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The effect of physical activity, body mass index, and sleep quality on students' physical fitness

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ABSTRACT

This study aimed to examine the direct and indirect effects of physical activity, body mass index, and sleep quality on students' physical fitness. This quantitative study used a path analysis design involving 85 students from SMA Pembangunan Laboratory, Padang State University. Physical fitness was measured using the Nusantara Student Fitness Test, physical activity using PAQ-A/GPAQ, body mass index through anthropometric measurement, and sleep quality using the Pittsburgh Sleep Quality Index. Physical activity significantly affected physical fitness ($\beta = 0.352$, $p < 0.001$), and sleep quality also had a significant effect ($\beta = 0.353$, $p < 0.001$). Body mass index showed no significant effect ($\beta = -0.026$, $p = 0.786$). The model explained 30.4% of physical fitness variance. Physical activity and sleep quality are key determinants of students' physical fitness.

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Introduction

Physical fitness is widely recognized as a fundamental indicator of adolescents' health because it reflects the integrated functioning of the cardiovascular, musculoskeletal, metabolic, and neuromotor systems. Beyond supporting daily physical performance, adequate physical fitness contributes to disease prevention, psychological well-being, cognitive function, and academic achievement (Godoy-Cumillaf et al., 2023; Welis & Tri Mario, 2023). Despite these benefits, evidence indicates a continuous decline in physical fitness among adolescents worldwide, largely driven by increasingly sedentary lifestyles and unhealthy behavioral patterns. The World Health Organization reports that more than 80% of adolescents fail to achieve the recommended level of daily physical activity, thereby increasing the risk of obesity, cardiovascular disease, metabolic disorders, and reduced functional capacity later in life (Dodd et al., 2023; Hébert et al., 2020). Similar trends have also been observed in Indonesia, where rapid technological development, prolonged screen exposure, and reduced participation in organized sports have substantially changed adolescents' lifestyles and may adversely affect their physical fitness (Welis & Tri Mario, 2023). These conditions highlight the need to identify modifiable factors that can effectively improve adolescents' physical fitness within the Indonesian educational context.

Among the various determinants of physical fitness, physical activity has consistently been identified as the most influential behavioral factor. Regular participation in moderate-to-vigorous physical activity induces physiological adaptations, including improved cardiac output, enhanced oxygen utilization, increased muscle strength, greater mitochondrial efficiency, and better metabolic regulation, all of which contribute to higher physical fitness. Numerous studies have demonstrated that physically active adolescents exhibit significantly

superior cardiorespiratory endurance, muscular fitness, and overall health compared with their less active peers (Chen, 2017; Eddolls et al., 2018). However, the prevalence of insufficient physical activity among adolescents remains alarmingly high because of excessive screen time, dependence on digital technology, and declining engagement in recreational and school-based sports. Consequently, physical inactivity has become a major public health concern that not only reduces physical fitness but also accelerates the development of various chronic health problems during adolescence and adulthood (Aniśko et al., 2025; Ayán-Pérez et al., 2024; Dewi et al., 2021).

Body mass index (BMI) and sleep quality have also been recognized as important factors influencing adolescents' physical fitness, although their roles remain less conclusive than that of physical activity. BMI is commonly used to represent nutritional status and body composition, with previous studies reporting that adolescents with normal BMI generally demonstrate better physical fitness than those who are underweight or overweight (Annesi et al., 2016; Müller et al., 2019). Nevertheless, BMI cannot distinguish fat mass from lean body mass, which may explain the inconsistent findings reported across studies regarding its association with physical fitness. In addition, sleep quality has emerged as a critical physiological factor because adequate sleep facilitates hormonal regulation, muscle recovery, glycogen replenishment, immune function, and neuromuscular restoration, thereby supporting optimal physical performance. Adolescents with poor sleep quality are more likely to experience fatigue, impaired concentration, reduced exercise capacity, and lower physical fitness than those with healthy sleep patterns (Khatoon et al., 2021; Rosa-Guillamón et al., 2020). Previous studies further suggest that adequate sleep duration and high-quality sleep contribute positively to both physical fitness and overall health outcomes among adolescents (Berntzen et al., 2018; Monacis et al., 2024; Vaccaro & Huffman, 2016). Although these variables have frequently been investigated independently, their interrelationships remain insufficiently understood.

Existing evidence demonstrates that physical activity, body mass index, sleep quality, and physical fitness are closely related; however, the relationships reported in previous studies remain fragmented. Most investigations have examined these variables independently or focused only on bivariate associations, limiting a comprehensive understanding of how multiple behavioral and physiological factors interact to influence adolescents' physical fitness. Furthermore, inconsistent findings regarding the contribution of BMI suggest that its association with physical fitness may depend on other modifiable factors, particularly physical activity and sleep quality (Annesi et al., 2016; Müller et al., 2019). Although recent studies have highlighted the importance of sleep for physical performance, the physiological mechanism through which sleep quality may strengthen the effect of physical activity on physical fitness has received relatively limited empirical attention (Khatoon et al., 2021; Monacis et al., 2024; Vaccaro & Huffman, 2016). Consequently, the current body of evidence has not yet provided an integrated explanation of the pathways linking these variables.

This limitation is particularly evident in developing countries, including Indonesia, where adolescents are experiencing rapid lifestyle transitions characterized by declining physical activity, increasing sedentary behavior, irregular sleep patterns, and changing nutritional status. Despite these trends, empirical studies simultaneously examining physical activity, body mass index, sleep quality, and physical fitness among Indonesian adolescents remain scarce (López-Gil et al., 2021; Wilson et al., 2019). Moreover, previous studies conducted in Indonesia have generally emphasized direct associations without exploring the potential mediating role of sleep quality within a comprehensive analytical framework. Considering the sociocultural and environmental differences between Indonesia and developed countries, findings from international studies cannot be generalized directly. Therefore, further investigation is required to generate context-specific evidence that can support effective school-based health promotion strategies for Indonesian adolescents.

Based on these considerations, this study aims to examine the direct and indirect effects of physical activity, body mass index, and sleep quality on students' physical fitness using path analysis. The novelty of this study lies in the development of an integrated causal model that simultaneously evaluates the direct contributions of physical activity and body mass index as well as the mediating role of sleep quality in explaining variations in physical fitness. This framework extends previous studies that predominantly investigated these determinants separately and provides a more comprehensive understanding of the behavioral and physiological mechanisms underlying adolescent physical fitness (Creasy et al., 2022; Rubio-Arias et al., 2024). The findings are expected to enrich the literature on adolescent health while providing scientific evidence for designing integrated school-based interventions that promote active lifestyles, healthy sleep behaviors, and sustainable improvements in students' physical fitness.

Method

This study employed a quantitative correlational design using path analysis to examine the direct and indirect relationships among physical activity, body mass index (BMI), sleep quality, and physical fitness among high school students. Physical activity (X_1) and BMI (X_2) were specified as exogenous variables, sleep quality (X_3) as the intervening variable, and physical fitness (Y) as the endogenous variable. Path analysis was selected because it enables the simultaneous estimation of direct and indirect effects within a theoretically developed causal model. The study was conducted in July 2024 at SMA Pembangunan Laboratory, Universitas Negeri Padang, Indonesia. The study population comprised 566 students from Grades X–XII, and a sample of 85 participants was determined using the Slovin formula with a 95% confidence level. Participants were selected through simple random sampling to ensure that each student had an equal probability of being included in the study.

Data were collected using standardized and validated instruments. Physical fitness was assessed using the Tes Kebugaran Pelajar Nusantara (TKPN), physical activity was measured using the Physical Activity Questionnaire for Adolescents (PAQ-A), BMI was calculated from anthropometric measurements of body weight and height, and sleep quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI). Descriptive statistics were first employed to summarize the characteristics of each variable, followed by assumption testing, including normality and linearity analyses, to verify the suitability of the data for path analysis. Hypothesis testing was subsequently performed using path analysis in IBM SPSS Statistics version 25.0 to estimate standardized path coefficients, significance levels, and direct and indirect effects among the study variables. This analytical approach enabled a comprehensive evaluation of the structural relationships proposed in the research model.

Results and Discussions

The results of this study are presented systematically to provide a comprehensive overview of the relationships among physical activity, body mass index, sleep quality, and physical fitness among high school students. The analysis begins with descriptive statistics to illustrate the characteristics and distribution of each study variable, followed by assumption testing to verify the suitability of the data for path analysis. Subsequently, direct and indirect effects among variables are examined through path analysis and hypothesis testing to determine the magnitude and significance of the relationships within the proposed conceptual model.

Table 1. Descriptive Statistics of Study Variables

Variable	N	Minimum	Maximum	Mean	SD	Variance	Category
Physical Activity (X1)	85	1	4	2.39	0.557	0.310	Low
Body Mass Index (X2)	85	1	3	2.69	0.557	0.310	Normal
Sleep Quality (X3)	85	0	1	0.47	0.520	0.252	Poor
Physical Fitness (Y)	85	1	4	2.05	0.562	0.316	Moderate

Table 1 presents the descriptive characteristics of all variables included in the study. Physical activity showed a relatively low average score (M = 2.39, SD = 0.557), while body mass index was generally within the normal range (M = 2.69, SD = 0.557). Sleep quality was predominantly poor (M = 0.47, SD = 0.520), and physical fitness was classified as moderate (M = 2.05, SD = 0.562). The relatively low standard deviations indicate that the responses were fairly homogeneous across participants.

Table 2 demonstrates that most students had low physical activity levels (58%) and low physical fitness levels (49%). The majority of participants (74%) exhibited normal body mass index, whereas more than half of the students (53%) experienced poor sleep quality. These findings collectively suggest that insufficient physical activity and inadequate sleep remain prevalent among adolescents despite generally normal nutritional status.

Table 2. Distribution of Participants Across Variable Categories

Category	Physical Activity n (%)	Body Mass Index n (%)	Sleep Quality n (%)	Physical Fitness n (%)
Very Good	0 (0.0)			1 (1.0)
Good	6 (7.0)		40 (47.0)	4 (5.0)
Moderate/Normal	18 (21.0)	63 (74.0)		38 (45.0)
Low	49 (58.0)	10 (12.0)	45 (53.0)	42 (49.0)
Very Low	12 (14.0)	1 (1.0)		0 (0.0)
Overweight		8 (9.0)		
Obesity		3 (4.0)		

Table 3. Results of Assumption Testing

Assumption Test	Variable Relationship	Sig.	Decision
Normality (Kolmogorov-Smirnov)	Residuals	0.078	Normal
Linearity	Physical Activity to Physical Fitness	0.962	Linear
Linearity	Body Mass Index to Physical Fitness	0.465	Linear
Linearity	Sleep Quality to Physical Fitness	0.282	Linear

The normality test produced a significance value of 0.078, exceeding the threshold of 0.05 and indicating normally distributed residuals. Furthermore, all predictor variables demonstrated linear relationships with physical fitness, as evidenced by significance values greater than 0.05. Therefore, the assumptions required for path analysis were satisfactorily fulfilled.

Table 4. Direct Effects Among Variables

Path	Standardized Beta (β)	Sig.	Decision
Physical Activity to Sleep Quality	0.232	0.036	Significant
Body Mass Index to Sleep Quality	0.055	0.613	Not Significant
Physical Activity to Physical Fitness	0.352	0.000	Significant
Body Mass Index to Physical Fitness	-0.026	0.786	Not Significant
Sleep Quality to Physical Fitness	0.353	0.000	Significant

Physical activity significantly predicted sleep quality ($\beta = 0.232$, $p = 0.036$) and physical fitness ($\beta = 0.352$, $p < 0.001$). Likewise, sleep quality positively influenced physical fitness ($\beta = 0.353$, $p < 0.001$). In contrast, body mass index did not significantly affect either sleep quality or physical fitness.

Table 5. Direct and Indirect Effects of Variables on Physical Fitness

Predictor	Direct Effect	Indirect Effect Through Sleep Quality	Total Effect	Contribution (%)
Physical Activity	0.352	0.082	0.432	18.7
Body Mass Index	-0.026	0.019	-0.006	-0.0036

Table 5 indicates that physical activity exerted both direct and indirect effects on physical fitness through sleep quality. The total effect of physical activity reached $\beta = 0.432$, contributing 18.7% to the variance in physical fitness. Conversely, body mass index showed a negligible indirect effect and an overall negative total effect, indicating that BMI did not meaningfully contribute to physical fitness within this sample.

The hypothesis testing revealed that physical activity and sleep quality significantly influenced physical fitness, each contributing approximately 12% of the explained variance. Sleep quality also functioned as a mediator that strengthened the effect of physical activity on physical fitness, increasing the total contribution to 18.7%. Meanwhile, body mass index exhibited neither significant direct nor indirect effects. Simultaneously, physical activity, body mass index, and sleep quality collectively explained 30.4% of the variance in physical fitness, indicating that nearly one-third of students' physical fitness can be accounted for by these variables, while the remaining variance is attributable to other unexamined factors.

Table 6. Summary of Hypothesis Testing

Hypothesis	Relationship	β	Contribution (%)	Decision
H1	Physical Activity to Physical Fitness	0.352	12.4	Accepted
H2	Body Mass Index to Physical Fitness	-0.026	-0.07	Rejected
H3	Sleep Quality to Physical Fitness	0.353	12.5	Accepted
H4	Physical Activity to Sleep Quality to Physical Fitness	0.432	18.7	Accepted
H5	Body Mass Index to Sleep Quality to Physical Fitness	-0.006	-0.0036	Rejected
H6	Physical Activity, Body Mass Index, and Sleep Quality to Physical Fitness ($R^2 = 0.304$)		30.4	Accepted

The present study found that the overall physical fitness of students remained suboptimal, with a mean score of 2.05 ± 0.562. Nearly half of the participants (49%) were classified in the low fitness category, while only a small proportion achieved good fitness levels. This finding was accompanied by a low level of physical activity (M = 2.39 ± 0.557), where 58% of students were categorized as having low physical activity and 14% as very low. These results indicate that insufficient participation in regular physical activity remains a major concern among adolescents and may partly explain the moderate-to-low level of physical fitness observed in this study. This pattern is consistent with previous evidence showing that physically inactive adolescents generally exhibit lower cardiorespiratory endurance, muscular performance, and overall health status than their physically active peers (Aniśko et al., 2025; Ayán-Pérez et al., 2024; Dewi et al., 2021). Considering the rapid growth of sedentary lifestyles among Indonesian adolescents, these findings further emphasize the importance of promoting regular physical activity as a primary strategy for improving health-related physical fitness.

Path analysis demonstrated that physical activity exerted a positive and significant direct effect on physical fitness ($\beta = 0.352$, $p < 0.001$), explaining 12.4% of the variance in physical fitness. Although this contribution was statistically significant, it also indicates that physical activity alone is insufficient to explain overall physical fitness, suggesting the involvement of additional behavioral and physiological determinants. Physiologically, regular physical activity enhances cardiovascular efficiency, muscular strength, metabolic function, and oxygen utilization, thereby improving functional capacity and exercise performance. The magnitude of the standardized coefficient obtained in this study is comparable to previous findings reporting that adolescents who consistently engage in moderate-to-vigorous physical activity achieve significantly better fitness outcomes than their less active counterparts (Annesi et al., 2017; Bai et al., 2024; Boddy et al., 2025). Therefore, the present findings reinforce the established evidence that increasing physical activity remains one of the most effective approaches to enhancing adolescents' physical fitness.

Sleep quality also emerged as a significant determinant of physical fitness. More than half of the participants (53%) reported poor sleep quality, and path analysis revealed that sleep quality significantly influenced physical fitness ($\beta = 0.353$, $p < 0.001$), accounting for 12.5% of the explained variance. Interestingly, the magnitude of this effect was slightly greater than that of physical activity, indicating that adequate sleep contributes substantially to maintaining optimal physical fitness. From a physiological perspective, sufficient sleep facilitates hormonal balance, muscle protein synthesis, glycogen replenishment, tissue repair, and neuromuscular recovery, all of which support physical performance and exercise adaptation. These findings are consistent with previous studies demonstrating that adolescents with better sleep quality generally exhibit superior physical fitness and overall health outcomes (Jalal et al., 2021; Kurniawan et al., 2023; Weaver et al., 2020). Collectively, these findings suggest that physical fitness is influenced not only by active movement behaviors but also by adequate physiological recovery, highlighting the importance of integrating sleep health into school-based physical fitness promotion programs.

Another important finding of this study is that sleep quality partially mediated the relationship between physical activity and physical fitness. Physical activity significantly improved sleep quality ($\beta = 0.232$, $p = 0.036$), while the indirect effect of physical activity on physical fitness through sleep quality reached 0.082, resulting in a total effect of 0.432 and an overall contribution of 18.7%. These findings indicate that the benefits of physical activity extend beyond direct physiological adaptations by improving recovery processes through better sleep quality. Regular physical activity has been shown to enhance sleep efficiency, regulate circadian rhythms, and improve hormonal responses associated with recovery, thereby facilitating better physical performance. Consequently, adolescents who maintain an active lifestyle are more likely to experience

restorative sleep, which subsequently supports higher physical fitness. This finding strengthens the conceptual proposition that physical activity and sleep quality are complementary health behaviors rather than independent determinants of physical fitness and is consistent with previous studies highlighting the interconnected roles of these variables in adolescent health (Li et al., 2025; Mahfouz et al., 2020; Saat et al., 2021).

In contrast, body mass index did not demonstrate either significant direct or indirect effects on physical fitness. Although 74% of participants were classified as having a normal BMI, the direct effect of BMI on physical fitness was negative and statistically insignificant ($\beta = -0.026$, $p = 0.786$), while the indirect effect through sleep quality was negligible ($\beta = -0.006$). These findings suggest that BMI alone may not adequately represent adolescents' physical fitness because it reflects body weight relative to height without distinguishing lean body mass from fat mass. Furthermore, the predominance of participants within the normal BMI category may have reduced the variability required to detect meaningful statistical associations. This interpretation is supported by previous studies reporting that the relationship between BMI and physical fitness is influenced by body composition, age, and habitual physical activity rather than BMI alone (Albqoor & Shaheen, 2021; Liu et al., 2021; Özduran & Yücecan, 2024). Therefore, future studies should consider incorporating more comprehensive indicators of body composition, such as body fat percentage or skeletal muscle mass, to better explain variations in adolescents' physical fitness.

Collectively, physical activity, body mass index, and sleep quality explained 30.4% of the variance in physical fitness ($R^2 = 0.304$, $p < 0.001$), indicating that the proposed model possessed moderate explanatory power. Nevertheless, approximately 69.6% of the variance remained unexplained, suggesting that physical fitness is a multidimensional outcome influenced by additional factors, including dietary habits, sedentary behavior, screen time, genetic predisposition, psychological well-being, motivation, and participation in organized sports. These findings provide important theoretical evidence that adolescents' physical fitness should be understood through an integrated behavioral and physiological perspective rather than a single risk factor. From a practical standpoint, schools should implement comprehensive health promotion programs that simultaneously encourage regular physical activity and healthy sleep behaviors instead of focusing solely on nutritional status. Such integrated interventions are likely to produce greater improvements in adolescents' physical fitness and long-term health outcomes (Cicek et al., 2025; Ercan et al., 2021; Park & Suh, 2020).

Conclusions

This study concludes that physical activity and sleep quality are significant determinants of students' physical fitness, whereas body mass index does not significantly contribute to either the direct or indirect pathways influencing physical fitness in this population. Physical activity improves physical fitness both directly and indirectly through enhanced sleep quality, confirming the mediating role of sleep quality within the proposed causal model. These findings extend previous evidence by demonstrating that adolescents' physical fitness is better explained through an integrated behavioral model rather than by considering each determinant independently. Therefore, school-based health promotion programs should prioritize increasing students' participation in regular physical activity while simultaneously fostering healthy sleep habits to achieve sustainable improvements in physical fitness. Future studies are recommended to incorporate additional determinants, such as dietary habits, sedentary behavior, body composition, and psychological factors, to develop a more comprehensive model of adolescent physical fitness.

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