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Adherence to 24-hour movement guidelines, BMI, and academic performance in primary school children

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Abstract

The 24-Hour Movement Guidelines integrate physical activity, screen time, and sleep as interrelated behaviors that influence children's health and academic outcomes. However, evidence from Indonesian primary school populations remains limited. This study aimed to examine adherence to the 24-Hour Movement Guidelines and to analyze its associations with body mass index (BMI) and academic performance among primary school children in Jambi City. A cross-sectional study was conducted involving 325 students (mean age 9.79 ± 0.90 years). Physical activity was assessed using the PAQ-C, screen time through a sedentary behavior questionnaire, and sleep quality using the Pittsburgh Sleep Quality Index (PSQI). BMI was calculated from measured height and weight, and academic performance was obtained from school records. Data were analyzed using descriptive statistics, Chi-square tests, Pearson correlation, and multiple linear regression. Overall adherence to all guideline components was low. Regression analysis showed that physical activity was negatively associated with BMI ($B = -0.027$, $p = 0.006$), while screen time ($B = 0.056$, $p = 0.016$) and sleep quality score ($B = 0.041$, $p < 0.001$) were positively associated with BMI. In relation to academic performance, sleep quality showed a positive association ($B = 0.079$, $p < 0.001$), followed by screen time ($B = 0.107$, $p = 0.039$), whereas physical activity showed a negative association ($B = -0.066$, $p = 0.002$). The results demonstrate that each component of movement behavior exhibits distinct statistical associations with BMI and academic performance among primary school children, without implying causal relationships due to the cross-sectional design.

Keywords: 24-Hour movement guidelines, body mass index, screen time, academic performance.

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Authors contribution: a – Preparing concepts; b – Formulating methods; c – Conducting research; d – Processing results; e – Interpretation and conclusions; f - Editing the final version.

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INTRODUCTION

Consistently performing physical activity with appropriate attention to frequency, duration, and intensity has been shown to contribute to improvements in physical fitness (Carbone et al., 2021; Tarigan et al., 2022). Previous studies have generally examined the health effects of each movement behavior, namely, physical activity, sedentary behavior, and sleep, separately (Groves et al., 2024; Sampasa-Kanyinga et al., 2020). However, such an approach may lead to incomplete interpretations of health outcomes, as it does not account for the inherent interactions and time trade-offs between behaviors within a finite 24-hour period. Time allocated to one behavior inevitably reduces time available for others, indicating that these components are not independent but dynamically interrelated. In recent years, the concept of the 24-hour movement cycle has gained increasing attention from researchers and public health institutions (Zhao et al., 2024). Emerging evidence indicates that all behaviors within the movement spectrum are interrelated and collectively contribute to overall health. In other words, "every activity within a full 24-hour day" plays an important role in individual health and well-being, making balance among the three main components, physical activity, sedentary behavior, and sleep duration, crucial (Janssen et al., 2020).

This paradigm shift underlies the publication of the Canadian 24-Hour Movement Guidelines for children and adolescents aged 5–17 years in 2020 as a reference for the formulation of child and adolescent health policies (Zhao et al., 2024). These guidelines recommend at least 60 minutes of daily physical activity, limiting screen use to a maximum of 2 hours per day, and ensuring uninterrupted, good-quality sleep for 9–11 hours (Janssen et al., 2017). From a physiological perspective, adequate physical activity supports cardiovascular fitness, musculoskeletal development, and energy expenditure, while excessive sedentary behavior, particularly prolonged screen time, may reduce metabolic efficiency and contribute to adiposity through lower energy expenditure and altered metabolic regulation (Carson et al., 2017; Chaput et al., 2016). At the same time, sufficient and good quality sleep plays a critical role in hormonal balance, including the regulation of leptin and ghrelin, which are associated with appetite control and body weight (Eum & Jung, 2021). Alongside this, scientific evidence on this topic continues to grow, with several recent systematic reviews emphasizing that research on 24-hour movement behaviors is still in its early stages. Researchers have also highlighted the importance of studies that evaluate compliance with the 24-hour recommendations while simultaneously considering various factors that may influence such compliance, including academic achievement and body mass index (Baillot et al., 2022; Bao et al., 2024). Importantly, these three movement behaviors do not operate independently but function as an integrated system within a 24-hour cycle that simultaneously influences multiple domains of child development. Adequate physical activity contributes to improved cerebral blood flow and neuroplasticity, which are associated with enhanced executive function, including attention control and working memory.

In contrast, excessive sedentary behavior, particularly prolonged screen time, may displace cognitively stimulating activities and reduce opportunities for active engagement, thereby negatively affecting cognitive development. At the same time, sufficient and high-quality sleep plays a critical role in memory consolidation, emotional regulation, and neural recovery processes, which are essential for optimal cognitive functioning and learning readiness. Therefore, the balance among physical activity, sedentary behavior, and sleep is not only important for physiological and metabolic regulation but also for supporting children's executive function and their readiness to engage effectively in academic learning.

Recent findings indicate that children who meet all three recommendations have a lower odds ratio for obesity than those who do not meet the recommendations (OR = 0.28, 95% CI 0.18–0.45) (Roman-Viñas et al., 2016). Other studies have also shown that higher BMI is associated with lower levels of physical activity, increased sedentary time, and poorer sleep quality (Oberle et al., 2025). In addition, adherence to the 24-Hour Movement Guidelines has been associated with improved academic performance among adolescents (Tapia-Serrano, García-Hermoso, et al., 2022). A systematic meta-analysis found that among children and adolescents, compliance with all three recommendations (physical activity, sleep duration, and screen time limitation) is small but positively correlated with academic achievement (r = 0.17; 95% CI = 0.10–0.24) (Bao et al., 2024). However, evidence from Indonesia remains limited. Previous studies in the Indonesian context have primarily assessed movement behaviors separately, such as physical activity, sedentary behavior, or sleep, rather than examining them as integrated components within a 24-hour behavioral framework.

Furthermore, limited evidence is available regarding the simultaneous relationship between adherence to the 24-Hour Movement Guidelines, body mass index (BMI), and academic achievement among primary school children. Nonetheless, much data suggest that the extent to which Indonesian students comply with all elements of the 24-Hour Movement Guidelines, and the correlation between this adherence and BMI and academic achievement, remains unclear. This information is crucial for facilitating health monitoring initiatives and for guiding the formulation of more effective government policies.

Data from the 2023 Indonesian Health Survey (SKI) revealed that only 6.79% of children had physical fitness levels categorized as good or above. Meanwhile, 77.12% of children were classified as having poor or very poor physical fitness (Saparia et al., 2025). Additionally, the main barrier to engaging in physical activity is limited time (48.7%), which reflects a low awareness of the importance of physical activity (Saparia et al., 2025). The absence of complete data on children's compliance with the 24-Hour Movement Guidelines, particularly concerning health indicators like body weight and academic achievement, constitutes a pressing issue that necessitates additional examination.

Based on this background, the present study aims to determine the prevalence of adherence to the 24-Hour Movement Guidelines among primary school children in Jambi City and to examine the associations between adherence components and both body mass index (BMI) and academic performance. Beyond reporting prevalence, this study contributes to the scientific literature by providing empirical evidence on the multidimensional relationships between daily movement behaviors, physical activity, screen time, and sleep, and both health and educational outcomes within a single analytical framework. Importantly, evidence from developing countries remains limited, particularly among elementary school populations. By situating the analysis within the context of Indonesian primary school children, this study expands the global evidence base. It offers context-specific insights into how integrated movement behaviors relate to physical health and academic achievement in low- and middle-income settings.

METHOD

The study employed a cross-sectional survey design conducted in primary schools in Jambi City, Indonesia, an urban area with diverse socioeconomic and educational backgrounds, making it relevant for examining daily movement behaviors among elementary school children in a developing country context. This design allowed for efficient assessment of prevalence and associations between adherence to the 24-Hour Movement Guidelines, body mass index (BMI), and academic performance within a single time frame, although causal relationships cannot be established.

The target population consisted of primary school students aged 8–12 years enrolled in public schools in Jambi City. A purposive sampling approach was used to ensure participants met predefined inclusion criteria and to facilitate administrative access. Schools were selected in coordination with the Jambi City Department of Education based on geographic representation, willingness to participate, and availability of complete academic records. Eligible students were those aged 8–12 years, enrolled in the corresponding grade levels, physically healthy, and with parental consent. From approximately 1,176 eligible students, a total of 325

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students (170 boys and 155 girls) met the criteria and completed all study measurements.

Research Instruments

Anthropometry

Information on children's age was collected using a self-administered questionnaire under the supervision of trained research assistants and classroom teachers. Standardized instructions and limited assistance—such as clarifying item wording and reading questions aloud—were provided to ensure comprehension without influencing responses. Reported age data were verified using official school records, and discrepancies were corrected. Anthropometric measurements were conducted using standardized procedures, with height measured with a Gea HT721 stature meter and body weight measured with an OMRON Karada Scan HBF-375 scale, with participants barefoot and wearing light clothing. Each measurement was taken twice and averaged to reduce error. To ensure data quality and minimize reporting bias, research assistants were trained, pilot testing was conducted, and data were checked for completeness and consistency using a double-entry procedure.

Physical Exercise

Children's physical activity was assessed using the Physical Activity Questionnaire for Children (PAQ-C), a self-report instrument designed to evaluate physical activity over the previous seven days among children aged 8–14 years (Benítez-Porres et al., 2016). The questionnaire consists of nine core items, with optional additional items in certain versions, capturing various domains of physical activity, including school-time activity, recess, after-school activities, and weekend activity patterns. Each item is scored using a five-point Likert scale ranging from very inactive (score = 1) to very active (score = 5), with intermediate categories of slightly inactive (score = 2), somewhat active (score = 3), and active (score = 4).

The PAQ-C has been widely used and demonstrates acceptable validity and reliability across different populations. Previous studies have reported good internal consistency, with Cronbach's alpha values typically ranging from 0.70 to 0.85, indicating reliable measurement of physical activity levels in children (Benítez-Porres et al., 2016). In addition, the instrument has shown satisfactory construct validity in assessing general physical activity patterns among school-aged populations. In this study, questionnaire administration was conducted under supervision to ensure that all participants clearly understood each item. Prior to data collection, the instrument was reviewed for linguistic clarity and contextual suitability for Indonesian primary school children. The revised PAQ-C scoring method involved calculating the mean score of the nine items by aggregating the scores and dividing by the number of items. Physical activity levels were subsequently categorized into two groups based on WHO recommendations (2020) and previous research: a PAQ-C score ≥ 3 indicated that the child met the recommended level of at least 60 minutes of daily physical activity, while a score < 3 indicated that the guideline was not met.

Screen Time

Screen time duration was measured using the Leisure-Time Sedentary Behavior Questionnaire (Atencio-Osorio et al., 2021), originally developed for Spanish adolescents. Prior to use, a systematic language and cultural adaptation process was conducted. The instrument was translated into Indonesian by two bilingual experts and then synthesized into a single version. A back-translation was subsequently performed by independent translators to ensure semantic equivalence with the original version. Content validity was evaluated by a panel of experts in sports science, pediatric health, and educational psychology, who assessed item relevance, clarity, and cultural appropriateness. Minor revisions were made based on their feedback.

A pilot test was conducted among primary school children to ensure comprehension, and internal consistency showed acceptable reliability (Cronbach's alpha ≥ 0.70). Participants reported their daily screen-based activity time (television, video games, computer, and mobile phone). Average daily screen time was calculated using a 5:2 weighted formula:

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((weekday × 5) + (weekend × 2)) / 7, and total screen time was obtained by summing all activities.

Quality of Sleep

Sleep quality and patterns during the previous month were assessed using the Pittsburgh Sleep Quality Index (PSQI) (Wang et al., 2022). The objective is to assess subjective sleep quality, encompassing not just duration but also factors such as regularity, sleep disruptions, and daily dysfunction arising from sleep issues. The PSQI has 19 self-reported items categorized into seven component scores. Every component is scored on a scale of 0 to 3, with 0 denoting no difficulty, 1 denoting mild difficulty, 2 denoting moderate difficulty, and 3 denoting severe difficulty.

Although originally developed for adults, the PSQI has been applied in adolescent and school-aged populations and has demonstrated acceptable validity and reliability in these groups (Wang et al., 2022). Previous studies have reported adequate internal consistency and construct validity when used among children and adolescents, supporting its suitability for assessing sleep-related outcomes in younger populations.

In this study, the administration of the PSQI was conducted under supervision to ensure that participants clearly understood each item. Minor language adjustments were made to improve clarity and age-appropriateness for primary school children. These procedures were implemented to enhance the accuracy and reliability of responses in the study population. Then, the purposes of the PSQI components are explained in Table 1 below:

Table 1. Purpose of PSQI Components

No	PSQI Component	Brief Description
1	Subjective Quality of Sleep	Respondents' overall perception of their sleep quality
2	A Latency of Sleep	The amount of time required to fall asleep after going to bed
3	Duration of Sleep	The total length of the respondent's main sleep period per night
4	Sleep Effectiveness	The proportion of time spent in bed to total sleep time
5	Sleep Disorders	Frequency of disturbances such as nighttime awakenings, pain, nightmares, etc.
6	Using Sleep Aids	How often do respondents use sleep medications
7	Diurnal Dysfunction	Difficulties performing daytime activities due to sleepiness or fatigue

The PSQI scoring process commences with the completion of all 19 questions that encapsulate the respondent's sleep experience over the preceding month. The response data will be categorized into the seven components of the Pittsburgh Sleep Quality Index (PSQI): subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disruptions, usage of sleeping medicine, and daytime dysfunction. A scale from 0 to 3 is used to evaluate each component. The seven component ratings were combined to get the overall PSQI score, which ranges from 0 to 21. Higher scores indicate lower-quality sleep. A score of ≤5 indicates good sleep quality, a score of 6–10 shows poor sleep quality, and a score of >10 suggests very poor sleep quality or severe sleep disruptions.

Academic Performance

Academic performance data were obtained from students' most recent semester report card scores. To ensure comparability across schools with potentially different grading systems, scores were standardized to a common percentage scale using school records. Where minor variations in grading criteria existed, scores were aligned with the national grading framework used in Indonesian primary education. Following standardization, academic performance was categorized into three levels: High (≥85), Medium (70–84), and Low (<70) (Tapia-Serrano, Sánchez-Oliva, et al., 2022). The use of categorized grades was intended to minimize inter-school grading variability and to provide a consistent basis for statistical comparison across participants.

Data Analysis

All variables were analyzed using descriptive statistics. Based on the Canadian 24-Hour Movement Guidelines (Tremblay et al., 2016), physical activity, screen time, and sleep duration were categorized into “meeting” and “not meeting” the recommendations. BMI was calculated from body weight, and academic performance was classified into low, medium, and high categories. Descriptive statistics included frequencies and percentages for categorical variables, and means, standard deviations, and ranges for numerical variables.

Group differences were analyzed using the Chi-square test for categorical variables and the Independent Samples t-test or Mann–Whitney U test for numerical variables, depending on data distribution. Pearson

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correlation analysis was used to examine relationships between physical activity, sleep duration, screen time, BMI, and academic performance.

RESULT

Anthropometric data, such as gender, were presented as percentages, whereas age, height, and body weight were reported as mean values with standard deviations, and significance levels between the two groups were reported. A total of 325 participants, all of whom were primary school students in Jambi City, were included in the study. Of these, 170 participants (52.3%) were boys and 155 participants (47.7%) were girls (see Figure 1).

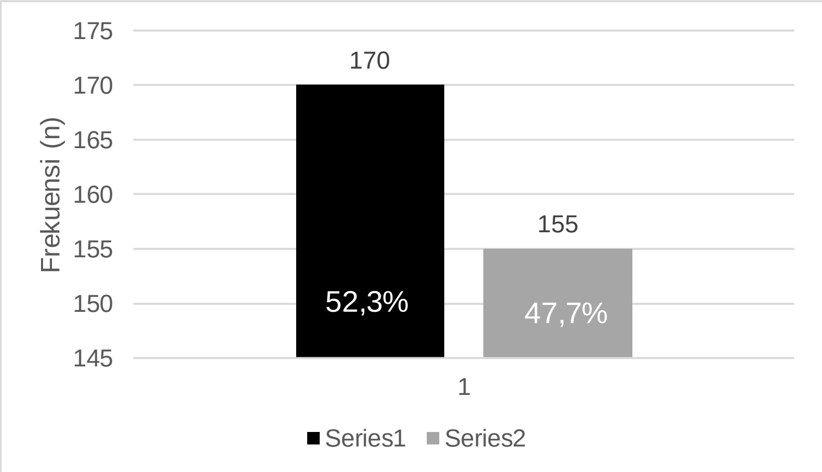

Figure 1. Chart of Respondent Characteristics by Gender

Table 2 shows that there were no statistically significant differences between boys and girls in age and body weight (p > 0.05). However, boys were significantly taller than girls (p < 0.05). Overall, the anthropometric characteristics between groups were relatively comparable, except for height (see Table 2).

Table 2. Anthropometric Data Comparison for Boys and Girls

Variable	Total (N=325)	Group		*p-value*
		Boys (n=170)	Girls (n=155)	
Age (years)	9.79 ± 0.90	9.77 ± 1.02	9.80 ± 0.75	0.766
Weight (kg)	31.37 ± 6.19	31.84 ± 6.05	30.85 ± 6.33	0.154
Height (cm)	133.26 ± 7.50	134.22 ± 7.13	132.20 ± 7.76	0.015*

*significance *p*<0.05

As presented in Table 3, adherence to daily physical activity recommendations differed significantly between boys and girls, with boys demonstrating higher compliance (χ^2, $p < 0.001$). In contrast, no meaningful gender differences were observed in screen time distribution. Regarding sleep quality, the majority of students in both groups were classified as having poor or very poor sleep quality, with girls showing a relatively higher proportion in the poor category (see Table 3).

Table 3. Prevalence of 24-Hour Movement Guidelines in Male and Female Groups

Variable	Total (N=325) n (%)	Groups	
		Boys (n=170) n (%)	Girls (n=155) n (%)
Physical activity			
>60 minutes/ day	136 (41.8)	94 (55.3)	76 (44.7)**
<60 minutes/ day	189 (58.2)	42 (27.1)	113 (72.9)**
Screen Time			
≤2 hours/ day	27 (8.3)	15 (8.8)	12 (7.7)
>2-4 hours/ day	100 (30.7)	59 (34.7)	41 (26.5)
>4 hours/ day	198 (60.9)	96 (56.5)	102(65.8)
Sleep Duration			
Good	17 (5.2)	14 (8.2)	3 (1.9)**
Poor	98 (30.2)	40 (23.5)	58 (37.4)**
Very poor	209 (64.3)	116 (68.2)	93 (60.6)**

Screen time distribution did not differ significantly between boys and girls, with the majority of participants in both groups exceeding the recommended daily limit. Sleep quality assessed using the Pittsburgh Sleep Quality Index (PSQI) showed that most participants were classified as having poor or very poor sleep quality. This pattern was consistent across both boys and girls, with only a small proportion categorized as having good sleep quality.

Table 4. Prevalence of BMI and Academic Achievement in Male and Female Groups

Variable	Total (N=325) n (%)	Group	
		Boys (n=170) n (%)	Girls (n=155) n (%)
Health indicators (BMI)			
Under Weight	13 (4.0)	6 (3.5)	7 (4.5)
Normal	132 (40.6)	67 (39.4)	65 (41.9)
Over Weight	125 (38.5)	71 (41.8)	54 (34.8)
Obese	55 (16.9)	26 (15.3)	29 (18.7)
Academic Performance			
High	64 (19.7)	19 (11.2)	45 (29.0)
Moderate	133 (40.9)	62 (36.5)	71 (45.8)
Low	128 (39.4)	89 (52.4)	39 (25.2)

No significant association was found between BMI categories and gender ($p > 0.05$), indicating that the distribution of BMI was comparable between boys and girls. In contrast, academic performance differed significantly by gender ($p < 0.001$). Girls were more frequently represented

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in the higher achievement categories, whereas boys were more commonly found in the lower category (see Table 4).

Table 5. The 24-Hour Movement Guidelines and BMI were put through a multiple linear regression analysis.

Guideline Component	Body Mass Index							
	B	Beta	t	Sig.	CI 95%		TL	VIF
					lower	Upper		
Physical Activity	-0.027	-0.160	-2.795	0.006	-0.045	-0.008	0.851	1.174
Screen Time	0.056	0.136	2.431	0.016	0.010	0.101	0.883	1.133
Sleep Duration	0.041	0.287	5.271	0.000	0.026	0.056	0.946	1.057

Model Summary:
R2 = 0.101
Adjusted R2 = 0.092

Physical activity showed a significant negative association with BMI (B = −0.027, p = 0.006). In contrast, screen time (B = 0.056, p = 0.016) and sleep quality score (B = 0.041, $p < 0.001$) were positively associated with BMI (see Table 5).

Table 6. Findings of the 24-Hour Movement Guidelines on Academic Achievement: Multiple Linear Regression Analysis

Guideline Component	Academic Performance							
	B	Beta	t	Sig.	CI 95%		TL	VIF
					lower	Upper		
Physical Activity	-0.066	-0.179	-2.092	0.001	-0.108	-0.024	0.851	1.174
Screen Time	0.107	0.118	2.075	0.039	0.006	0.208	0.883	1.133
Sleep Duration	0.079	0.251	4.574	0.001	0.045	0.113	0.946	1.057

Model Summary:
R2 = 0.082
Adjusted R2 = 0.074

Academic performance was significantly associated with all components of the 24-Hour Movement Guidelines. Sleep quality showed a positive association (B = 0.079, $p < 0.001$), followed by screen time (B = 0.107, p = 0.039), while physical activity showed a negative association (B = −0.066, p = 0.002) (see Table 6).

DISCUSSION

The study's conclusions show that among elementary school students, the degree of adherence to the 24-Hour Movement Guidelines' components, physical activity, sleep duration, and screen time, varies by group and is correlated with body mass index (BMI). Although not all components consistently demonstrated a significant relationship with BMI, there is a pattern indicating that low adherence to one or more recommendations is correlated with higher BMI, which signals a risk of overweight or obesity.

The findings of this study are generally consistent with previous research indicating that adherence to the 24-Hour Movement Guidelines is associated with both health and academic outcomes (Tapia-Serrano, García-Hermoso, et al., 2022). However, a more nuanced interpretation is required when considering differences in population context. Most prior studies have been conducted in high-income countries, where children typically have more structured physical activity opportunities, regulated screen time, and more consistent sleep routines (Chaput et al., 2016; Tremblay et al., 2016). In contrast, the present study was conducted among primary school children in an Indonesian urban setting, where lifestyle patterns may differ substantially.

From a biological perspective, the associations observed in this study between movement behaviors and BMI can be interpreted in relation to metabolic regulation mechanisms. In the present study, sleep quality score showed a significant positive association with BMI ($B = 0.041$, $p < 0.001$), indicating that poorer sleep quality was linked to higher BMI. This finding is consistent with biological evidence suggesting that insufficient or poor-quality sleep may disrupt hormonal balance, particularly by increasing ghrelin and decreasing leptin levels, which in turn can stimulate appetite and promote excessive energy intake (Eum & Jung, 2021). These findings are consistent with evidence indicating that physical activity, sedentary behavior, and sleep operate as interdependent components within a 24-hour movement cycle, where imbalance in one behavior may reduce time allocation for others and contribute to suboptimal health outcomes in children (Galih Dwi et al., 2024).

Similarly, screen time demonstrated a positive association with BMI ($B = 0.056$, $p = 0.016$), which may reflect prolonged sedentary behavior contributing to reduced energy expenditure. In contrast, physical activity showed a significant negative association with BMI ($B = –0.027$, $p = 0.006$), indicating that higher levels of physical activity were linked to lower BMI

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values. This result aligns with evidence that adequate physical activity increases total daily energy expenditure and helps maintain energy balance (Jakubec et al., 2020; Zhao et al., 2025). More importantly, physical activity, screen time, and sleep should be understood as interdependent behaviors within a fixed 24-hour cycle. Time spent on one behavior inevitably reduces the time available for other behaviors. For example, excessive screen time may displace physical activity and shorten sleep duration, while insufficient sleep may reduce children's readiness to engage in physical activity during the day. This imbalance may contribute to lower energy expenditure, disrupted metabolic regulation, and increased risk of unhealthy weight status within an integrated child health framework.

From a cognitive and educational neuropsychology perspective, the interaction between physical activity, sleep quality, and screen time may also influence cognitive function and academic performance through several mechanisms. Physical activity has been shown to enhance brain function through increased cerebral blood flow, neurogenesis, and synaptic plasticity, particularly in the prefrontal cortex, which is responsible for executive functions such as attention, working memory, and cognitive flexibility (Álvarez-Bueno et al., 2017). The combined pattern of physical activity, sleep quality, and screen time may be understood as a behavioral context that supports or constrains children's cognitive readiness for learning. Physical activity may contribute to executive function by supporting cerebral blood flow, neuroplasticity, and prefrontal cortex activity, which are related to attention control, working memory, and cognitive flexibility. Sleep quality may further support academic functioning through memory consolidation, emotional regulation, and attentional stability. In contrast, excessive screen time may increase cognitive load, reduce sustained attention, and displace both sleep and active learning opportunities. Therefore, the associations observed in this study between sleep quality, screen time, physical activity, and academic performance may reflect the combined influence of these daily behaviors on executive function and readiness to learn, rather than the effect of a single behavior alone.

In contrast, poor sleep quality may impair memory consolidation, reduce attentional control, and negatively affect emotional regulation. Sleep plays a crucial role in strengthening neural connections formed during learning and facilitating long-term memory storage, which directly supports academic performance (Chaput et al., 2016). Excessive screen time may further contribute to reduced cognitive performance by increasing cognitive load and decreasing sustained attention. According to cognitive load theory, prolonged exposure to screen-based stimuli can overload working memory capacity and reduce the efficiency of information processing during learning activities (Radesky & Christakis, 2016). This pattern aligns with findings suggesting that balanced daily movement behaviors, including sufficient physical activity and adequate sleep, are associated with improved cognitive engagement, attention control, and learning outcomes among school-aged children (Rizqy et al., 2025). The association between screen time and academic performance may also be explained through potential mediating mechanisms. Excessive screen exposure may weaken self-regulation, reduce attention control, and disrupt study habits, which can indirectly affect academic performance. In addition, high screen time may interfere with sleep quality, thereby reducing cognitive readiness, memory consolidation, and learning efficiency. These mechanisms suggest that screen time may influence academic outcomes not only directly, but also indirectly through behavioral and cognitive pathways.

Taken together, these findings suggest that the combined pattern of movement behaviors across a 24-hour period may influence both physiological regulation and cognitive functioning. The interaction between adequate physical activity, sufficient sleep, and controlled screen time supports optimal brain function and learning processes, which may explain their associations with academic performance observed in this study (Rollo et al., 2020).

These findings are also in line with previous research showing that children who do not meet the combined recommendations for physical activity, sleep, and screen time are at greater risk of overweight and obesity

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(Carson et al., 2017). Therefore, the statistical results of this study suggest that the combined pattern of movement behaviors is associated with children’s weight status, potentially through biological mechanisms related to energy balance, metabolic regulation, and sleep-related hormonal processes.

Conversely, excessive screen time on digital devices (≥ 2 hours per day) is negatively associated with academic performance. Research from the Canadian 24-Hour Movement Guidelines revealed that excessive screen time was linked to concentration disturbances, reduced study time, and lower academic outcomes. In the context of the 24-hour behavioral combination, Rollo et al. (2020) reported that children who adhere to all three components of the guidelines are more likely to have higher grades compared to those who comply with only one or two components. They concluded that a holistic approach to daily health behaviors is far more effective in improving children’s academic achievement than single-component interventions.

Thus, this study's findings indicate that adherence to the 24-Hour Movement Guidelines is associated with both physical health and academic performance among primary school children. However, given the cross-sectional design, these relationships should be interpreted as associative rather than causal, and caution is required when generalizing these findings to broader policy contexts (Carson et al., 2017; Rollo et al., 2020). This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design does not allow causal conclusions to be drawn between adherence to the 24-Hour Movement Guidelines, BMI, and academic performance. Second, several behavioral variables were assessed using self-report questionnaires, which may be subject to recall bias and reporting bias, particularly among younger children. Third, although data were collected from primary school children in Jambi City, the use of purposive sampling may limit the representativeness of the sample and the generalizability of the findings to broader populations. Future studies should consider longitudinal or experimental designs, objective behavioral measures, and broader sampling strategies.

From a practical perspective, the results highlight that different components of daily movement behaviors are linked to outcomes in distinct ways. In this study, physical activity showed a negative association with BMI, suggesting its relevance in weight management, while sleep quality demonstrated a stronger positive association with academic performance, indicating its importance in learning outcomes. These findings are consistent with previous research showing that physical activity contributes to energy balance and obesity prevention, whereas adequate sleep supports cognitive processes essential for academic achievement (Chaput et al., 2016; Jakubec et al., 2020).

Based on these statistical findings, school-based interventions should adopt a targeted yet integrated approach. Based on these associations, school-based programs that increase opportunities for physical activity may be relevant to BMI-related health monitoring, while sleep hygiene education, including regular sleep schedules and reduced nighttime screen exposure, may be relevant to supporting students' cognitive readiness and academic performance. In addition, managing screen time is important, as excessive screen exposure may displace both physical activity and sleep, thereby indirectly affecting both BMI and learning outcomes (Radesky & Christakis, 2016; Tremblay et al., 2016).

In the context of elementary schools, such strategies include integrating structured physical activity programs, promoting sleep education in collaboration with parents, and implementing guidelines for appropriate screen use in both academic and home environments. These approaches are consistent with evidence suggesting that balanced movement behaviors across a 24-hour period are associated with children's health and academic development, while avoiding the assumption that any single behavior independently determines these outcomes (Rollo et al., 2020; Tapia-Serrano, Sánchez-Oliva, et al., 2022). Further longitudinal or experimental studies are needed to confirm causal relationships.

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CONCLUSION

The findings indicate that not all components of the 24-Hour Movement Guidelines are associated with BMI and academic performance to the same extent, with physical activity showing the strongest negative association with BMI and sleep quality demonstrating the strongest positive association with academic performance, followed by screen time. Given the cross-sectional design, these relationships should be interpreted as associative rather than causal. These results suggest that physical activity is more closely related to weight status, while sleep quality is more strongly associated with academic outcomes, and screen time may relate to both through its association with physical activity and sleep patterns. Based on these associations, school-based approaches that promote physical activity, support healthy sleep habits, and guide appropriate screen use may be relevant for supporting students' health and learning outcomes.

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