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RESEARCH ARTICLES

Sleep Quality, Physical Activity, and Burnout with Short-Term Memory among Medical Students

Kualitas Tidur, Aktivitas Fisik, dan Burnout dengan Memori Jangka Pendek pada Mahasiswa Kedokteran

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Abstract

Short-term memory serves as a temporary information storage system and plays a crucial role in supporting the learning processes of medical students. This study aimed to examine the association between sleep quality, physical activity, and burnout with short-term memory among medical students. An analytical observational design with a cross-sectional approach was applied, and 284 medical students from the Faculty of Medicine, Universitas Muhammadiyah Surakarta were selected using a proportionate stratified random sampling technique. Data collection was conducted using validated questionnaires (Pittsburgh Sleep Quality Index, Global Physical Activity Questionnaire, and Maslach Burnout Inventory-Student Survey) and the Scenery Picture Memory Test (SPMT). Data were analyzed using descriptive statistics, Chi-square tests, and robust Poisson regression to identify factors independently associated with short-term memory. The results showed that the majority of students (53.2%) had good short-term memory. Bivariate analysis indicated that sleep quality (p = 0.028), physical activity (p = 0.046), and burnout (p = 0.015) were significantly associated with short-term memory. However, robust Poisson regression analysis revealed that only burnout remained significantly associated with short-term memory (p = 0.022). The pseudo R-square value of 0.060 indicated limited explanatory power of the model, suggesting that other unmeasured factors may also contribute to short-term memory performance. Short-term memory in medical students is influenced by multiple factors, with burnout identified as the main determinant. Therefore, the prevention and management of burnout should be prioritized, along with the adoption of healthy sleep patterns and regular physical activity to support cognitive health and academic performance.

Keywords: burnout, physical activity, sleep quality, short-term memory

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Abstrak

Memori jangka pendek berfungsi sebagai sistem penyimpanan informasi sementara dan memainkan peran penting dalam mendukung proses pembelajaran mahasiswa kedokteran. Penelitian ini bertujuan untuk menganalisis hubungan antara kualitas tidur, aktivitas fisik, dan burnout dengan memori jangka pendek pada mahasiswa kedokteran. Penelitian ini menggunakan desain observasional analitik dengan pendekatan cross-sectional dan melibatkan 284 mahasiswa Fakultas Kedokteran Universitas Muhammadiyah Surakarta yang dipilih menggunakan teknik proportionate stratified random sampling. Pengumpulan data dilakukan menggunakan kuesioner yang tervalidasi (Pittsburgh Sleep Quality Index, Global Physical Activity Questionnaire, dan Maslach Burnout Inventory-Student Survey) serta Scenery Picture Memory Test (SPMT). Analisis data menggunakan statistik deskriptif, uji Chi-square, dan regresi Poisson robust untuk mengidentifikasi faktor-faktor yang berhubungan secara independen dengan memori jangka pendek. Hasil penelitian menunjukkan bahwa sebagian besar mahasiswa (53,2%) memiliki memori jangka pendek yang baik. Analisis bivariat menunjukkan bahwa kualitas tidur (p = 0,028), aktivitas fisik (p = 0,046), dan burnout (p = 0,015) berhubungan signifikan dengan memori jangka pendek. Namun, analisis regresi Poisson robust menunjukkan bahwa hanya burnout yang tetap berhubungan signifikan dengan memori jangka pendek (p = 0,022). Nilai pseudo R-square sebesar 0,060 menunjukkan kemampuan prediksi model yang terbatas, mengindikasikan bahwa faktor-faktor lain yang tidak diukur juga dapat memengaruhi memori jangka pendek. Memori jangka pendek pada mahasiswa kedokteran dipengaruhi oleh berbagai faktor, dengan burnout sebagai faktor penentu utama. Oleh karena itu, pencegahan dan penanganan burnout perlu diprioritaskan, disertai penerapan pola tidur yang sehat dan aktivitas fisik yang teratur untuk mendukung kesehatan kognitif serta performa akademik.

Kata Kunci: *aktivitas fisik, burnout, kualitas tidur, memori jangka pendek*

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Highlight:

- Cognitive Behavioral Play Therapy (CBPT) improved emotion regulation in children with ADHD.
- CBPT helped children recognize, express, and manage emotions more adaptively through structured play activities.
- CBPT can be integrated into school-based psychological and nursing services to support emotional development in children with ADHD.

INTRODUCTION

Short-term memory is defined as memory that receives information temporarily for about fifteen to thirty seconds. If this information is not repeated, it will gradually disappear (Alzuhra, 2024). Short-term memory capacity makes an important contribution to the effectiveness of learning mechanisms among medical students, particularly in acquiring new information, integrating clinical skills, and supporting long-term memory performance (Lienardy et al., 2021). Adequate short-term memory capacity is a key component of success in medical education, as limitations in this

cognitive function may reduce learning efficiency and impair accurate clinical decision-making (Azzam and Easteal, 2021). Globally, memory-related problems among young individuals remain prevalent, affecting approximately 10.7% of the youth population worldwide. In Indonesia, national data reported that 6.1% of adolescents experienced memory disturbances in 2021 (UNICEF, 2021). This condition is further supported by findings indicating that more than half of medical students demonstrated poor short-term memory performance (Hasibuan et al., 2024).

Sleep quality is a crucial factor affecting cognitive function, especially short-term memory. The sleep quality of medical students tends to be lower compared to students from other study programs, which can negatively impact academic performance, mental and physical health, and general well-being (Rao et al., 2020). Previous studies have reported a significant association between poor sleep quality and decreased short-term or working memory performance (Hasibuan et al., 2024; Xie et al., 2019). However, other studies have failed to demonstrate a significant association, demonstrating inconsistent findings regarding the effect of sleep quality on short-term memory (Febrian et al., 2021; Pöhlchen et al., 2021).

Physical activity is widely acknowledged as a significant determinant of cognitive performance, particularly short-term memory. Nevertheless, medical students frequently encounter difficulties in achieving the recommended levels of physical exertion, primarily due to the rigorous demands of their academic schedules (Aritonang et al., 2022). National health survey data in Indonesia reported that approximately 40% of individuals aged 20-24 years engage in low levels of physical activity. Several studies have found a link between physical activity and short-term memory ability. These findings underscore the premise that the intensity of bodily movement directly contributes to the operational efficiency of human memory (Andayani and Nugraha, 2020; Zhao et al., 2024). However, other research have reported no significant association, suggesting that the role of physical activity in short-term memory remains inconclusive (Nadira and Daulay, 2022; Loprinzi, 2019).

Burnout is a common condition among medical students and is frequently accompanied by psychological distress due to prolonged academic stress (A'yunin et al., 2023). This condition is characterized by emotional exhaustion and a high level of cynicism (Vincenzo et al., 2024). Accumulating empirical evidence suggests a strong link between burnout and cognitive impairment, particularly deficits in memory functioning.[18] However, contrasting evidence indicates that burnout may not significantly affect short-term memory, highlighting ongoing debate regarding its cognitive impact (Cortés-Álvarez et al., 2024).

The research gap in the existing literature is the limited simultaneous analysis of sleep quality, physical activity, and burnout in a single analytical model to determine their influence on short-term memory among medical students, particularly in the Indonesian context. This study is important because medical students face high academic pressure, increasing their vulnerability to sleep disturbances, physical inactivity, and burnout, all of which can simultaneously impact cognitive function, particularly short-term memory (Almarzouki, 2024; Gavelin et al., 2022). The novelty of this study lies in the simultaneous analysis of these three factors using robust Poisson regression to identify the most dominant determinant of short-term memory among medical students at Universitas Muhammadiyah Surakarta. This study differs from previous studies that primarily examined these factors separately or without multivariate analysis. Therefore, this study aims to examine the association of sleep quality, physical activity, and burnout with short-term memory among medical students.

METHODS

The method used in this study is an analytical observational study with a cross-sectional design to measure the prevalence of a phenomenon or condition. The target population consisted of medical students at Universitas Muhammadiyah Surakarta, spanning the academic cohorts of 2022, 2023, 2024, and 2025. The inclusion of the 2025 cohort is justified as data collection was conducted from November to December 2025, by which time these students had completed at least one semester of academic activities and were considered active students. To achieve a reliable estimate, the minimum sample size was derived in accordance with predefined statistical assumptions relevant to the study design. The Slovin formula was used for sample size calculation with a 10% dropout rate, based on the assumption of finite population sampling for descriptive-analytic studies. However, the use of this formula is acknowledged as a limitation, and future studies are recommended to use more advanced sample size formulas for analytical studies. This approach aimed to strengthen the statistical validity of the results and ensure the representation of each stratum (2022-2025 classes). Therefore, this study determined a sample of 284 subjects who were divided proportionally according to the number of students in each class using the proportionate stratified random sampling technique. The study took place in late 2025, specifically from November to December.

The inclusion criteria for this study encompassed active medical students who voluntarily consented to participate. All participants were required to provide a signed letter of voluntary intent as formal verification of their voluntary involvement, were students from the 2022, 2023, 2024, and 2025 cohorts, and were in good physical, mental, and social health. Exclusion criteria included students with a history of neurological disorders, severe mental illness, recent serious physical injury, use of medications that affect cognitive function or sleep quality, and those who were unwilling or absent during data collection.

Data were collected using validated questionnaires and a cognitive performance test. Data acquisition regarding sleep quality involved the administration of the Pittsburgh Sleep Quality Index (PSQI). This approach was utilized to derive global sleep scores, ensuring a reliable categorization of sleep quality among the medical students, a validated tool that assesses seven domains of sleep over a one-month interval. The PSQI instrument exhibited acceptable internal coherence across the composite score with a Cronbach's alpha coefficient value of 0.83, as well as high stability in test-retest reliability ($r = 0.85$) (Carpi, 2025). Participants were categorized based on their global PSQI scores, with values exceeding 5 identifying poor sleepers and scores of 5 or below reflecting good sleep quality (Jia et al., 2019). The PSQI instrument validated in the Indonesian context has an adequate reliability value of a Cronbach's alpha of 0.72 and for each item ranges between 0.69–0.72. Furthermore, statistical analysis revealed significant associations between individual component scores and the overall global score, confirming its psychometric robustness (Setyowati and Chung, 2021).

The Global Physical Activity Questionnaire (GPAQ) is a research instrument used to measure an individual's level of physical activity in daily life, consisting of 16 items. This standardized metric was employed to derive metabolic equivalent (MET) values for each respondent. This instrument has demonstrated robust reliability ($\kappa = 0.67$-0.73) and acceptable concurrent validity when compared to accelerometer data

and IPAQ measurements (r = 0.226-0.672) (Abduloh et al., 2025; Panthoja and Wibowo, 2022; Ribeiro et al., 2024). Total physical activity was quantified in MET-minutes per week and subsequently dichotomized into two categories comprising active participants (≥600 MET-minutes/week) and inactive participants (<600 MET-minutes/week) (Mengesha et al., 2019). To measure academic burnout, this study utilized the Maslach Burnout Inventory-Student Survey (MBI-SS), which comprises 15 items. Responses are measured using a seven-point scale reflecting frequency (0 = never; 6 = every day) to evaluate core burnout components, specifically emotional exhaustion, depersonalization/cynicism, and reduced academic efficacy (Olson et al., 2025). The results of the reliability test showed that the EX, CY, and RAE subscales had good internal consistency (α = 0.84; 0.87; 0.88) and high test-retest reliability (r = 0.86; 0.91; 0.89; $p < 0.001$) (Sahanaya et al., 2025; Wickramasinghe et al., 2018). The Indonesian version showed acceptable construct validity and reliability (Cronbach's α = 0.756) (Sahanaya et al., 2025). Burnout was defined using the exhaustion + 1 criterion (EX >14 combined with CY >6 or RAE ≤22). [29] The Scenery Picture Memory Test (SPMT) served as the primary metric for quantifying short-term memory capacity, a visual memory assessment in which participants were asked to observe an image containing 23 objects for one minute, followed by a distraction task, and subsequently recall as many objects as possible within three minutes. A score of ≥12 was categorized as good short-term memory, while a score <12 indicated poor performance (Az Zahra et al., 2023). The SPMT has demonstrated good psychometric properties, with sensitivity of 84.4%, specificity of 90.7%, and high test-retest reliability (r = 0.898) (Krisnanda et al., 2020; Takechi and Dodge, 2010).

Data acquisition was performed once for each subject and subjected to univariate, chi-square, and multivariable analysis using robust Poisson regression to obtain Adjusted Prevalence Ratio (PR), maintaining a statistical significance threshold of $p < 0.05$. The dependent variable (short-term memory) was coded as 1 = poor and 0 = good. Independent variables were coded as follows: sleep quality (1 = poor, 0 = good), physical activity (1 = inactive, 0 = active), and burnout (1 = burnout, 0 = no burnout). This coding scheme was applied consistently throughout the analysis to ensure accurate interpretation of the Adjusted PR values. Potential confounding variables, including age, gender, and academic year, were controlled for in the multivariate model through simultaneous entry into the regression equation. The limited pseudo R-square value was acknowledged and discussed as an indication of the model's explanatory power.

This study was carried out in accordance with recognized ethical guidelines and was formally approved by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Muhammadiyah Surakarta (No. 5965/B.1/KEPK-FKUMS/XI/2025), and documented informed consent was secured from all individuals prior to enrollment.

RESULTS AND DISCUSSIONS

Subject characteristics

This study was conducted at Universitas Muhammadiyah Surakarta from November to December 2025. The total sample consisted of 284 subjects who satisfied the established eligibility criteria. The baseline characteristics and demographic distribution of the study population are summarized in Table I. This table provides a comprehensive overview of the participant profiles relevant to the current analysis. As

shown in the table, regarding the gender distribution, a significant majority of the participants were female (72.9%), whereas males accounted for the remaining 27.1% of the total sample. In terms of age distribution, the vast majority of subjects fell within the 19–21 year old bracket, accounting for 72.9% of the total sample. This concentration reflects the typical age of students in the middle years of medical school. In terms of class, the majority of subjects came from the class of 2025 (27.8%), followed by the class of 2024 (25.4%), the class of 2023 (24.6%), and the class of 2022 (22.2%). This finding indicates that the study subjects were predominantly female students in early adulthood, with a relatively even distribution across academic cohorts.

Table 1. Characteristics of subjects

Characteristics	n	%
Gender		
Male	77	27.1
Female	207	72.9
Age		
16-18 years	53	18.7
19-21 years	207	72.9
22-25 years	24	8.5
Class		
2022	63	22.2
2023	70	24.6
2024	72	25.4
2025	79	27.8

Sumber: Data primer, 2025

Short-term memory and health-related variables

Based on Table 2, the majority of participants demonstrated good short-term memory, with 151 students (53.2%), while 133 students (46.8%) were classified as having poor short-term memory. These findings indicated that more than half of the participants exhibited adequate short-term memory performance, although a substantial proportion showed impaired short-term memory. Based on sleep quality categories, 149 students (52.5%) were classified as having poor sleep quality, while 135 students (47.5%) reported good sleep quality. As shown in Table 2, more than half of the participants were physically inactive, totaling 153 students (53.9%). In terms of burnout, the majority of students were not classified as burned out, with 251 students (88.4%), whereas 33 students (11.6%) experienced burnout. These findings suggest that although most students did not experience burnout, a substantial proportion reported poor sleep quality and insufficient physical activity, which may contribute to cognitive and academic challenges among medical students.

Tabel 2. Memori jangka pendek dan variabel terkait kesehatan

Variable	n	%
Short-term memory		
Good (≥12)	151	53.2
Poor (<12)	133	46.8
Kurang baik (<12)	133	46,8
Kualitas tidur		
Baik (≤5)	135	47,5

Variable	n	%
Buruk (>5)	149	52,5
Aktivitas fisik		
Aktif (≥600 MET-menit/minggu)	131	46,1
Tidak aktif (<600 MET-menit/minggu)	153	53,9
Burnout		
Burnout (kriteria *exhaustion + 1*: EX >14 disertai CY >6 atau RAE ≤22)	33	11,6
Tidak *burnout*	251	88,4

Source: Primary data, 2025

Bivariate analysis of sleep quality, physical activity, and burnout in relation to short-term memory

The bivariate analysis presented in Table 3 reveals a statistically significant association between sleep quality and short-term memory performance (p = 0.028). A positive trend was observed where individuals with favorable sleep quality demonstrated enhanced short-term memory capacity compared to those reporting sleep disturbances. These findings suggest that sleep adequacy is a potential determinant of cognitive efficiency. Physical activity was also significantly associated with short-term memory (p = 0.046), indicating that physically active students were more likely to exhibit good short-term memory than inactive students. In addition, a significant relationship was observed between burnout and short-term memory (p = 0.015), suggesting that students who experienced burnout were more likely to have poorer short-term memory performance than those without burnout. A statistically significant correlation between short-term memory, sleep quality, physical activity, and burnout was identified at the bivariate level within this medical student population. These findings provide a foundational basis for further evaluation concerning the impact of mental and physical health on students' learning capacities.

Table 3. Bivariate analysis of sleep quality, physical activity, and burnout on short-term memory

Variables	Short-term memory						*p-value*
	Good		Poor		Amount		
	n	%	n	%	n	%	
Sleep Quality							
Good (≤5)	81	28.5	54	19	135	47.5	0.028*
Poor (>5)	70	24.6	79	27.8	149	52.5	
Physical Activity	78	27.5	53	18.7	131	46.1	
Active (≥600 MET-minutes/week)	73	25.7	80	28.2	153	53.9	0.046*
Inactive (<600 MET-minutes/week)							
Burnout	11	3.9	22	7.7	33	11.6	
Burnout (exhaustion + 1 criterion (EX >14 combined with CY >6 or RAE ≤22) Not burnout	140	49.3	111	39.1	251	88.4	0.015*

Keterangan: *Uji *Chi-square*, signifikan jika *p-value* < 0,05

Multivariate analysis of sleep quality, physical activity, and burnout in relation to short-term memory

The multivariate analysis using robust Poisson regression demonstrated that sleep quality, physical activity, and burnout were associated with short-term memory to varying degrees after adjustment for potential confounding variables including age, gender, and academic year. Sleep quality showed an Adjusted Prevalence Ratio (Adjusted PR) of 1.518 (95% CI: 0.934–2.465; p =0.092), indicating that participants with poor sleep quality had a 1.518-times higher prevalence of impaired short-term memory compared with those with good sleep quality. However, this association was not statistically significant because the *p-value* exceeded 0.05 and the confidence interval included 1 (Table 4).

Table 4. Multivariate analysis of sleep quality, physical activity, and burnout on short-term memory using obust Poisson regression

Variable	B	*p-value*	Adjusted PR	95% CI	Pseudo R Square
Sleep quality	0.417	0.092	1.518	0.934–2.465	0,060
Physical activity	0.427	0.085	1.533	0.943–2.493	
Burnout	-0.905	0.022	0.405	0.186–0.879	
Constant	0.282	0.756	1.326		

Note: Regresi Poisson robust; B = koefisien regresi; Adjusted PR = Adjusted Prevalence Ratio; CI = Confidence Interval; Pseudo R-square = 0,060

Physical activity demonstrated an Adjusted PR of 1.533 (95% CI: 0.943–2.493; p = 0.085), suggesting that participants with lower levels of physical activity were 1.533 times more likely to experience impaired short-term memory than those with adequate physical activity. Nevertheless, this association also did not achieve statistical significance after adjustment in the multivariate model.

In contrast, burnout was significantly associated with short-term memory, with an Adjusted PR of 0.405 (95% CI: 0.186-0.879; p = 0.022). Based on the coding scheme where burnout was coded as 1 and no burnout as 0, and short-term memory was coded as 1 = poor and 0 = good, the Adjusted PR value below 1 indicates that students with burnout had a lower prevalence of good short-term memory compared with those without burnout. This inverse association indicates that higher burnout levels were associated with poorer short-term memory performance.

The pseudo R square value of 0.060 indicates that the variables included in the model explained approximately 6.0% of the variation in short-term memory, which reflects limited explanatory power. This finding suggests that the majority of variation in short-term memory performance (94%) may be influenced by other factors not included in the present study, such as academic stress, nutritional status, mental health conditions, learning strategies, and screen time exposure. This limitation should be considered when interpreting the findings and highlights the need for future studies to incorporate additional relevant variables.

Sleep quality on short-term memory

This study examines the effect of sleep quality, physical activity, and burnout on short-term memory among medical students. The discussion focuses on answering the research hypotheses by comparing the findings with previous research and explaining the mechanisms underlying the observed relationships. Suboptimal sleep quality has

been identified as a contributing factor to decreased short-term memory efficiency, as demonstrated by current data. The proportion of students with poor short-term memory was more pronounced among individuals with poor sleep quality compared with those reporting good sleep quality. This consistent relationship indicates the importance of sleep for medical students' cognitive function (Ampofo et al., 2025; Skourti et al., 2023). A linear relationship between improved sleep quality and academic achievement has been empirically proven. Adequate sleep duration is a crucial factor in strengthening memory and optimizing cognitive function (Ampofo et al., 2025). The consolidation of memory is heavily contingent upon sleep, which provides the necessary neurobiological environment for information retention and integration. During slow-wave sleep, newly acquired information is reactivated and transferred from the hippocampus to neocortical regions, while rapid eye movement sleep is involved in procedural memory and emotional processing (Brodt et al., 2023; Barbato, 2021). Disruption of these sleep phases interferes with synaptic plasticity and weakens memory traces, resulting in impaired short-term memory performance (Yuksel et al., 2023). Diminished sleep quality exerts a negative influence on molecular pathways, leading to impaired hippocampal neurogenesis and compromised neuronal proliferative activity (Jia et al., 2024; Wu and Zhang, 2023; Yuksel et al., 2023). Sleep deprivation has been documented to markedly attenuate the regulation of brain-derived neurotrophic factor (BDNF) expression. This specific neurotrophin serves as a vital mediator for synaptic plasticity, neuronal viability, and the consolidation of memory (Alruwaili and Alasmari, 2025; Wang et al., 2024). Decreased levels of brain-derived neurotrophic factor impair long-term potentiation in hippocampal neurons, thereby weakening short-term memory encoding and consolidation processes (Chen et al., 2023; Trigo et al., 2022). These molecular alterations provide a plausible biological explanation for the observed association between poor sleep quality and impaired short-term memory. Interestingly, a proportion of subjects with poor sleep quality still demonstrated adequate short-term memory performance. This finding suggests the presence of compensatory mechanisms or protective factors such as resilience, effective coping strategies, or strong social support (Balsamo et al., 2024; Barwal and Cherian, 2024). Neurophysiological studies have demonstrated adaptive neural responses during sleep deprivation, indicating that the brain may temporarily reorganize cognitive resources to preserve performance despite reduced brain-derived neurotrophic factor activity (Shao et al., 2025). This phenomenon highlights individual variability in vulnerability to sleep-related cognitive impairment.

Physical activity on short-term memory

The current study further established that physical activity levels exert a significant influence on the subjects' short-term memory performance. This suggests that engagement in physical exertion is a notable correlate of immediate mnemonic efficiency. These findings align with previous research showing that regular physical activity positively impacts cognitive function, including working memory and attention (Andayani and Nugraha, 2020; Zhao et al., 2024). Similar results have been reported in systematic reviews highlighting the cognitive benefits of an active lifestyle in young adults (Srinivas et al., 2021). The augmentation of blood perfusion to specific brain regions, particularly the prefrontal cortex and the hippocampus, serves as the fundamental explanation for how physical activity optimizes cognitive performance (Octaviani et al., 2021; Renke et al., 2022). Improved cerebral perfusion enhances oxygen and glucose delivery, supporting neuronal metabolism and information

processing (Buxton, 2021). In addition, physical activity serves as a powerful inducer of brain-derived neurotrophic factor (BDNF) synthesis, which facilitates neurogenesis, synaptic plasticity, and strengthening of hippocampal neural circuits involved in short-term memory (Cefis et al., 2023; Sadri et al., 2024). Regular physical activity has been shown to upregulate BDNF expression through activation of calcium-dependent signaling pathways and increased neuronal activity, thereby enhancing memory encoding and retrieval (Karakilic et al., 2021; Qi et al., 2022). Physical activity increases the expression of vascular endothelial growth factor (VEGF), which stimulates the formation of new blood vessels. VEGF itself is a key mediator in the process of angiogenesis, thus forming new neurovascular vessels that facilitate neuroplasticity mediated by BDNF. The interaction between angiogenesis and neurogenesis creates a positive loop that reinforces the effects of physical activity on cognitive function (Llorente et al., 2022). These synergistic mechanisms explain the beneficial association between physical activity and short-term memory observed in this study. However, inconsistencies exist in the literature. In contrast, several studies failed to observe a statistically significant relationship between physical activity engagement and short-term memory performance (Nadira and Daulay, 2022; Loprinzi, 2019). These differences may be attributed to variations in physical activity intensity, duration, and frequency, which influence brain-derived neurotrophic factor release to varying degrees. Methodological differences, particularly reliance on self-reported physical activity, may also contribute to inconsistent findings.

Burnout on short-term memory

Burnout showed the strongest association with short-term memory impairment in this study. The present findings accord with previously published evidence that burnout is closely linked to cognitive dysfunction, particularly in short-term memory (Cortés-Álvarez et al., 2024). Burnout is a chronic stress condition characterized by emotional exhaustion, cynicism, and reduced academic efficacy (Khammissa et al., 2022; Kong et al., 2025). The biological expression of burnout involves dysregulation marked by excessive activation of the HPA axis, leading to sustained increases in stress hormone secretion and subsequent detrimental effects on central nervous system function (Correia et al., 2023; James et al., 2023). Chronic stress has been shown to suppress brain-derived neurotrophic factor expression across the hippocampal and prefrontal cortical regions, resulting in impaired synaptic plasticity and reduced cognitive flexibility (Bayes et al., 2021; Ciobanu et al., 2021). Decreased BDNF availability under chronic stress conditions contributes to hippocampal atrophy and persistent short-term memory deficits. Burnout is also strongly associated with sleep disturbances, which further exacerbate reductions in brain-derived neurotrophic factor levels and impair memory consolidation (Qin et al., 2022). These interacting mechanisms explain why burnout emerged as the most dominant factor influencing short-term memory in this study.

The combined association of sleep quality, physical activity, and burnout with short-term memory

The present study demonstrated that burnout was the only variable significantly associated with short-term memory after adjustment using robust Poisson regression analysis. Based on the variable coding scheme where burnout was coded as 1 (burnout) and 0 (no burnout), and short-term memory was coded as 1 (poor) and 0 (good), the Adjusted PR of 0.405 (95% CI: 0.186-0.879; p = 0.022) indicates that students with

burnout had a lower prevalence of good short-term memory compared with those without burnout. This finding suggests that psychological exhaustion may substantially impair cognitive functioning among medical students. Burnout has been widely associated with chronic stress exposure, emotional exhaustion, and impaired executive functioning, all of which may negatively affect memory encoding, attention, and information retrieval. Prolonged activation of stress-related neuroendocrine pathways, particularly elevated cortisol secretion, may disrupt hippocampal activity and subsequently reduce cognitive performance, including short-term memory capacity.

Although sleep quality was not significantly associated with short-term memory in the multivariate model, students with poor sleep quality tended to have a higher prevalence of impaired short-term memory compared with those with good sleep quality (Adjusted PR = 1.518; p = 0.092). Sleep is known to play a critical role in cognitive restoration, learning consolidation, and memory processing. Insufficient or poor-quality sleep may impair synaptic plasticity and reduce attention and working memory performance. The lack of statistical significance in the present study may be attributable to sample size limitations, variability in sleep patterns, or the influence of stronger psychological factors such as burnout.

Similarly, low physical activity demonstrated a tendency toward increased prevalence of impaired short-term memory (Adjusted PR = 1.533; p = 0.085), although the association did not reach statistical significance. Regular physical activity has been reported to enhance cerebral blood flow, neurogenesis, and neurotransmitter regulation, thereby supporting cognitive function and memory performance. However, differences in exercise intensity, frequency, and participant lifestyle characteristics may have contributed to the non-significant findings observed in this study.

The pseudo R-square value of 0.060 indicates that the independent variables included in the model explained only 6.0% of the variation in short-term memory. This limited explanatory power suggests that additional factors not examined in the current study, such as academic stress, nutritional status, mental health conditions, learning strategies, and screen time exposure, may also contribute substantially to cognitive performance among medical students. Future research should incorporate these variables to improve the predictive capacity of the model.

In the combined analysis of sleep quality, physical activity, and burnout, burnout remained the most influential factor. This finding suggests that burnout may act as a central mediator through which sleep quality and physical activity affect cognitive function, partly through dysregulation of brain-derived neurotrophic factor pathways (Sousa and Sail, 2021; Zhai et al., 2021). Chronic stress associated with burnout may blunt the beneficial effects of physical activity and adequate sleep on brain-derived neurotrophic factor expression, leading to diminished cognitive benefits.[19] These findings support a biopsychosocial model of cognitive health in medical students, emphasizing that psychological stress, lifestyle behaviors, and neurobiological factors such as brain-derived neurotrophic factor are closely interconnected. Scientifically, this study strengthens evidence that alterations in brain-derived neurotrophic factor may represent a key biological mechanism linking burnout and lifestyle factors to cognitive performance and student's well-being (Dam, 2021; Kusumaningrum et al., 2021; Nurdiyanto and Harjanty, 2022).

Study limitations

Several methodological constraints characterize this study, particularly the use of a cross-sectional approach, which prevents definitive conclusions regarding causal

relationships. The use of the Slovin formula for sample size calculation, rather than more advanced formulas specifically designed for analytical studies, is acknowledged as a limitation. Additionally, the use of self-reported instruments for measuring physical activity and sleep quality may introduce recall bias, and the potential for social desirability bias cannot be excluded. Confounding variables, although controlled for in the multivariate model, may not have been fully addressed due to the observational nature of the study design. To better elucidate the directionality of the observed associations, further investigations employing longitudinal designs are warranted. Additionally, other factors influencing short-term memory, such as academic stress, anxiety, depression, learning strategies, and screen time, were not assessed. The limited pseudo R-square value suggests that future studies should include additional relevant variables to improve model fit. Despite these limitations, the findings provide valuable insights and a strong foundation for future research.

CONCLUSIONS

In conclusion, burnout was identified as the only independent factor significantly associated with short-term memory among medical students after adjustment using robust Poisson regression analysis. Based on the coding scheme applied in this study, students with burnout had a lower prevalence of good short-term memory compared with those without burnout, indicating that higher burnout levels were associated with poorer short-term memory performance. Although poor sleep quality and low physical activity showed a tendency toward increased prevalence of impaired short-term memory, these associations were not statistically significant in the multivariate model. These findings suggest that psychological factors, particularly burnout, may have a stronger influence on cognitive function among medical students than lifestyle-related factors. Future research should employ longitudinal designs to establish causal relationships and include additional variables such as academic stress, nutritional status, and mental health conditions to improve the explanatory power of the model. The prevention and management of burnout should be prioritized, along with the adoption of healthy sleep patterns and regular physical activity to support cognitive health and academic performance.

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CONFLICT OF INTEREST

The author(s) declare that they have no conflict interest

REFERENCES

Abduloh, S., Septiadi, F., Nugraheni, W., 2025. Analisis Perbandingan IPAQ dan GPAQ dalam Investigasi Aktivitas Fisik Mahasiswa pada Program MBKM. Jurnal Olahraga dan Kesehatan Indonesia 5(2), 154-160. https://jurnal.stokbinaguna.ac.id/index.php/JOK/article/view/3980

Almarzouki, A.F., 2024. Impact of On-Call on Working Memory and The Role of Burnout, Sleep, and Mental Well-Being in Trainee Physicians. Postgraduate Medicine 136(3), 312–317. https://doi.org/10.1080/00325481.2024.2347195

Alruwaili, R.F., Alasmari, A.A., 2025. Sleep Patterns and Short-Term Memory Performance Among Saudi University Students: A Structural Equation Modelling Approach. Cognitive Processing 27, 167-190. https://link.springer.com/10.1007/s10339-025-01293-6

Alzuhra, N., 2024. Efektivitas Peningkatan Memori pada Siswa. Buletin Ilmiah Psikologi 5(3), 397-406. https://doi.org/10.24014/pib.v5i3.26438

Ampofo, J., Sun, B., Bentum-Micah, G., Qinggong, L., Changfeng, W., Guoan, L., Xusheng, Q., 2025. Investigating the Impact of Sleep Quality on Cognitive Functions Among Students in Tokyo, Japan, and London, UK. Frontiers, 1-17. https://doi.org/10.3389/frsle.2025.1537997

Andayani, N.L.N., Nugraha, M.H.S., 2020. Hubungan antara Tingkat Aktivitas Fisik terhadap Kemampuan Memori Jangka Pendek Mahasiswi Program Studi Fisioterapi, Fakultas Kedokteran, Universitas Udayana. Majalah Ilmiah Fisioterapi Indonesia 8(1), 64–66. https://garuda.kemdiktisaintek.go.id/documents/detail/1705177

Aritonang, J.P., Widiastuti, I.A.E., Harahap, I.L., 2022. Gambaran Tingkat Aktivitas Fisik Mahasiswa Pendidikan Dokter Fakultas Kedokteran Universitas Mataram di Masa Pandemi COVID-19. EJournal Kedokteran Indonesia 10(1), 58-63. https://ejki.fk.ui.ac.id/index.php/journal/article/view/129

A'yunin, Q., Fatmaningrum, W., Soetjipto, S., 2023. Gambaran Burnout Akademik Mahasiswa Kedokteran Universitas Airlangga Angkatan 2021. Jurnal Ilmiah Universitas Batanghari Jambi 23(3), 3083-3086. https://doi.org/10.33087/jiubj.v23i3.4096

Az Zahra, A.F., Supatmo, Y., Ekaputera, M.R.W., 2023. Comparison between pilates Exercise and Combination with Transcen-Dental Meditation towards Short-Term Memory among Adult Females. Jurnal Kedokteran dan Kesehatan Indonesia 14(3), 281-288. https://doi.org/10.20885/jkki.vol14.iss3.art8

Azzam, M.B., Easteal, R.A., 2021. Pedagogical Strategies for the Enhancement of Medical Education. Medical Science Educator 31(6), 2041–2048. https://pmc.ncbi.nlm.nih.gov/articles/PMC8651936/

Balsamo, F., Berretta, E., Meneo, D., Baglioni, C., Gelfo, F., 2024. The Complex Relationship between Sleep and Cognitive Reserve: A Narrative Review Based on Human Studies. Brain Sciences 14(7), 1-20. https://doi.org/10.3390/brainsci14070654

Barbato, G., 2021. REM Sleep: An Unknown Indicator of Sleep Quality. International Journal of Environmental Research and Public Health 18(24), 1-12. https://doi.org/10.3390/ijerph182412976

Barwal, V., Cherian, M.J., 2024. The Influence of Social Support and Resilience with Coping Strategies among Students. International Journal of Indian Psychology 12(2), 1553-1573.

Bayes, A., Tavella, G., Parker, G., 2021. The Biology of Burnout: Causes and Consequences. The World Journal of Biological Psychiatry 22(9), 686–98. https://doi.org/10.1080/15622975.2021.1907713

Brodt, S., Inostroza, M., Niethard, N., Born, J., 2023. Sleep A Brain State Serving Systems Memory Consolidation. Neuron 111(7), 1050–1075. https://doi.org/10.1016/j.neuron.2023.03.005

Buxton, R.B., 2021. The Thermodynamics of Thinking: Connections between Neural Activity, Energy Metabolism and Blood Flow. Royal Society Publishing 376(1815), 1-13. https://doi.org/10.1098/rstb.2019.0624

Carpi, M., 2025. The Pittsburgh Sleep Quality Index: A Brief Review. Occupational Medicine 75(1), 14–15. https://doi.org/10.1093/occmed/kqae121

Cefis, M., Chaney, R., Wirtz, J., Méloux, A., Quirié, A., Leger, C., Tessier, A.P., Garnier, P., 2023. Molecular Mechanisms Underlying Physical Exercise-Induced Brain BDNF Overproduction. Frontiers in Molecular Neuroscience 5(16), 1-19. https://pubmed.ncbi.nlm.nih.gov/37868812/

Chen, P., Ban, W., Wang, W., You, Y., Yang, Z., 2023. The Devastating Effects of Sleep Deprivation on Memory: Lessons from Rodent Models. Clocks and Sleep 5(2), 276–294. https://doi.org/10.3390/clockssleep5020022

Ciobanu, A.M., Damian, A.C., Neagu, C., 2021. Association between Burnout and Immunological and Endocrine Alterations. Romanian Journal of Morphology and Embryology 62(1), 13–18. https://pmc.ncbi.nlm.nih.gov/articles/PMC8597388/

Correia, A.S., Cardoso, A., Vale, N., 2023. Oxidative Stress in Depression: The Link with the Stress Response, Neuroinflammation, Serotonin, Neurogenesis and Synaptic Plasticity. Antioxidants 12(2), 1-18. https://www.mdpi.com/2076-3921/12/2/470

Cortés-Álvarez, N.Y., Lara-Morales, A., Bautista-Rodríguez, E., Marmolejo-Murillo, L.G., Jiménez, A.D., Hernández, L.A.V., Moya, M.F., Vuelvas-Olmos, C.R., 2024. Job Burnout, Cognitive Functioning, and Brain-Derived Neurotrophic Factor Expression among Hospital Mexican Nurses. PLoS ONE 19(5), 1-16. https://doi.org/10.1371/journal.pone.0304092

Dam, A.V., 2021. Clinical Perspective on Burnout: Diagnosis, Classification, and Treatment of Clinical Burnout. European Journal of Work and Organizational Psychology 30(5), 732–741. https://doi.org/10.1080/1359432X.2021.1948400

Febrian, R.G., Jaeri, S., Muniroh, M., Indraswari, D.A., 2021. Relationship of Sleep Quality with Short-Term Memory and Reaction Time in First Year Medical Students of Diponegoro University. Jurnal Kedokteran Diponegoro 10(5), 332–336. https://ejournal3.undip.ac.id/index.php/medico/article/view/31391/0

Gavelin, H.M., Demollof, M., Åström, E., Nelson, A., Launder, N.H., Neely, A.S., Lampit, A., 2022. Cognitive Function in Clinical Burnout: A Systematic Review and Meta-Analysis. International Journal of Work, Helath & Organisations 36(1), 86–104. https://doi.org/10.1080/02678373.2021.2002972

Hasibuan, I.I.S., Nadira, C.S., Novalia, V., 2024. Pengaruh Kurang Tidur terhadap Short Term Memory pada Mahasiswa Kedokteran Universitas Malikussaleh. Jurnal Sosial dan Sains 5(4), 9–10. https://sosains.greenvest.co.id/index.php/sosains/article/view/32149

James, K.A., Stromin, J.I., Steenkamp, N., Combrinck, M.I., 2023. Understanding the Relationships between Physiological and Psychosocial Stress, Cortisol and Cognition. Frontiers in Endocrinology 14, 1-20. https://www.frontiersin.org/journals/endocrinology/articles/10.3389/fendo.2023.1085950/full?utm

Jia, J., Tao, W., Chen, T., Zhong, Q., Sun, J., Xu, Y., Sui, X., Chen, C., Zhang, Z., 2024. SIRT6 Improves Hippocampal Neurogenesis Following Prolonged Sleep Deprivation through Modulating Energy Metabolism in Developing Rats. Molecular Neurobiology 62(4), 5349–5351. https://doi.org/10.1007/s12035-023-03585-4

Jia, Y., Chen, S., Deutz, N.E.P., Bukkapatnam, S.T.S., Woltering, S., 2019. Examining the Structure Validity of the Pittsburgh Sleep Quality Index. Sleep and Biological Rhythms 17(2), 209–221.

Karakilic, A., Yuksel, O., Kizildag, S., Hosgorler, F., Topcugil, B., Ilgin, R., Gumus, H., Guvendi, G., Koc, B., Kandis, S., Ates, M., Uysal, N., 2021. Regular Aerobic Exercise Increased VEGF Levels in Both Soleus and Gastrocnemius Muscles Correlated with Hippocampal Learning and VEGF levels. Acta Neurobiol Exp 81(1), 1–9. https://doi.org/10.21307/ane-2021-001

Khammissa, R.A., Nemutandani, S., Feller, G., Lemmer, J., Feller, L., 2022. Burnout Phenomenon: Neurophysiological Factors, Clinical Features, and Aspects of Management. Journal of International Medical Research 50(9), 1-22. https://pmc.ncbi.nlm.nih.gov/articles/PMC9478693/

Kong, Y., Somdee, T., Yangyuen, S., 2025. Academic Burnout and its Association with Psychological Factors among Medical Students in Guangxi, China. Jurnal Educ Health Promot 28(14), 1-16. https://doi.org/10.4103/jehp.jehp_1762_24

Krisnanda, M.A., Hasianna, S.T., Limyati, Y., 2020. Attention and Short-Term Memory Improvement in Young Adult Women with Anxiety After Coloring Therapy. Journal of Medicine and Health 2(5), 31-39. https://journal.maranatha.edu/index.php/jmh/article/view/2030/1497

Kusumaningrum, T.A.I., Kusumawati, Y., Indriawan, T., Saputri, M.W., Pebrianti, S., Liswanti, A.L., 2021. Formation of Peer Educators in Information Dissemination Efforts to Prevent HIV Risky Behavior in Students. Media Informasi dan Komunikasi Hasil Pengabdian kepada Masyarakat 24(4), 677-686. https://journals.ums.ac.id/index.php/warta/article/view/15035/6987

Lienardy, G.Q., Purnawati, S., Muliarta, I.M., Tirtayasa, K., 2021. Hubungan antara Kualitas Tidur dan Jenis Kelamin dengan Memori Jangka Pendek Mahasiswa Fakultas Kedokteran Universitas Udayana. E-Jurnal Medika Udayana 10(12), 33.

Llorente, V., Velarde, P., Desco, M., Gómez-Gaviro, M.V., 2022. Current Understanding of the Neural Stem Cell Niches. Cells 11(19), 1-27. https://www.mdpi.com/2073-4409/11/19/3002

Loprinzi, P., 2019. The Effects of Sedentary Behavior on Memory and Markers of Memory Function: A Systematic Review. Physician and Sportsmedicine 47(4), 387–394. https://doi.org/10.1080/00913847.2019.1607603

Mengesha, M.M., Roba, H.S., Ayele, B.H., Beyene, A.S., 2019. Level of Physical Activity among Urban Adults and the Socio-Demographic Correlates: A Population-Based Cross-Sectional Study using the Global Physical Activity Questionnaire. BMC Public Health 19(1), 1-11. https://doi.org/10.1186/s12889-019-7465-y

Nadira, S.R., Daulay, M., 2022. Korelasi Aktivitas Fisik dengan Memori Kerja pada Mahasiswa Pendidikan Dokter Fakultas Kedokteran Universitas Sumatera Utara. Scientific Medical Journal 3(2), 106–113. https://talenta.usu.ac.id/scripta/article/view/6863

Nurdiyanto, F.A., Harjanti, E.P., 2022. The Hidden Impacts: Identifying Psychological Burdens During the Covid-19 Pandemic. Jurnal Ilmiah Psikologi 7(2), 130-144. https://journals.ums.ac.id/index.php/indigenous/article/view/17472/7831

Octaviani, N.A., Widodo, S., Wati, A., Sumekar, T.A., 2021. The Effect of High Intensity Interval Training (HITT) on Short-Term Memory Study Among Medical Student in Semarang. Jurnal Kedokteran Diponegoro 10(1), 1-8. https://doi.org/10.14710/dmj.v10i1.29279

Olson, N., Oberhoffer-Fritz, R., Reiner, B., Schulz, T., 2025. Stress, Student Burnout and Study Engagement – A Cross-Sectional Comparison of University Students of Different Academic Subjects. BMC Psychology 13(1), 1-10. https://doi.org/10.1186/s40359-025-02602-6

Panthoja, D., Wibowo, S., 2022. Survei Aktivitas Fisik dan Perilaku Pasif Siswa SMA Setelah Pandemi COVID 19. Jurnal Ilmiah Bidang Sosial, Ekonomi, Budaya, Teknologi, dan Pendidikan 1(8), 1463–1472. https://publish.ojs-indonesia.com/index.php/SIBATIK/article/view/196

Pöhlchen, D., Pawlizki, A., Gais, S., Schönauer, M., 2021. Evidence Against a Large Effect of Sleep in Protecting Verbal Memories from Interference. Journal of Sleep Research 30(2), 1-22. https://doi.org/10.1111/jsr.13042

Qi, C., Song, X., Wang, H., Yan, Y., Liu, B., 2022. The Role of Exercise-Induced Myokines in Promoting Angiogenesis. Frontiers in Physiology 26(13), 1-12. https://doi.org/10.3389/fphys.2022.981577

Qin, L., Chen, S., Luo, B., Chen, Y., 2022. The Effect of Learning Burnout on Sleep Quality in Primary School Students: The Mediating Role of Mental Health. Healthcare 10(10), 1-11. https://pmc.ncbi.nlm.nih.gov/articles/PMC9602333/

Rao, W.W., Li, W., Qi, H., Hong, L., Chen, C., Li, C.Y., Ng, C., Ungvari, G.S., Xiang, Y., 2020. Sleep Quality in Medical Students: A Comprehensive Meta-Analysis of Observational Studies. Sleep and Breathing 24(3), 1151–1165. https://doi.org/10.1007/s11325-020-02020-5

Renke, M.B., Marcinkowska, A., Kujach, S., Winklewski, P.J., 2022. A Systematic Review of the Impact of Physical Exercise-Induced Increased Resting Cerebral Blood Flow on Cognitive Functions. Frontiers in Aging Neuroscience 14, 1-14.

Ribeiro, M., Fernandes, E., Borges, M., Pires, M., Melo. X., Pinto, F.J., Abreu, A., Pinto, R., 2024. Reliability and Validity of the Global Physical Activity Questionnaire for Portuguese Adults. Percept Mot Skills 131(5), 1548–1570. https://doi.org/10.1177/00315125241266341

Sadri, I., Nikookheslat, S., Karimi, P., Khani, M., Nadimi, S., 2024. Aerobic Exercise Training Improves Memory Function through Modulation of Brain-Derived Neurotrophic Factor and Synaptic Proteins in the Hippocampus and Prefrontal Cortex of Type 2 Diabetic Rats. Journal of Diabetes and Metabolic Disorders 23(1), 849–58. https://link.springer.com/article/10.1007/s40200-023-01360-9

Sahanaya, D.D., Ramadhan, Y.A., Purwaningrum, E.K., Amelia, R., Qasrin, M.R.S., 2025. Penyusunan Skala Burnout Akademik. Jurnal Penelitian Multidisiplin 3(3), 1008–1017. https://ejournal.lumbungpare.org/index.php/maras/article/view/1149

Setyowati, A., Chung, M., 2021. Validity and Reliability of the Indonesian Version of the Pittsburgh Sleep Quality Index in Adolescents. International Journal of Nursing Practice 27(5), 1-16. https://doi.org/10.1111/ijn.12856

Shao, Y., Xu, L., Peng, Z., An, X., Gong, J., Han, M., 2025. Non-Linear Effects of Acute Sleep Deprivation on Spatial Working Memory: Cognitive Depletion and Neural Compensation. Brain Sciences 15(1), 1-13. https://doi.org/10.3390/brainsci15010018

Skourti, E., Simos, P., Zampetakis, A., Koutentaki, E., Zaganas, I., Alexopoulou, C., Vgontzas, A., 2023. Long-Term Associations between objective Sleep Quality and Quantity and Verbal Memory Performance in Normal Cognition and Mild Cognitive Impairment. Frontiers in Neuroscience 17, 1-14. https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2023.1265016/full

Sousa, A.D., Sail, D., 2021. Neurobiological Correlates of Burnout. Telangana Journal of Psychiatry 7(2), 87-93.

Srinivas, N.S., Vimalan, V., Padmanabhan, P., Gulyás, B., 2021. An Overview on Cognitive Function Enhancement through Physical Exercises. Brain Sciences 11(10), 1-17. https://doi.org/10.3390/brainsci11101289

Takechi, H., Dodge, H., 2010. Scenery Picture Memory Test: A New Type of Quick and Effective Screening Test to Detect Early Stage Alzheimer's Disease Patients. Geriatr Gerontol Int 10(2), 183–190. https://doi.org/10.1111/j.1447-0594.2009.00576.x

Trigo, D., Avelar, C., Fernandes, M., Sá, J., Silva, O., 2022. Mitochondria, Energy, and Metabolism in Neuronal Health and Disease. FEBS Letters 596, 1095–1110. https://doi.org/10.1002/1873-3468.14298

[UNICEF] United Nations Children's Fund., 2021. Profil Remaja 2021 [WWW Document]. https://www.unicef.org/indonesia/media/12345/file/Profil%20Remaja%202021.pdf. [Diakses Januari 2026].

Vincenzo, M.D., Arsenio, E., Rocca, B.D., Rosa, A., Tretola, L., Toricco, R., Boiano, A., Catapago, P., Cavaliere, S., Fiorillo, A., 2024. Is There a Burnout Epidemic among Medical Students? Results from a Systematic Review. Medicina 60(4), 1-22. https://doi.org/10.3390/medicina60040575

Wang, X., Chen, H., Tang, T., Zhan, X., Qin, S., Hang, T., Song, M., 2024. Chronic Sleep Deprivation Altered the Expression of Memory-Related Genes and Caused Cognitive Memory Dysfunction in Mice. International Journal of Molecular Sciences 25(21), 1-17. https://doi.org/10.3390/ijms252111634

Wickramasinghe, N.D., Dissanayake, D.S., Abeywardena, G.S., 2018. Clinical Validity and Diagnostic Accuracy of the Maslach Burnout Inventory-Student Survey in Sri Lanka. Health Qual Life Outcomes 16(1), 1-9. https://doi.org/10.1186/s12955-018-1048-y

Wu, A., Zhang, J., 2023. Neuroinflammation, Memory, and Depression: New Approaches to Hippocampal Neurogenesis. Journal of Neuroinflammation 20(283), 1-20. https://link.springer.com/article/10.1186/s12974-023-02964-x

Xie, W., Berry, A., Lustig, C., Deldin, P., Zhang, W., 2019. Poor Sleep Quality and Compromised Visual Working Memory Capacity. Journal of the International Neuropsychological Society 25(6), 583–594. https://pmc.ncbi.nlm.nih.gov/articles/PMC6620134/

Yuksel, C., Denis, D., Coleman, J., Ren, B., Oh, A., Cox, R., Morgan, A., Sato, E., Stickgold, R., 2023. Emotional Memories are Enhanced When Reactivated in Slow-Wave Sleep but Impaired in REM. Preprint Server for Biology 29, 1-11. https://doi.org/10.1101/2023.03.01.530661

Zhai, X., Wu, N., Koriyama, S., Wang, C., Shi, M., Huang, T., Wang, K., Sawada, S., Fan, X., 2021. Mediating Effect of Perceived Stress on the Association between Physical Activity and Sleep Quality Among Chinese College Students. International Journal of Environmental Research and Public Health 18(1), 1–11. https://doi.org/10.3390/ijerph18010289

Zhao, Q., Wang, X., Li, S.F., Wang, P., Wang, X., Xin, X., Yin, S.W., Song, W., Mao, L.J., 2024. Relationship between Physical Activity and Specific Working Memory Indicators of Depressive Symptoms in University Students. World Journal of Psychiatry 14(1), 148–158. https://doi.org/10.5498/wjp.v14.i1.148