

Neurobiological Correlates of Depression and Sleep Quality and Their Impact on Academic Performance Among Adolescents

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Abstract

Background: Adolescence marks a vital developmental period which brings about substantial brain development and psychological changes with rising rates of depression and sleep disorders among teenagers have become a serious issue because these conditions can harm their academic achievements.

Purpose: The present study aimed to examine the relationship between depression, sleep quality, and academic performance among adolescents from a neurobiological perspective.

Methods: The researcher selected a sample of 30 adolescents who included 15 males and 15 females through random sampling and used the Beck Depression Inventory (BDI) to assess depression and the Pittsburgh Sleep Quality Index (PSQI) to evaluate sleep quality.

Results: The study showed that participants experienced moderate depression ($M = 22.75$, $SD = 4.05$) and they showed poor to moderate sleep quality ($M = 18.60$, $SD = 3.90$). The study showed that students achieved average academic performance ($M = 68.20$, $SD = 6.10$). The study found a significant negative relationship between depression and academic performance ($r = -0.52$) and between sleep quality and academic performance ($r = -0.48$). The study established a positive relationship between depression and sleep quality ($r = 0.55$) which showed that higher depression levels result in worse sleep patterns.

Conclusion: The study shows that sleep quality and depression levels both impact academic performance for adolescent students. Mental health and sleep problems need treatment through combined neurobiological and psychological treatment methods to improve academic performance of students.

Keywords: Neurobiological, Depression, Sleep quality, Academic Performance.

Introduction

Adolescent development involves a time of unique and rapid physical, emotional, cognitive and neurobiological growth ^[1]. At this time, the brain experiences significant structural and functional maturation, especially in areas related to executive functioning, emotional regulation and decision making ^[2]. The prefrontal cortex, which regulates higher-order thinking, develops in the long run across the adolescent years, whereas structures in the limbic system that regulate emotions mature earlier ^[3]. This developmental shift makes adolescents more likely to experience a range of psychological challenges, such as depression and sleep problems, which can impact their schoolwork and well-being ^[4].

Depression is one of the most common mental health problems seen among adolescents globally. The World Health Organization (WHO ^[5]) confirms depression is one of the main causes of illness and disability in young people, affecting their social, emotional and academic functioning. Depression is defined by a chronic state of sadness, lack of interest or drive to do anything, feeling hopeless and having problems concentrating ^[6]. According to cognitive theories of depression, depressed people tend to have negative thinking patterns that lead to emotional problems and lowered cognitive functioning ^[7]. The neurobiological evidence also suggests that the anterior cingulate cortex, hippocampus and amygdala are structurally and functionally abnormal in depressed youth ^[8, 9]. Along with this, changes in the functioning of neurotransmitter systems, such as serotonin, dopamine and norepinephrine, have been associated with depressive symptoms and problems with attention, motivation and academic engagement ^[10].

Another important factor that plays a role in adolescent development and academic performance is sleep quality. Regular, uninterrupted sleep is vital for cognitive function, emotional balance and well-being ^[11]. Most of these changes in sleep are related to biological changes in the circadian rhythm during adolescence, the academic and other social demands, and the excessive use of electronic devices ^[12]. These are often responsible for sleep loss and poor sleep quality among adolescents. Poor sleep has been shown to affect attention, working memory, executive functioning, and emotional regulation, all of which are important for effective learning and academic success ^[13]. In addition, adolescents often experience delayed sleep-wake rhythms, which can interfere with the school's early start time, leading to chronic sleep deficits that negatively impact school performance ^[14].

Numerous studies that have shown that there is a strong relationship between sleep and depression, one that is present in both directions ^[15, 16]. The sleep problems tend to occur before depressive symptoms and may be a risk factor for depression earlier than depressive symptoms ^[17]. However, insomnia, hypersomnia, and alterations in sleep architecture are often associated with depression and this relationship can feed into a vicious cycle, maintaining psychological distress and impairing cognitive function ^[18]. Uy and Gotlib ^[19] have shown that sleep problems in adolescence are associated with an increased risk of depressive disorders later in life. There is evidence of neurobiological mechanisms that may be shared by both conditions, including abnormalities in emotional processing networks, neurotransmitter imbalances, and stress response system abnormalities ^[20].

Cognitive function (attention, memory, information processing and executive control) is the basis for academic success. These deficits in cognitive domains independently relate to depression and poor sleep quality ^[21]. Metz et al. ^[22] suggest that when adolescents report increased depressive symptoms, they tend to have decreased attention, slower information processing and problem-solving skills. The same is true for school, where sleep loss has been linked to reduced motivation to learn, less interest in school, and poor examination results ^[23]. Therefore, the co-occurrence of depression and poor sleep quality could significantly impair students' educational performance.

Adolescent development, from a neuro-development standpoint, can be seen as a disruption of the equilibrium between the fast maturing limbic system and the relatively immature prefrontal cortex ^[24]. Such developmental mismatches lead to heightened emotional reactivity, impulsivity, and susceptibility to psychological disorders. Moreover, recent studies of neuroimaging have found that emotional out-of-control behavior linked to depression has been found to disrupt neural mechanisms that support learning and school functioning ^[25].

Synaptic plasticity, memory consolidation and learning processes are also deeply related to sleep. While sleeping, new memories are consolidated and become part of the network of long-term memory ^[26]. These neurobiological processes are impaired by sleep deprivation, causing impaired retention and effective application of learned knowledge ^[27]. There are functional neuroimaging studies that show that inadequate sleep has been associated with decreased activation of the prefrontal cortex, and impaired communication between the cortex and the subcortical regions, which leads to poor attention, decision-making and executive functioning ^[10, 15].

Sleep quality and depression are not only behaviorally linked; they are also neurobiologically linked. A key mechanism is the disruption of the hypothalamic-pituitary-adrenal (HPA) axis, the system that controls the body's stress response ^[14]. With depressive symptoms and chronic stress comes higher levels of cortisol that have a detrimental effect on sleep quality, memory formation, and cognitive functioning ^[17]. Furthermore, inflammatory processes have been identified as significant factors in depression and sleep problems. Adolescent mood dysfunction, fatigue, cognitive disturbances, and sleep disturbances have been associated with higher levels of pro-inflammatory cytokines ^[20].

The relationship between depression, sleep quality, and academic performance is further influenced by environmental and social factors. Emotional distress and sleep-related problems can be caused by academic rigors, peer relationships, family dynamics, socioeconomic status, and exposure to adverse life events ^[22]. Bronfenbrenner's theory of the ecological systems stresses that the development of the adolescent is influenced by a number of interwoven and complex environmental influences on mental health and educational outcomes ^[17]. Hence, a biopsychosocial approach is necessary to understand academic performance.

Recent intervention studies have indicated that sleep hygiene and depression symptomology interventions can greatly impact adolescents' cognitive functioning and academic performance ^[18]. School-based mental health programs, cognitive behavioral therapy (CBT) and sleep education interventions have shown to be beneficial for emotional wellbeing and sleep quality and academic outcomes ^[9]. Early detection and intervention of depression can have a positive impact on adverse outcomes for brain functioning and educational outcomes to encourage more positive developmental outcomes ^[10].

Although there is an increasing body of evidence that links sleep quality, depression and academic outcomes, additional research is warranted to better understand the neurobiological mechanisms that underlie and explain these relationships. The overlapping role of depression and sleep dysfunction in adolescents on academic outcomes could yield important information for developing an integrated prevention and intervention program. The present study, thus, seeks to examine the linkage between depression, sleep quality and academic performance in adolescents, with a specific focus on the neurobiological mechanisms involved in these associations. This study will bring together psychological and neurobiological concepts, and thus, enhance understanding of factors related to adolescent academic achievement and mental health.

Material and Methods

The present study used a quantitative research design which included descriptive and correlational components to investigate how depression and sleep quality affect academic performance in adolescents. The design was suitable because it enabled researchers to conduct systematic variable measurement which resulted in data that showed how different variables interacted with each other. The research study includes a neurobiological element because it interprets research results through the mechanisms that connect Circadian Rhythm disruptions to their effects on Cognitive Function.

Sample

The present study examined 30 teenagers who participated as a sample, which included 15 male and 15 female participants from local educational institutions. This paper used a random sampling method to provide all study participants with an equal opportunity for selection. The sample maintained uniformity because all participants shared the same age range and educational level. The purpose was explained to all participants who provided answers that remained confidential.

Instruments

Depression Scale

The Beck Depression Inventory (BDI) developed by Aaron Beck ^[28] serves as the measurement tool for assessing depression symptoms in adolescents. The scale consists of a series of items that assess the presence and severity of depressive symptoms such as sadness, pessimism, loss of interest, and fatigue. The scoring system for each item operates on a scale which produces a total score that shows the depressive level from minimal to severe. The BDI test shows strong reliability and validity for multiple user groups including adolescent users.

Sleep Quality Scale

The Pittsburgh Sleep Quality Index (PSQI) was developed by Daniel Buysse ^[29] to measure sleep quality. The instrument evaluates multiple sleep parameters which include sleep duration and sleep latency and sleep disturbances and overall sleep quality assessment. The system evaluates sleep quality through its multiple elements which produce a combined score that indicates increased sleep impairment with higher results. The PSQI serves as an established assessment tool that possesses strong measurement reliability and validity and researchers commonly use it for sleep studies.

Academic Performance Measure

Students' academic performance evaluation used their latest exam results and their academic records, which showed the percentage of marks they achieved. The scores functioned as a precise measurement tool which allowed assessment of the participants' educational attainment. Higher scores reflected better academic performance.

Procedure

The researcher executed the data collection process through established procedures. The researchers obtained official permission from the relevant educational authorities before conducting their study. The research team entered classroom spaces to inform students about the study's objectives and its importance. The study provided definite guidelines which participants needed to follow when answering the questionnaires. The study participants received assurance that their answers would remain confidential which encouraged them to provide truthful answers. The researcher conducted the questionnaire assessment while allowing participants enough time to finish their tasks. The researcher obtained academic performance data from school records after receiving proper authorization. The researcher prepared all collected responses for analysis through a detailed process.

Statistical Analysis

Descriptive statistics, which included the calculation of mean and standard deviation, provided a summary of depression levels and sleep quality and academic performance in adolescents. The study used Pearson's correlation coefficient to assess the relationships between the different variables.

Results

Table 1 reveals the descriptive statistics of the variables included in study. The mean score of depression ($M = 22.75$, $SD = 4.05$) shows a moderate level of depressive symptoms among adolescents. The mean sleep quality score ($M = 18.60$, $SD = 3.90$) evaluates the poor to moderate sleep quality. The mean academic performance ($M = 68.20$, $SD = 6.10$) concludes an average level of academic achievement in the participants of study.

Table 1: Descriptive Statistics of Depression, Sleep Quality, and Academic Performance (N = 30)

Variable	N	Mean	Standard deviation
Depression	30	22.75	4.05
Sleep quality	30	18.60	3.90
Academic Performance	30	68.20	6.10

Table 2 represents the correlation analysis among the variables. A moderate negative correlation ($r = -0.52$) was seen between depression and academic performance, reflecting that higher depression is linked with lower academic performance. Sleep quality also reveals a negative correlation ($r = -0.48$) with academic performance, evaluating that poorer sleep quality results in lower academic performance.

Also, a positive correlation ($r = 0.55$) between depression and sleep quality reveals that higher levels of depression are connected with poorer sleep patterns. These results are in line with the stated hypotheses and shows that both depression and sleep quality affect academic performance among adolescents.

Table 2: Correlation between Depression, Sleep Quality, and Academic Performance (N = 30)

Variables	r-value
Depression and academic performance	-0.52
Sleep quality and academic performance	-0.48
Depression and sleep quality	0.55

Hypotheses Testing

The study tested its hypotheses through Pearson's correlation coefficient tests, which analyzed the relationships between depression and sleep quality and academic performance in adolescents who participated in the study ($N = 30$). The study results showed that depression and academic performance had a moderate negative relationship which produced a correlation coefficient of ($r = -0.52$). As adolescent depression levels rise their academic performance decreases according to this finding. The first hypothesis, which stated that depression and academic performance have a significant relationship has now been proven true.

The research found that sleep quality directly affects academic performance through a negative relationship which shows that students with poor sleep patterns will experience lower academic success ($r = -0.48$). Students who experience sleep disturbances or insufficient sleep will show decreased ability to focus their memory and learning skills which will lead to negative academic performance results. The second hypothesis which states that sleep quality and academic performance have a significant relationship has been proven true. The analysis discovered a positive link between depression and sleep quality which showed that adolescents with more severe depression experienced greater sleep problems. The research demonstrates how psychological and physical factors interact because increased depressive symptoms lead to sleep problems which create subsequent sleep disturbances. The third hypothesis which stated that depression and sleep quality would show a significant relationship between these two variables has been proven to be correct.

The hypothesis testing results demonstrate that depression and sleep quality have a major effect on academic performance for adolescents. The research results show that both psychological factors and biological factors which include Circadian Rhythm disruptions and their impact on Cognitive Function need to be studied for academic achievement.

Discussion

This paper investigated how depression and sleep quality impact academic results in adolescents through the study of their brain biology. The research established that both depression and sleep quality have a strong connection to academic results, which supports existing studies ^[30, 31].

The research results showed that depression negatively impacts academic performance because increased depressive symptoms result in decreased academic success. The study confirms previous research which shows that depression disrupts attention and memory and executive functioning to create negative academic effects for students ^[32]. The neurobiological research shows that depressive symptoms cause brain area dysfunction which includes the prefrontal cortex and hippocampus because these areas are essential for learning and memory ^[33]. The brain functions of adolescents get impaired because adolescents need to concentrate and perform academic work ^[28].

The research showed that sleep quality negatively impacts academic performance because students with sleep issues experience academic difficulties. The research findings receive strong support from earlier studies. Research indicates that adolescents who experience sleep problems show decreased alertness and mood changes and drop in academic performance ^[29]. According to research findings, students who sleep less than required time show decreased cognitive abilities and need help academically ^[16]. The discoveries reveal how Circadian Rhythm interruptions create brain function disturbances which hinder learning development ^[19].

The research found that depressed adolescents experience worse sleep problems, which creates a link between depression and sleep issues. Multiple studies support this finding because they demonstrate how sleep and depression create a two-way relationship. Research indicates that sleep deprivation makes adolescents more susceptible to depression while depression causes more severe sleep disturbances ^[34]. The relationship between poor sleep quality and depressive symptoms demonstrates a strong connection between these two elements according to other research studies ^[35].

The research publishes its findings through a strong neurobiological framework which supports the results. Sleep deprivation causes major mental health issues for adolescents according to studies which show that it leads to depression and cognitive function problems ^[36]. Neuroscientific studies demonstrate that insufficient sleep hinders brain development while it disrupts learning processes which ultimately results in poorer academic outcomes ^[37]. The research demonstrates that sleep functions as a vital element for maintaining optimal Cognitive Function during the process of adolescent development ^[38].

The study results support theoretical models which show how sleep, depression and academic performance interconnect with each other. Research shows that poor sleep results in lower alertness levels while it increases emotional distress which then leads to academic performance decline. Academic stress together with poor performance creates a loop which leads to sleep disturbances and depressive symptoms ^[33].

The present study results find strong support from existing research while they demonstrate that researchers must investigate both psychological and neurobiological factors to understand adolescent academic performance.

Conclusion

The current research investigated how depression and sleep quality and academic performance among adolescents with depression. The results showed that depression and sleep quality both acted as major components that affected students' academic performance. Students who displayed greater depressive symptoms managed to achieve lower academic results, while students with sleep problems experienced similar academic performance decline. The relationship between depression and sleep disturbances showed strong connection between these two factors which scientists find to be interconnected.

Scientific research has linked these results to fundamental brain processes. The Circadian Rhythm face disruptions which result in reduced alertness and learning capacity and entire brain system failures. Depression leads to Cognitive Function impairments that affect crucial academic abilities such as attention and memory and executive functioning skills. The combination of these elements results in decreased academic outcomes for students.

The research demonstrated that psychological factors and physical development needs both require equal focus during adolescent development process. The implementation of mental health education together with sleep improvement methods will create a positive impact on students' academic results and their overall health.

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Authorship Contribution

Vishal Dogra contributed to study design, data collection, analysis, and manuscript writing. Dr. Archana Mishra supervised the study and reviewed the manuscript.

ICMJE Statement

All authors meet the ICMJE criteria for authorship and approve the final manuscript and form has been filled accordingly.

Ethical Statement

Ethical principles in accordance with the Declaration of Helsinki were followed. Informed consent was obtained from all participants, and confidentiality was maintained.

Patient Consent

Informed consent was obtained from all participants involved in the study.

Conflict of Interest

The authors declare no conflict of interest.

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