Physical Activity as a Contributing Factor to Cognitive Function and Sleep Quality among Senior High School Adolescents

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ABSTRACT
Adolescents represent an age group that is particularly vulnerable to declines in cognitive function and disturbances in sleep quality, often associated with low levels of physical activity. This condition has become an increasingly concerning public health issue, as it directly affects students' learning concentration, memory capacity, and psychological well-being. The purpose of this study was to examine the relationship between physical activity, cognitive function, and sleep quality among eleventh-grade students at Sekolah Menengah Atas Negeri 1 Ngamprah. This study employed a quantitative design with a correlational approach and a cross-sectional framework. A total of 76 students were selected using stratified random sampling. Physical activity was measured using the International Physical Activity Questionnaire (IPAQ), cognitive function was assessed using the Indonesian version of the Montreal Cognitive Assessment (MoCA-Ina), and sleep quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI). Data were analyzed using Fisher's Exact correlation test. The findings indicate a significant relationship between physical activity and cognitive function ($p = 0.021$), as well as between physical activity and sleep quality ($p = 0.007$). These results demonstrate that higher levels of physical activity are associated with better cognitive performance and improved sleep quality among adolescents. As conclusion, this study highlights the essential role of physical activity in supporting cognitive function and sleep quality in adolescents. It is recommended that adolescents engage in regular moderate-to-vigorous physical activity for at least 150 minutes per week as a promotive and preventive measure against cognitive and sleep disturbances.
Keywords: physical activity; cognitive function; sleep quality; adolescents

INTRODUCTION
Adolescence represents a critical developmental stage characterized by profound and rapid changes across biological, psychological, and social domains. During this transitional period from childhood to adulthood, individuals experience accelerated physical growth, hormonal maturation, emotional fluctuation, and evolving social roles. These multidimensional changes significantly influence health behaviors, learning capacity, and overall well-being. Consequently, adolescence constitutes a pivotal window for establishing healthy lifestyle patterns that may persist into adulthood. Among these behaviors, physical activity plays a central role in supporting optimal growth, maintaining physiological balance, and promoting psychological resilience.

Engagement in regular physical activity contributes not only to cardiovascular and musculoskeletal health but also to cognitive development and academic performance. Physical activity enhances cerebral blood flow, stimulates neurogenesis, and supports synaptic plasticity, thereby facilitating improved attention, executive functioning, and memory processes. Moreover, active adolescents are more likely to develop a positive self-concept and higher self-efficacy, which are important determinants of academic engagement and achievement. Despite these well-documented benefits, global evidence indicates that approximately 81% of adolescents aged 11–17 years do not meet the recommended levels of physical activity [1]. This high prevalence of physical inactivity represents a major public health concern.

In the Indonesian context, the situation reflects similar trends. National data show that approximately 49.6% of adolescents aged 15–19 years exhibit low levels of physical activity [2]. At the regional level, West Bandung Regency has been reported as the district with the lowest prevalence of adequate physical activity in West Java, reaching 56.86% [3]. Such findings suggest that a substantial proportion of adolescents are exposed to the adverse consequences of sedentary lifestyles. Insufficient physical activity may negatively affect students' concentration during learning activities, impair memory retention, and contribute to decreased overall academic performance. Furthermore, prolonged sedentary behavior is frequently associated with increased screen time, which may further disrupt healthy sleep patterns.

Cognitive function, which encompasses attention, concentration, working memory, and executive control, is closely linked to physical fitness, muscular strength, and hormonal regulation [4]. Adequate levels of physical activity help maintain neuroendocrine balance and reduce stress-related cortisol levels, thereby supporting optimal brain functioning. Conversely, reduced cognitive function may manifest as difficulty sustaining attention, slower information processing, and diminished problem-solving capacity, all of which can hinder academic success. In the school setting, these impairments may be observed as reduced classroom participation, incomplete task performance, and lower academic achievement.

Sleep quality constitutes another essential determinant of adolescent health that is intricately associated with both physical activity and cognitive performance. Adequate and restorative sleep facilitates metabolic recovery, strengthens immune function, consolidates memory, and regulates emotional stability [5]. During sleep, particularly in slow-wave and rapid eye movement (REM) phases, neural connections are reorganized and strengthened, enabling effective learning and long-term memory retention. However, many adolescents experience insufficient or poor-quality sleep due to sedentary lifestyles, academic demands, psychosocial stressors, and habitual late-night use of electronic devices [6]. Sleep disturbances may result in daytime fatigue, irritability, reduced motivation, and impaired cognitive performance, thereby creating a cycle that further compromises academic outcomes.

A growing body of research demonstrates that regular physical activity is associated with improved brain performance, enhanced concentration, and better regulation of circadian rhythms through increased melatonin production [7, 8]. Physical activity also contributes to stress reduction and emotional regulation, which indirectly support improved sleep quality. Despite these established benefits, the World Health Organization (WHO) recommends that adolescents engage in at least 60 minutes of moderate-to-vigorous physical activity daily [9], yet school-based physical education programs often allocate only 1–2 hours per week for structured physical activity. This limited exposure may be insufficient to counterbalance prolonged sedentary time spent in classrooms and during leisure screen use. Additionally, limited awareness among students regarding the cognitive and sleep-related benefits of physical activity further reduces motivation to engage in regular exercise.

Preliminary findings from interviews conducted with 15 eleventh-grade students at SMAN 1 Ngamprah revealed common complaints of physical fatigue, difficulty maintaining concentration during classroom instruction, and habitual late-night sleeping due to gadget use and academic

assignments. These patterns suggest the presence of interconnected issues involving low physical activity, suboptimal cognitive functioning, and poor sleep quality. Such interrelationships warrant systematic investigation to better understand how these variables interact within the adolescent population.

Given the developmental vulnerability of adolescence and the critical role of physical activity in supporting both cognitive and sleep outcomes, it is essential to examine these associations empirically. Therefore, this study aims to analyze the relationship between physical activity levels and cognitive function as well as sleep quality among eleventh-grade students of SMAN 1 Ngamprah. By quantitatively exploring these relationships, the findings are expected to provide an evidence-based foundation for designing promotive health interventions and optimizing physical education policies that align more closely with adolescents' developmental and academic needs.

METHODS

This study employed a quantitative correlational design with a cross-sectional approach to examine the relationship between physical activity and cognitive function and sleep quality among adolescents. The research was conducted at SMAN 1 Ngamprah, West Bandung Regency. The site was selected based on its representative student population and the identification of health-related issues, including fatigue, decreased learning concentration, and irregular sleep patterns, as identified in a preliminary interview study with 15 students conducted on July 15, 2025. The primary data collection was carried out on July 29, 2025.

The study population comprised all eleventh-grade students of SMAN 1 Ngamprah aged 15–17 years, totaling 315 students. A stratified random sampling technique was employed to ensure proportional representation from each class stratum. Based on this method, a sample of 76 students who met the inclusion criteria was obtained.

The independent variable in this study was physical activity, while the dependent variables were cognitive function and sleep quality. Data were collected using standardized instruments with established validity and reliability. Physical activity was measured using the International Physical Activity Questionnaire (IPAQ), cognitive function was assessed using the Indonesian version of the Montreal Cognitive Assessment (MoCA-Ina), and sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI). Data collection procedures involved providing respondents with an explanation of the study objectives and procedures, followed by self-administered questionnaire completion according to the given instructions.

Data analysis was conducted in several stages. Descriptive analysis was used to describe respondent characteristics and the distribution of research variables in terms of frequencies and proportions [10,11]. Subsequently, bivariate analysis was performed using Fisher's Exact Test to assess the relationship between physical activity and cognitive function and sleep quality. This test was selected due to the presence of contingency table cells with expected frequencies of less than five, thereby violating the assumptions of the Chi-Square test. The level of statistical significance was set at $\alpha < 0.05$.

RESULTS

Table 1 shows that the majority of respondents were 16 years old (71%). The sample was predominantly male (62%). Most respondents reported no health problems, totaling 73 students (96%). Regarding physical activity, the majority were classified in the high physical activity category (65%). The most common cognitive function criterion was no cognitive impairment (75%). Additionally, most respondents reported good sleep quality (60%).

Based on Table 2, respondents with high physical activity predominantly demonstrated no cognitive impairment, totaling 83.67%. Conversely, the smallest proportion was observed among respondents with low physical activity and no cognitive impairment, with 0%. Table 3 indicates that most respondents with high physical activity had good sleep quality, totaling 71.43%. In contrast, respondents with moderate physical activity were more likely to report poor sleep quality, accounting for 61.54%.

The Fisher's exact test yielded a p-value of 0.021 for the association between physical activity and cognitive function, and 0.007 for the association between physical activity and sleep quality. Since both p-values are below the significance threshold of 0.05, it can be concluded that there is a statistically significant relationship between physical activity and both cognitive function and sleep quality among eleventh-grade students of SMAN 1 Ngamprah.

Table 1. Distribution of respondents by demographic characteristics, physical activity, cognitive function, and sleep quality

Variable	Category	Frequency	Percentage
Age	15 years	6	8
	16 years	54	71
	17 years	16	21
Sex	Male	47	62
	Female	29	38
Health problems	No health problems	73	96
	Epistaxis	1	2
	Asthma	2	2
Physical activity	High	49	65
	Moderate	26	34
	Low	1	1
Cognitive function	Severe impairment	0	0
	Mild impairment	19	25
	No impairment	57	75
Sleep quality	Good	46	60
	Poor	30	40

Table 2. The association between physical activity and cognitive function

Physical activity	Cognitive impairment				p-value
	Mild		No impairment		
	Frequency	Percentage	Frequency	Percentage	
High	8	16.33	41	83.67	0,021
Moderate	10	38.46	16	61.54	
Low	1	100	0	0	

Table 3. The association between physical activity and sleep quality

Physical activity	Cognitive impairment				p-value
	Good		Poor		
	Frequency	Percentage	Frequency	Percentage	
High	35	71.43	14	28.57	0,007
Moderate	10	38.46	16	61.54	
Low	1	100	0	0	

DISCUSSION

This study demonstrates that adolescents aged 15–17 years at SMAN 1 Ngamprah generally exhibit adequate levels of physical activity, predominantly normal cognitive function, and relatively good sleep quality. These findings illustrate that adolescence represents a developmental phase in which physical activity plays a substantial role in maintaining balance among physical health, psychological well-being, and cognitive functioning. During this period, rapid physiological and neurological maturation occurs, making physical activity a crucial factor influencing cognitive performance and sleep quality. These findings are consistent with the definition of adolescence proposed by WHO and the Indonesian Ministry of Health, which describe adolescence as a stage characterized by significant biological, psychological, and social changes.

Regular and sufficient physical activity is associated with enhanced brain function. Bodily movement increases cerebral blood flow and oxygenation, strengthens synaptic connectivity, and stimulates the production of Brain-Derived Neurotrophic Factor (BDNF), a protein essential for memory, concentration, and learning processes [12]. The present study found that students who engaged in regular physical exercise

demonstrated better cognitive function than their less active peers. This result aligns with Liu et al. (2025), who reported that routine physical exercise significantly improves cognitive performance among children and adolescents. Physical activity is known to stimulate the prefrontal cortex, which governs decision-making and self-regulation, thereby enabling physically active adolescents to think more effectively and manage academic stress more adaptively [13].

Conversely, mild cognitive decline observed in a proportion of adolescents may be associated with sedentary behavior, academic stress, and excessive gadget use. These factors can interfere with attention and working memory processes. Lukman et al. (2025) reported that approximately one-fifth of adolescents experience mild cognitive impairment due to irregular sleep patterns and high levels of school-related stress. These findings reinforce the notion that physical activity contributes not only to physical fitness but also to the maintenance of mental and neurological balance during adolescence [14].

Beyond its effects on cognitive function, physical activity is closely associated with sleep quality. In this study, adolescents with higher levels of physical activity generally reported better sleep patterns, faster sleep onset, and greater feelings of restfulness upon awakening. Physiologically, physical activity helps regulate circadian rhythms, reduces sleep latency, and enhances sleep duration and quality during the non-rapid eye movement (NREM) phase. Alnawwar et al. (2023) emphasized that exercise improves sleep efficiency by reducing stress and anxiety [15], while Khairunissa et al. (2024) explained that healthy physiological fatigue induced by physical activity facilitates restorative sleep [16].

Adolescents' lifestyle habits further influence this relationship. Hanum (2021) noted that adolescents' sleep duration often decreases due to increasing daily responsibilities and activities. In the present study, students who frequently stayed up late or used electronic devices at night tended to report poorer sleep quality compared with those who managed their time effectively [17]. Husnani et al. (2024) similarly found that excessive activity without adequate rest diminishes sleep quality. In contrast, balanced time management between study, physical activity, and rest supports both sleep quality and cognitive stability [18].

Sleep quality is directly linked to cognitive function. Santika (2022) explained that high-quality sleep is characterized by the achievement of deep sleep stages, which are critical for memory consolidation and neural recovery [19]. Miransya et al. (2024) further highlighted that optimal sleep quality depends on the appropriate progression through REM and NREM stages. Thus, physical activity and sleep form a reciprocal relationship: physical activity enhances sleep, while adequate sleep strengthens cognitive function [20]. Narayana et al. (2023) supported this bidirectional association, demonstrating a positive relationship between high physical activity and good sleep quality, whereas low physical activity was associated with poor sleep quality [21].

Individual characteristics also contribute to these outcomes. The findings indicate that male students were generally more physically active than female students, consistent with Sabila (2022) and Putri et al. (2024), who reported higher physical activity levels among males due to physiological, hormonal, and activity preference differences. Nevertheless, the cognitive and sleep-related benefits of physical activity were observed across both sexes when engagement was consistent [22, 23]. These findings differ from Rosyidah, who reported that most adolescents experienced poor sleep quality, suggesting that school environment and daily routines substantially influence adolescent health behaviors [24].

Potential confounding factors identified in the preliminary study, such as academic stress and gadget use, warrant further attention. The impact of gadget use extends beyond reduced sleep duration; exposure to blue light physiologically suppresses melatonin production [25]. Souissi et al. (2025) demonstrated that nighttime blue light exposure, particularly after 21:00, significantly disrupts circadian rhythms, prolongs sleep onset latency, and reduces overall sleep quality in adolescents [26]. This decline in sleep quality has been shown to directly impair cognitive function, memory performance, and academic achievement the following day [27]. Conversely, the relatively high level of physical activity among respondents may serve as an effective buffer against academic stress. Physical activity reduces cortisol (stress hormone) levels and increases endorphin production, thereby improving mood and facilitating sleep regulation [28]. These mechanisms strengthen the present findings of significant associations between physical activity and sleep quality ($p = 0.007$) as well as cognitive function ($p = 0.021$).

One noteworthy finding is the relatively high proportion of respondents with high physical activity (65%) and normal cognitive function (75%), which contrasts with global and national data reporting high prevalence of physical inactivity among adolescents. This discrepancy may reflect specific characteristics of the school environment or student habits, but it should also be critically considered from a methodological perspective. Several limitations must be acknowledged. First, the cross-sectional design precludes causal inference. Second, the use of self-reported questionnaires to measure physical activity may introduce reporting bias, particularly overestimation of activity duration and intensity. Niestrój-Jaworska et al. [29] found that the International Physical Activity Questionnaire (IPAQ) demonstrates weak-to-moderate correlation with objective measures and tends to overestimate actual physical activity levels. Third, this study did not fully control for other confounding variables, such as academic stress levels, duration of gadget use, and psychosocial factors, which may influence cognitive function and sleep quality.

Future research should employ longitudinal or experimental designs to evaluate causal relationships among physical activity, cognitive function, and sleep quality. The use of objective measurement tools, such as accelerometers for physical activity and actigraphy for sleep assessment, is recommended to enhance data accuracy. Additionally, incorporating psychological variables such as stress, anxiety, and time management as moderating or mediating factors would provide a more comprehensive understanding.

From a nursing perspective, these findings have significant practical implications. School nurses occupy a strategic role as educators, counselors, and change agents within the school setting [30]. Reports of fatigue and decreased concentration identified in the preliminary study can serve as a basis for active screening initiatives. Nurse-led school-based interventions, such as health education programs, have been shown to effectively improve students' understanding of healthy sleep habits [31]. Promotively, nurses can advocate for the "health triangle" concept—physical activity, cognitive function, and sleep quality—as essential components of academic success. Interventional efforts may include sleep hygiene counseling, a crucial non-pharmacological strategy, emphasizing reduced gadget use before bedtime, stress management techniques, and collaboration with physical education teachers to design inclusive and enjoyable physical activities [32].

Overall, this study reinforces existing evidence that physical activity plays a vital role in supporting cognitive function and sleep quality among adolescents. Regular physical activity enhances neuroplasticity, reduces stress, and improves sleep patterns through both physiological and psychological mechanisms. These findings are consistent with Prianthara et al. (2021), who also reported significant associations among physical activity, cognitive function, and sleep quality in adolescents [33]. Therefore, fostering active lifestyles through school sports, extracurricular activities, and daily routines is essential for promoting cognitive development and emotional well-being during adolescence.

CONCLUSION

This study concludes that physical activity is significantly associated with cognitive function and sleep quality among adolescents at SMAN 1 Ngamprah. Higher levels of physical activity are linked to better cognitive performance and more optimal sleep quality. These findings underscore the importance of promoting regular physical activity as a key determinant of cognitive health and sleep quality during adolescence.

Ethical consideration, competing interest and source of funding

-Ethical considerations were comprehensively addressed throughout all stages of the study. The research adhered to the principles of autonomy, beneficence, non-maleficence, and justice. Participation was voluntary and free from coercion, and respondents had the right to refuse or withdraw at any time without academic consequences. Confidentiality and anonymity were ensured by excluding personal identifiers from data collection forms and using the data solely for research purposes. Ethical approval was obtained from the Health Research Ethics Committee of Universitas Jenderal Achmad Yani Cimahi under reference number 119/KEPK/FITKes-Unjani/VII/2025.

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