



Investigating the Role of Sleep Problems, Emotional Impulsivity, and Hot and Cold Executive Functions in Students with Attention-Deficit/Hyperactivity Disorder Symptoms in Zanjan City, Iran

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Abstract

Background: Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by inattention, hyperactivity, and impulsivity. The condition arises due to an imbalance in neurotransmitters and abnormal activity in certain parts of the brain. In children, it typically manifests as difficulty concentrating and hyperactive behavior, while in adults, it presents as poor time management and distractibility.

Objectives: The present study aimed to investigate the role of sleep problems, emotional impulsivity, and cold and warm executive functions (EFs) in explaining ADHD symptoms among students in Zanjan, Iran, in 2024.

Methods: To conduct this cross-sectional study, 170 students from Islamic Azad University-Zanjan Branch were selected through convenience sampling, of which 118 completed the questionnaires. The data collection tools included the Barkley Deficits in Executive Functioning Scale (BDEFS), Adult ADHD Self-report Scale (ASRS), Pittsburgh Sleep Quality Index (PSQI), and Impulsive Behavior Scale (UPPS). After collecting the questionnaires, their raw findings were extracted and then analyzed using SPSS software (version 26).

Results: The results of the present study showed that sleep problems had a significant relationship with ADHD ($R = 0.46$; $R^2 = 0.21$; $F = 567.49$; $P < 0.01$). Additionally, emotional impulsivity components, including perseverance, urgency, and sensation seeking, were able to predict ADHD symptoms ($R^2 = 0.33$; $R^2_{adj} = 0.31$; $F = 19.04$; $P < 0.01$). Furthermore, two components of EFs, namely "time self-management" and "emotional self-regulation", significantly explained nearly half of the variance in ADHD symptoms ($R^2 = 0.52$; $R^2_{adj} = 0.51$; $F = 63.22$; $P < 0.01$).

Conclusions: The findings of the study indicate that sleep problems, emotional impulsivity, and EFs play a significant role in the development of ADHD symptoms. Accordingly, it can be said that weaknesses in EFs and poor sleep quality are among the most important factors associated with the severity of the symptoms of this disorder. These results can be used in the design of psychological interventions and preventive strategies for students with ADHD symptoms.

Keywords: Mental Disorders, Attention Deficit/Hyperactivity Disorder, Sleep Quality, Emotional Impulsivity, Executive Functions

1. Background

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder that the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), defines as "a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development". The disorder is

characterized by persistent symptoms of inattention (such as difficulty organizing tasks and being easily distracted) and/or hyperactivity/impulsivity (such as fidgeting and talking excessively) that cause significant impairment in functioning (1). These symptoms can persist into adulthood (2). The prevalence of ADHD in adults varies from 0.6% to 7.3% in different countries (3) and is estimated to affect 2% to 8% of students in the

United States (4). In recent years, an increase in the prevalence of ADHD symptoms among students has been reported (5). In Iran, the prevalence of this disorder has been reported to be 72.8% on average (6), and its academic prevalence is estimated to be between 2% and 8% (7). Students, especially as a significant subgroup of adults, are at high risk for a wide range of psychological problems. Depression, anxiety, decision-making problems, smoking, and ADHD symptoms are among the most common reasons for referral to psychologists in this group. The importance of these findings is due to the association of these problems with academic performance and quality of life for students (8).

One potential contributor to ADHD is sleep disturbance, which is common in adults with the disorder, with a prevalence ranging from 31% to 56% in the general population (9). Inattention, as a core symptom of ADHD, is closely related to insomnia, and these disorders are often associated with circadian rhythm deficits and nocturnality (8, 9). Sleep deprivation likely affects cognition by causing instability in attentional networks (10), increased global signal variability, and impaired frontal functions (11-13), thereby exacerbating a wide range of ADHD symptoms (14). Because ADHD is associated with processing instability (15) and reduced top-down control in the frontal lobes even after normal sleep, individuals with ADHD are unlikely to be able to fully compensate for the effects of sleep deprivation (11). Therefore, sleep disturbances can exacerbate ADHD symptoms, and in some cases, ADHD symptoms may be caused by chronic sleep disturbances (14). These hypotheses are largely supported by cross-sectional studies that show that poor sleep is associated with lower performance on tests of executive function (EF) in ADHD (16). In addition, interventional findings also suggest that sleep restriction has a greater effect on EF in individuals with ADHD than in controls (17).

Another contributing factor to ADHD is emotional impulsivity, which refers to a person's tendency to react strongly to emotional states without sufficient thought. Barkley's research has shown that emotional impulsivity is as important as the two traditional dimensions of ADHD and is also associated with disorders beyond these two traditional dimensions. The severity of sleep disturbance can lead to numerous problems in the areas of work, education, criminality, driving, and finances that go beyond the classic symptoms of ADHD (18). This feature may lead to immature behavior and poor decision-making in various situations. Furthermore, the

interaction between sleep problems and emotional impulsivity in students with ADHD can cause more serious problems in social and academic interactions (5). Barkley emphasizes that emotional impulsivity is one of the key factors that exacerbates the challenges faced by adults and students with ADHD. Accordingly, emotional self-regulation is considered a core component of ADHD, and therapeutic interventions should focus on improving emotional control to reduce impulsivity and improve the individual's overall functioning (19). The ADHD is a heterogeneous disorder that is associated with a range of cognitive problems, including impairments in EFs, delay avoidance, reward sensitivity, and temporal information processing (16).

Modern approaches in the field of neuropsychology consider ADHD to be caused by a deficiency in the EFs of the brain. The EFs include a set of cognitive, emotional, and motor abilities, such as self-monitoring, planning, organization, reasoning, mental flexibility, and problem-solving. These skills guide how individuals organize their daily lives, plan, and execute activities (20).

The prefrontal cortex plays a key role in EFs. With over 30 sub-structures of EFs, their precise definition is difficult due to their breadth and complexity. The EFs can be divided into two distinct components: "Cold" and "hot", each of which links different cognitive pathways to the core symptoms of ADHD. Failure to properly manage sleep, impulsivity, and EF problems can lead to future psychological and social problems, including depression, anxiety, and reduced quality of life (21). Therefore, identifying and investigating these factors is essential to prevent future negative outcomes.

2. Objectives

The present study aimed to investigate the role of sleep problems, emotional impulsivity, and cold and warm EFs in explaining ADHD symptoms among students in Zanjan, Iran, in 2024.

3. Methods

3.1. Sampling and Study Design

The present study was descriptive-correlational and had a fundamental nature in terms of purpose. The statistical population included all students in Zanjan, Iran, in the academic year 2024, and the sample size was calculated based on a statistical power of 0.8 and an effect size of 0.3 using G*Power software, equivalent to

84 people. Considering the possibility of defects or errors in completing the questionnaires, twice the estimated sample size (equal to 170 people) was selected, and finally, 118 questionnaires were eligible for analysis. Students were selected through convenience sampling, and only those who met the inclusion criteria for the study were included. After obtaining informed consent from the participants, data were collected using four different questionnaires. The questionnaires were initially provided to the students as an online link, and those students who scored more than 4 in section (A) of the Adult ADHD Self-report Scale (ASRS) and scored more than 24 in total, and who also met the inclusion criteria, were included in the study. To maintain the confidentiality of information, identification codes were used instead of participants' names, and finally, the data were analyzed using SPSS software (version 26).

3.2. Inclusion and Exclusion Criteria

Inclusion criteria included (A) an age range of 18 to 40 years, (B) having symptoms of ADHD, (C) not having a severe psychiatric or physical disorder, (D) informed consent to participate in the study, and (E) not having a history of substance abuse. Exclusion criteria included (A) not consenting to continue cooperation during the research process and (B) incomplete response to the questionnaires.

3.3. Data Collection Tools

3.3.1. Barkley Deficits in Executive Functioning Scale

It is designed to assess EFs in adults, especially those with attention deficit/hyperactivity disorder, and consists of 89 questions. This Self-report Scale can be used for individuals aged 18 to 81 years and has five subscales, including time management (21 questions), self-organization and problem-solving (24 questions), self-control (19 questions), self-motivation (12 questions), and emotional self-regulation (13 questions). Higher scores on each subscale indicate greater impairment in the relevant EFs. This scale is easy to use, and the average response time is between 15 and 20 minutes. The psychometric properties of this scale have been examined for use in the Iranian population by Mashhadi et al. (22). The correlations of the total score with the subscales of time self-management, self-organization/problem-solving, self-control/inhibition, self-motivation, and emotional self-regulation were 0.89, 0.90, 0.84, and 0.83, respectively, all of which are significant at the 0.001 level. In addition, Cronbach's

alpha coefficients for the above-mentioned subscales were reported to be 0.926, 0.936, 0.911, 0.908, and 0.875, respectively (22).

3.3.2. Adult Attention-Deficit/Hyperactivity Disorder Self-report Scale

This scale was designed by Adler et al. in collaboration with the World Health Organization and consists of 18 questions based on the diagnostic criteria of DSM-5 (23). In this scale, the first 9 questions are related to attention problems, and the second 9 questions are dedicated to hyperactivity-impulsivity symptoms. Each question assesses the severity of an ADHD symptom over the past 6 months, and the participant specifies its severity on a five-point Likert scale (including "never", "rarely", "sometimes", "often", and "always"), which is assigned a score of 0 to 4, respectively. In each subscale, scores of 0 to 16 indicate a low probability of having ADHD, 17 to 23 a probability of having ADHD, and a score of 24 and above indicates a high probability of having ADHD. Although this questionnaire has not been standardized in Iran, its internal validity coefficient was determined by Kessler et al., who reported its reliability between 0.63 and 0.72 and its test-retest reliability (Pearson correlation) between 0.58 and 0.77 (24).

3.3.3. Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) is a self-report instrument developed by Buysse et al. (1989) at the Pittsburgh Psychiatric Institute (25). The questionnaire consists of nine main questions, but since the fifth question itself has ten sub-items, the questionnaire has a total of 19 items, which are scored on a four-point Likert scale from 0 to 3. The PSQI has seven subscales, including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The internal consistency of this scale, based on Cronbach's alpha coefficient, was reported to be 0.83, with the highest coefficient related to the subjective sleep quality and habitual sleep efficiency subscales (0.76) and the lowest coefficient related to sleep disturbances (0.35). In addition, the test-retest reliability of this questionnaire has been reported to be 0.85 (25).

3.3.4. Impulsive Behavior Scale

The Impulsive Behavior Scale (UPPS) was developed in a study by Lynam and Whiteside (2001) (26) to measure the construct of emotional impulsivity. This self-report

questionnaire consists of 45 items and identifies four different types of impulsive behavior. Responses are scored on a four-point Likert scale, and examples include questions such as “Sometimes when I feel bad, I can’t stop what I’m doing, even if it makes me feel worse” and “When I’m upset, I often act without thinking.” The subscales of this questionnaire are: Impulsive behavior, sensation seeking, continuous performance, and premeditation. The impulsive behavior subscale is associated with the neuroticism impulsivity dimension of the five-factor model of personality and can be associated with negative emotions such as anger, anxiety, or depression. Psychometric studies have confirmed the reliability and validity of this scale, and its reliability has been reported to be 0.88 based on Cronbach's alpha coefficient (26-30).

3.4. Statistical Analysis

The collected data were analyzed using SPSS software (version 26). The normality of the data was checked using the Kolmogorov-Smirnov test. Linear regression was used to analyze the relationships between variables, and analysis of covariance (ANCOVA) was used to examine the hypotheses and control for confounding variables. The use of the above-mentioned statistical tests at a significance level ($\alpha = 0.05$) allowed for a detailed examination of the role of independent variables, including sleep problems, emotional impulsivity, and cold and warm EFs, in predicting ADHD symptoms.

4. Results

As can be seen in Table 1, the independent variables, including EFs, sleep problems, and emotional arousal that were included in the regression analysis, were able to explain nearly 50% of the variance in ADHD symptoms ($R^2 = 0.55$; adjusted $R^2 = 0.54$). An examination of the adjusted R^2 shows that if the explained variance is generalized to the real population, this value will be equal to 0.54. Based on the findings presented in Table 2, among the predictor variables, only the variables “executive functions” and “sleep problems” were able to significantly predict ADHD symptoms ($P < 0.05$), while the variable “emotional arousal” did not show a significant effect ($P > 0.05$). According to the standardized beta (β) coefficients, it was found that EFs ($\beta = 0.64$) play a greater role in predicting ADHD symptoms than sleep problems ($\beta = 0.41$); in other words, for every one standard deviation change in each

of the predictor variables, ADHD symptoms increase by β .

Table 1. Summary of the Regression Model Between Sleep Problems, Emotional Impulsivity, and Executive Functions in Predicting Attention-Deficit/Hyperactivity Disorder

Regression Model Factors	R	R ²	Adjusted R ²	R ² Changes	Df-1	Df-2	Significance of F Changes	Durbin-Watson
Value	0.74	0.55	0.54	0.55	3	114	0.001	2.12

Abbreviation: DF, degree of freedom.

Table 2. Standardized Regression Coefficients in Predicting Attention-Deficit/Hyperactivity Disorder Symptoms

Variables	B	β	t	P	T	VIF	ANOVA	
							F	P-Value
EFs	0.18	0.64	9.17	0.001	0.80	1.24		
Emotional impulsivity	-0.08	0.10	1.57	0.119	0.96	1.04	4.89	0.001
Sleep problems	0.24	0.41	2.83	0.005	0.78	1.27		

Abbreviations: T, tolerance; VIF, variance inflation factor; EFs, executive functions.

Considering the significance level and regression indicators, it can be concluded that there is a significant correlation between sleep problems and ADHD symptoms ($P < 0.01$; $F = 567.49$; $R^2 = 0.21$; $R = 0.46$). Examination of the standardized coefficients shows that for every unit of change (one standard deviation) in sleep disorders, ADHD symptoms increase by 0.46 (Table 3).

Table 3. Summary of Regressions Between Sleep Problems and Attention-Deficit/Hyperactivity Disorder Symptoms with Standardized Beta Coefficients

Variable	B	β	t	T	VIF	F	F Changes	R	R ²	R ² Changes
Model	0.55	0.46	5.63	1	1	567.49	31.69	0.46	0.21	0.21

Abbreviations: T, tolerance; VIF, variance inflation factor.

Based on the results of stepwise regression, it was observed that among the independent variables, including foresight, sensation seeking, persistence, and urgency, only the components of persistence, urgency, and sensation seeking were able to predict ADHD symptoms at a significant level ($P < 0.01$; $F = 19.04$; $R^2 = 0.31$; $R^2_{adj} = 0.33$). Other variables, such as foresight, were removed from the model due to their weak role in predicting ADHD symptoms. Examination of the standard beta coefficients shows that among the predictor variables, persistence ($\beta = -0.42$) has the

Table 4. Overall Regression Indices for Predicting Attention-Deficit/Hyperactivity Disorder Symptoms Based on Arousal

Step-by-Step Models	B	β S-	t	T	VIF	F	F Changes	R	R ²	Adjusted R ²	R ² Changes
1						34.16	34.16	0.47	0.22	0.22	0.22
Perseverance	-1.04	-0.47	-5.48	1	1						
2						24.93	12.35	0.55	0.30	0.29	0.07
Perseverance	-0.79	0.36	-4.27	1.17	0.84						
Urgency	0.48	0.29	3.51	1.17	0.84						
3						19.04	5.37	0.57	0.33	0.31	5.37
Perseverance	-0.93	-0.42	-4.86	0.76	1.30						
Urgency	0.42	0.25	3.02	0.81	0.23						
Searching for emotion	0.28	0.18	2.31	0.89	1.11						

Abbreviations: T, tolerance; VIF, variance inflation factor.

largest negative contribution and has a more prominent role in predicting ADHD symptoms than urgency ($\beta = 0.25$) and sensation seeking ($\beta = 0.18$, Table 4).

As shown in Table 5, among the independent variables of EFs, only two components, including "time self-management" and "emotion self-regulation", were able to significantly predict nearly half of the variance of ADHD symptoms ($P < 0.01$; $F = 63.22$; $R^2 = 0.52$; $R^2_{adj} = 0.51$). Other components of EFs, including "self-organization", "self-control/inhibition", and "self-motivation", were removed from the equation due to their weak role in prediction. Examination of the standard regression coefficients shows that among the significant predictor components, time self-management ($\beta = 0.43$) has the highest contribution in predicting ADHD symptoms, followed by emotion self-regulation ($\beta = 0.37$). Overall, the analyses conducted show that there is a relationship between EFs, sleep problems, and emotional arousal with ADHD symptoms. In addition, EFs and sleep problems explain a significant portion of the variance of the criterion variable.

5. Discussion

The findings of this study show that there is a significant relationship between sleep problems and ADHD symptoms in students. Based on regression analysis and significance indices, sleep problems are significantly correlated with the severity of ADHD symptoms. These results are consistent with the studies of Cassoff et al. (31), Derakhshanpour et al. (32), Voinescu et al. (33), and Wynchank et al. (9). In explaining these findings, it can be argued that sleep, as one of the effective internal factors, plays an important role in the cognitive functions of people with ADHD and those who

show severe ADHD features. The impact of sleep is mainly due to the negative effects of sleep deprivation on cognitive abilities (34, 35). Sleep deprivation can affect cognitive abilities by creating instability in attentional networks, increasing variability in overall brain signals (10), and disrupting frontal lobe functions (11). These mechanisms contribute to the development of a wide range of ADHD symptoms (14). Given that ADHD itself is associated with cognitive instability even under normal sleep conditions (15) and reduced hierarchical control in frontal regions (36), full compensation for the effects of sleep deprivation is very limited, and sleep disturbances can exacerbate the severity of ADHD symptoms. The findings also support the hypothesis that in some cases, ADHD symptoms may be fundamentally caused by chronic sleep disturbances. Cross-sectional studies have shown that poor sleep quality is associated with poorer EF in people with ADHD, and intervention studies have also suggested that the effects of sleep restriction on EF are more severe in this population than in the general population (16).

In addition, the regression results showed that among the four independent variables, including forethought, sensation seeking, persistence, and urgency, three components – persistence, urgency, and sensation seeking – were able to significantly predict ADHD symptoms. This finding indicates that sensitivity to immediate stimuli, desire for experience, and a stable level of persistence are among the key indicators in explaining the symptoms of this disorder. These results are consistent with the research of Rasoulmahin et al. (37), Barkley and Fischer (2010) (18), Rosen and Factor (2015) (38), and Arianakia and Hasani (2014) (39). In explaining this issue, emotional impulsivity refers to a behavioral pattern characterized by rapid and intense emotional fluctuations in response to pleasant or

Table 5. Overall Regression Indices for Predicting Attention-Deficit/Hyperactivity Disorder Symptoms Based on Executive Functions

Step-by-Step Models	B	β S-	t	T	VIF	F	F Changes	R	R ²	Adjusted R ²	R ² Changes
1						88.08	88.08	0.65	0.43	0.42	0.43
Self-management of time	0.77	0.65	9.38	1	1						
2						63.22	22.23	0.72	0.52	0.51	0.09
Self-management of time	0.51	0.43	5.51	0.65	1.52						
Self-regulation of emotion	0.47	0.37	4.71	0.65	1.52						

Abbreviations: T, tolerance; VIF, variance inflation factor.

unpleasant stimuli and is usually manifested through repeated irrational reactions to emotional situations (40). In the ADHD population, this phenomenon often manifests itself in the form of immersion in negative emotions such as anger, frustration, boredom, or intense longing. These individuals often lack effective emotion regulation mechanisms that allow for the modulation or substitution of adaptive responses. As a result, there is a tendency to display strong emotional reactions, such as shouting or verbal aggression, especially in family interactions and close interpersonal relationships (38).

The results of the study also showed that there is a significant relationship between hot and cold EFs and ADHD symptoms in students. In other words, weaknesses in these functions can lead to the development of ADHD symptoms. This finding is consistent with the studies of Ghamarigivi (2009) (41), Poon (2018) (42), Heshmati et al. (43), Ganjei and Hashemi (2020) (44), Rasoulimahin et al. (37), Pimenta et al. (45), and Jang et al. (46). In explaining these findings, it can be said that patients with ADHD have major deficits in EFs; the most observed disorders are related to working memory for task determination, response inhibition, insomnia, and planning (47). Also, interference control, which is a key component of inhibitory functions, plays a crucial role in maintaining goal-directed behaviors and is considered equivalent to sustained attention according to Barkley's theory. In this framework, attention deficits appear as a secondary consequence of dysfunction in EFs. In other words, weaknesses in behavioral inhibition and self-control impair effective regulation, and impulsive behaviors serve as a direct sign of this dysfunction (44). Research in the field of neuroscience shows that the neural mechanisms associated with attentional control and working memory in ADHD have structural overlap. A study by Burgess et al. (48) showed that these two cognitive functions depend on common neural

networks, including the dorsolateral prefrontal cortex (DLPFC) in both hemispheres of the brain, which plays a key role in the pathophysiology of ADHD. Reduced activity in the left DLPFC is associated with impaired retention of information necessary for performing cognitive tasks (49).

5.1. Conclusions

Based on the findings of the present study, it can be concluded that sleep problems, emotional impulsivity, and EFs play a significant role in the development of symptoms of ADHD. Accordingly, it can be said that weaknesses in EFs and poor sleep quality are among the most important factors associated with the severity of symptoms of this disorder. These results can be used in the design of psychological interventions and preventive strategies for students with ADHD symptoms. In addition, the findings of this study suggest that multidimensional interventions, including improving sleep hygiene, emotional regulation training, and rehabilitation of EFs, can be useful in reducing the level and severity of ADHD symptoms.

5.2. Limitations

Two limitations of the present study can be mentioned: First, the samples were limited to Zanjan students, which limits the generalizability of the results to other groups. Second, the use of a self-report instrument may have led to bias in the responses. It is suggested that future research should include other non-student groups and use alternative instruments, such as interviews, to increase the generalizability of the results.

Footnotes

Authors' Contribution: A. Y. participated in study design, data collection, writing and revision of the

original and revised manuscript, and data analysis. R. Z. participated in study design, supervision, investigation, methodology, project administration, and data curation.

Conflict of Interests Statement: The authors declare no conflict of interest.

Data Availability: The dataset presented in the study is available on request from the corresponding author during submission or after publication.

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Informed Consent: Verbal and written consent were obtained from the parents of the participants for their participation in the present study.

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