regular sleep monitoring, and adherence to sleep hygiene should become routine among medical students (37).

This study also showed that 14.8% of the students experienced severe or extremely severe levels of stress, and after sleep disturbances, stress (0.826) had the second strongest effect on depression. Moreover, it was observed that the frequency of caffeine consumption could also indirectly impact depression through the disruption of sleep quality. Although no significant direct relationship was found between depression and caffeine consumption frequency, a significant indirect association was observed. This finding is in line with other research indicating that caffeine consumption is linked to impaired functioning, poorer sleep quality, the use of certain other substances, and increased depression, anxiety, as well as stress (42). Previous studies have demonstrated that depression can be related to dietary factors (43,44). While the literature reports mixed results regarding the association between caffeine consumption and depression—with some studies suggesting a positive relationship (45), and others a negative one (46,47)—recent analyses examining the dose-response relationship suggest that consuming less than 68 mg of caffeine per day might reduce the risk of depression by 8% for each cup of coffee, but higher caffeine intake leads to a nonlinear association and an increased risk of depression (48).

Conclusion

The present study had several limitations. Although efforts were made to include participants from all groups and academic years, the sampling method and the study's cross-sectional nature limited the generalizability of the findings to all medical students. Longitudinal research is needed to examine the persistence of these symptoms and the potential functional impairments over time. Furthermore, the study tools used brief self-report assessments of the studied variables, owing to the need for brevity. Future research is required to utilize alternative methodologies and larger sample sizes, including experimental tools, in order to yield more comprehensive findings.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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