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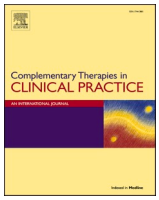

Adherence to 24-h movement guidelines and cognitive difficulties in adolescents

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ABSTRACT

Background: Studies have identified sleep, screen time, and physical activity as independent risk factors for cognitive impairment in adolescents. However, little is known about how these factors interact to contribute to cognitive difficulties. This study aimed to investigate the association between 24-h movement guidelines and cognitive difficulties in adolescents.

Methods: Data from the 2019 Youth Risk Behaviour Surveillance was used for analysis. Participants self-reported their screen time, sleep, and physical activity levels, and cognitive difficulty was assessed using a standardized protocol with a binary response (Yes or No). Logistic regression analysis was used to evaluate the association between 24-h movement behaviours and cognitive difficulty, with results reported as the odds ratio (OR) with a 95% confidence interval (CI).

Results: After controlling for covariates (e.g., sex, age), compared to adolescents not adhering to none of the 24-h movement guidelines, adhering to the screen time (OR = 1.68, 95%CI: 1.37–2.05) and sleep guidelines (OR = 1.32, 95%CI: 1.08–1.61) were more likely to report no cognitive difficulties in adolescents, respectively. Adhering to all the 24-h movement guidelines was also likely to increase the odds of reporting no cognitive difficulties (OR = 3.38, 95%: 2.15–5.30).

Conclusions: The study findings suggest that promoting better 24-h movement behaviours could be an effective approach to reducing cognitive difficulties in adolescents. Future studies should use improved study designs to confirm or refute these results.

1. Introduction

Minor lapses in attention, memory, and psychomotor coordination are frequently observed in individuals who experience daily cognitive challenges and failures. Examples of such lapses may include stuttering, forgetting appointments, or missing traffic signs. It is important to note that cognitive failure is usually the result of temporary and remediable errors, rather than a general cognitive or psychomotor deficiency [1,2]. There is a dearth of studies on cognitive problems, which may have a negative effect on the quality of life [3,4]. According to the recent study findings, participants had more difficulty coping with cognitive challenges on a daily basis, more worry over cognitive symptoms, and an increase in cognitive symptoms during the previous five years [4]. Additionally, it was found that subjects were more prone to commit cognitive errors when they were female [4], younger [3], fatigued [3,4], depressed [4] or showing signs of small-fiber neuropathy [4]. Learning difficulties in kids are frequently associated with working memory and attention deficits [5–7]. Children and teenagers who struggle with learning and reading, in particular, frequently experience a wide range of social and emotional difficulties, including low self-esteem [8]. These issues may have caused the children to visit their paediatricians. most studies on cognitive challenges include adults or particular populations. However, because of the rapid cognitive development that occurs in adolescence [9], assessing the degree of cognitive issues now may assist in avoiding more severe ones in later life. Additionally, it is crucial to investigate the correlates of teenagers' cognitive impairments in this group.

Shifts in research insights into daily movement behaviours are part of a paradigm shift, the Canadian 24-h movement guidelines for children and youth (at least 1 h of moderate-to-vigorous physical activity per week, and ≤2 h of recreational screen time per week; 9–11 h of continuous sleep per night for people in the age range of 5–13, 8–10 h of

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continuous sleep per night for people in the age range of 14–17) made the 24-h guidelines on physical activity, sedentary behaviour, and sleep [10]. According to research, 24-h movement guidelines are related to better health outcomes when adhered to. Meeting 24-h movement guidelines during childhood and adolescence is associated with favourable physiological [11,12] and psychological outcomes [13]. All three recommendations can lead to better cognitive function [14], weaker impulsivity [15], lower obesity probability [16], healthier dietary patterns [17], enhanced life quality [18], reduced risk of depression [19–21], and improved cardiometabolic, social, and emotional health [11,13,22] students who do not meet any of the recommendations. There was a significant reduction in medical visits related to mental illness among those who met 7 to 9 lifestyle recommendations found in a cohort study [23]. Previous studies have examined each movement behaviour's relationship with academic performance separately. Separate studies have investigated the relationship of movement behaviours with academic performance [24]. We are unaware of any research linking physical activity, screen time, and sleep to adolescents' cognitive difficulties. There is no evidence that meeting some or all of the guideline recommendations is relevant to adolescents' cognitive difficulties. Above understanding contributes to the improvement of the adolescent cognition.

Children and adolescents adhered to 24-h movement guidelines at different levels, according to several studies [18,22,25]. All three recommendations are met without gender differences among adolescents [22]. Boys showed a larger likelihood to satisfy the physical activity recommendation compared with girls. The screen time recommendation is more likely to be met by females than by males [22]. Considering the gender differences in cognitive difficulty in adolescence, it is possible that 24-h movement behaviours are associated with cognitive difficulties in different grades, and between boys and girls.

The goal of this study was to investigate the association between adolescents' cognitive difficulty and 24-h movement guidelines compliance using data from the youth risk behaviour survey (YRBS). We hypothesize that higher adherence to 24-h movement guidelines would be associated with decreased cognitive difficulties in adolescents.

2. Methods

2.1. YRBS design and participants

This study utilized data from the 2019 Youth Risk Behavior Survey (YRBS), a nationally representative survey that tracks various key health behaviors among high school students. These behaviors include physical activity, diet, alcohol use, violence, and sexual behaviors, among others. A three-stage sampling design was used to select a random sample of public and private schools in the United States to participate in the study. The YRBS utilized a computer-scannable questionnaire booklet that took approximately 45 min to complete. Most questions were answered in the form of single-choice questions. The survey questions have been shown to have good reliability [25]. The 2019 YRBS involved 13,872 questionnaires administered in 136 schools. After conducting quality control, 13,677 questionnaires were deemed usable for analysis. The school response rate, student response rate, and overall response rate were 75.1%, 80.3%, and 60.3%, respectively.

2.2. Independent variables

2.2.1. Physical activity

To measure physical activity, participants were asked to indicate the number of days in the past seven days that they engaged in physical activity for at least 60 min, including any activity that increased their heart rate and caused breathing difficulties. This single item was used to assess physical activity levels, and the response options ranged from 0 to 7 days [25]. According to the 24-h movement guidelines and consistent with previous studies, participants who reported engaging in physical activity for all 7 days were considered to have met the physical activity recommendation [26].

2.2.2. Screen time

Screen time was evaluated by asking participants about their daily television (TV) watching habits using the question, "How many hours do you typically spend watching TV on a regular school day?" Response options included "I do not watch TV", "less than 1 h per day", "1 h per day", "2 h per day", "3 h per day", "4 h per day", and "5 or more hours per day." In line with the 24-h movement guidelines, participants who reported watching TV for 2 h or less per day were considered to have met the screen time recommendation [27,28].

2.2.3. Sleep duration

The following question assessed sleep duration, that is "How many hours do you sleep on average on a normal school night?", which has been widely applied to measure sleep duration in adolescents [25,29]. Participants were provided with response options ranging from "4 or less hours" to "10 or more hours" to indicate their typical sleep duration. According to the 24-h movement guidelines, participants aged 5–13 who reported sleeping for 9–11 h per night, or participants aged 14–17 who reported sleeping for 8–10 h per night, were considered to have met the sleep duration recommendation [26].

2.3. Outcome variable: cognitive difficulty

Cognitive difficulty was evaluated by the question, that is "Affected by physical, mental, or emotional problem, do you suffer difficulty in concentrating, remembering, or making decisions?" Participants could answer as 'Yes' or 'No' [30]. Participants affirmatively answering 'yes' were considered as cognitively difficulty.

2.4. Covariates

Covariates including age, sex, grade, race/ethnicity, body mass index were included in this study. Information on the covariates was collected using a self-reported questionnaire.

2.5. Statistical analysis

We used SPSS 26.0 to conduct statistical analyses, which were performed on a nationally representative sample, taking into account the complex sampling design according to the YRBSS data analysis protocol. To ensure that our results were nationally representative, we excluded all cases with missing data and those out of the age range of 14–17 years old, rather than using imputation methods, as the amount of missing data was minimal. A total of 6032 study participants were included for analysis. Descriptive statistics in the form of percentages were used to summarize the categorical variables in our sample, and a 95% confidence interval was provided for the weighted estimates of the variables. To assess adherence to the guidelines, valid cases were grouped into one of four categories: no adherence, adherence to one guideline, adherence to two guidelines, and adherence to all three guidelines. Using binary logistic regression and adjusting for covariates such as ethnic group, grade, age, and sex, we compared participants who reported experiencing cognitive difficulty to the reference group. All odds ratios (ORs) were tested for statistical significance, with a two-sided p-value of <0.05 and a 95% confidence interval (CI).

3. Results

Table 1 provides information on the characteristics of the sample. Of the study participants, approximately 50.4% were female. The largest proportion of participants were in the 9^{th} grade (30.5%), while the smallest proportion were in 12^{th} grade (12.7%). White participants accounted for 54.0% of the sample, which was the highest proportion

Table 1
Demographic characteristics of the study participants.

	Sample size (n = 6032)	%
Age		
14 years old	761	12.6
15 years old	1729	28.7
16 years old	1865	30.9
17 years old	1677	27.8
Sex		
Female	3175	52.6
Male	2857	47.4
Grade		
9^{th}	1787	29.6
10^{th}	1859	30.8
11^{th}	1619	26.8
12^{th}	767	12.7
Race/ethnicity		
White	3127	51.8
Black or African American	657	10.9
Hispanic/Latino	1571	26
All other ethnicities	677	11.2
24-h movement guidelines		
Meeting none	2634	43.7
Meeting sleep guidelines	657	10.9
Meeting screen time guidelines	974	16.1
Meeting physical activity guidelines	661	11
Meeting physical activity + sleep guidelines	228	3.8
Meeting screen time + sleep guidelines	282	4.7
Meeting physical activity + screen time guidelines	420	7
Meeting all	176	2.9
Cognitive difficulty		
Yes	2251	37.3
No	3781	62.7
Body mass index (kg/m^2; mean + standard deviation)	23.6	5.3

compared to other racial groups. The average body mass index (BMI) was 23.6 ± 5.3 kg/m^2. Overall, only 2.9% of the sample met all of the 24-h movement guidelines. Compliance with each of the guidelines, including physical activity (PA), screen time (ST), and sleep, was 11%, 16.1%, and 10.9%, respectively. Approximately 37.3% of the participants were considered to have cognitive difficulties.

Tables 2 and 3 display the results of logistic regression analyses examining the association between adherence to the 24-h movement guidelines (in insolation and in its different combinations) and cognitive difficulties. After controlling for the covariates (i.e., age, sex, grade, race/ethnicity and body mass index.), compared to not adhering to any of the 24-h movement guidelines, meeting one or more of the guidelines in insolation except for physical activity guidelines was significantly associated with higher odds of being classified as having no cognitive difficulties. Specifically, compared to meeting none, meeting either the sleep (OR = 1.68, 95%CI: 1.37–2.05) or screen time (OR = 1.32, 95%CI: 1.08–1.61) guidelines was associated with higher odds of being classified as having no cognitive difficulties. Meeting any two of the guidelines was associated with from 1.69 to 2.48 times greater odds of being classified as having no cognitive difficulties. Finally, meeting all of the 24-h movement guidelines was most strongly associated with having no cognitive difficulties (OR = 3.38, 95%CI: 2.15–5.30).

Table 2
Unadjusted results for associations between adherence to 24-h movement guidelines and cognitive difficulties.

	OR	95% CI	
Adherence to sleep guidelines	1.71	1.40	2.08
Adherence to screen time guidelines	1.25	1.00	1.55
Adherence to physical activity guidelines	1.22	0.96	1.56
Adherence to physical activity + sleep guidelines	3.05	2.14	4.35
Adherence to screen time + sleep guidelines	1.95	1.49	2.54
Adherence to physical activity + sleep guidelines	1.85	1.36	2.51
Adherence to all	3.91	2.49	6.15

OR: odds ratio; CI: confidence interval.
Reference group: meeting none of the 24-h movement guidelines.
Models controlled for age, sex, grade, race/ethnicity and body mass index.

Table 3
Adjusted results for associations between adherence to the 24-h movement guidelines and cognitive difficulties.

	OR	95%CI	
Adherence to sleep guidelines	1.68	1.37	2.05
Adherence to screen time guidelines	1.32	1.08	1.61
Adherence to physical activity guidelines	1.04	0.81	1.32
Adherence to physical activity + sleep guidelines	2.48	1.71	3.60
Adherence to screen time + sleep guidelines	1.97	1.51	2.55
Adherence to physical activity + sleep guidelines	1.69	1.22	2.34
Adherence to all	3.38	2.15	5.30

OR: odds ratio; CI: confidence interval.
Reference group: meeting none of the 24-h movement guidelines.
Models controlled for age, sex, grade, race/ethnicity and body mass index.

4. Discussion

Using a large representative sample of adolescents in the US, this study examined the association between 24-h movement guidelines and cognitive difficulties. We found that adolescents who met the screen time and sleep guidelines were significantly likely not to have cognitive difficulties, but these significant associations were not observed when examining them between physical activity guidelines and cognitive difficulties. Furthermore, meeting the 24-h movement guidelines showed a significantly lower risk for developing cognitive difficulties.

4.1. Sleep and cognitive difficulty

In our study, adolescents who met the sleep guidelines had significantly higher odds of reporting no cognitive difficulties. For almost a century, researchers have been exploring the relationship between sleep and memory and learning. Numerous studies have demonstrated that sleep plays a critical role in the process of memory formation [31]. A number of review studies have summarized strong evidence that adolescents' learning ability can be enhanced followed by an episode of sleep rather than wakefulness [32], implying the importance of sufficient sleep on reducing risk of cognitive difficulties. Sleep significantly enhances the strength of memory for learned material. A growing body of research indicates that sleep deprivation has a negative impact on adolescents' educational outcomes. However, studies have shown that adolescents attending schools with later first-bell times have experienced improvements in several important areas [33]. The cognitive functioning of adolescents is often measured in the context of school performance, including academic performance and mood. A short night sleep also negatively affects school performance [34]. As summarized in prior studies, sleep's role in stabilizing learning is sequential as full night of sleep is crucial to performance gains [31].

4.2. Screen time and cognitive difficulty

Studies found that adolescents who reported meeting screen time guideline had significantly elevated odds of having no cognitive difficulties. Some evidence suggests that if children and adolescents spent too much time in using screen-based devise, their cognitive abilities (i.e., attention, memory, etc.) would be diminished [35]. In the literature, some forms of electronic media have been discussed. Hence, excessive screen time could result in reduced cognitive abilities in young people [35]. Other literature discussed some forms of electronic media, including video games, which may assist in improving some children's cognition-related brain areas, improving their visuospatial skills, attention, reading ability, memory, and problem solving skills [36].

Adolescents' prolonged sitting time may affect cognition in a variety of ways. However, the mechanisms are still unclear. Based on the neurobiological evidence, chronic sensory stimulation causes structural changes in the developing brain with potentially negative cognitive outcomes. The use of screen-based device may also contribute to damaged task switching caused by constant distractibility.

4.3. Physical activity and cognitive difficulty

The study showed that the relationship between adhering to physical activity guidelines and having no cognitive difficulty was not significant in adolescents. This result indirectly proves that the link between physical activity and cognition in adolescents remains controversial [37]. Research on the relationship between moderate-to-vigorous physical activity (MVPA) and cognition is mixed. It has been established that aerobic fitness has obvious relevance to cognition [38]. In addition to enhancing aerobic fitness [39], MVPA has also been demonstrated to improve cognitive ability indirectly [38]. Moreover, physical activity levels decline rapidly during adolescence, a period presenting the greatest declines in the physical activity level [40]. Increasing studies demonstrate the distinctive effects of physical activity on cognitive-related outcomes, including that attention, working memory, inhibition, and classroom behaviour are key aspects of cognition during adolescence [41]. In contrast, other studies provided conflicting evidence on the connection between physical activity and cognition [42]. A possible explanation for this contradictory evidence is that the assessment of cognitive difficulty arbitrarily depends on the academic and cognitive measures. Keeley et al. [42] proposes that cognitive performance is primarily affected by psycho-physiological changes in cerebral function. Accordingly, some studies show that the academic measure is moderately correlated with the cognitive measure in adolescents [43]. It is during adolescence that neurocognitive development is particularly vulnerable and critical. Brain plasticity can change with age [44], and some factors involved can be stimulated by physical activity [45]. Owing to the conflicting evidence found in our study, in the future, more evidence and samples are needed to further explore the association between physical activity and cognitive difficulty among adolescents.

4.4. 24-h movement guidelines and cognitive difficulty

When adolescents reported adhering to any two of the 24-h movement guidelines, the odds of not experiencing cognitive difficulties increased significantly, especially meeting all the 24-h movement guidelines. The study findings may support the general finding that adherence to 24-h movement guidelines improves cognition-related outcomes [24], which implies to the reduced risk of cognitive difficulties [46]. According to Walsh et al. [47], combinations of 24-h movement guidelines were related to cognition in children and adolescents. The authors indicated that adhering to all the 24-h guidelines was positively associated with global cognition among adolescents. Furthermore, meeting the sleep guidelines with one or more of the other guidelines conformed with some studies that investigated the impact of sleep on cognition [48]. Some studies have investigated the mechanism of how sleep affects cognition and have confirmed the positive impacts of sufficient sleep on cognitive function in adolescents. Cognitive function can be enhanced through better working memory, attention, and executive control [48]. The most distinct finding in the literature concerning 24-h movement guidelines and cognition-related outcomes [11,13,16,17] is that there is no evident dose-response relationship between adherence to the guidelines met and cognition-related outcomes. In general, adolescents who met all three guidelines experienced no cognitive difficulty. Hence, increasing adherence to 24-h guidelines may lead to greater cognitive benefits.

4.5. Study limitations

In light of better understanding of our research findings, it is necessary to acknowledge some inherent limitations in this study. First, the cross-sectional nature of the study cannot enable causal reference on the association between exposure and outcome. Second, as this study is based on public data, information or data collected using self-reported measures can be affected by measurement errors and social desirability. This limitation would be a barrier to the analysis accuracy. Third, as this study did not consider the sleep period on weekend days, it is not possible to entirely reflect the average night sleep duration. It is expected that future studies will address these weaknesses in the future.

5. Conclusions

According to this study, adolescents who adhered to 24-h movement guidelines had lower risk of cognitive difficulties. However, adherence to screen time and sleep guidelines were the main contributors to no cognitive difficulties. To confirm the current research findings, replicated studies with larger sample sizes and device-based measures of physical activity, screen time, and sleep are required. Experimental studies should also be conducted to examine the research findings.

Data availability statement

Publicly available datasets were analyzed in this study.

Ethics statement

This study used de-identified data and as such was not considered to be human subject research.

Author contributions

Yingna Lu is responsible for study design, data curation, data analysis and manuscript draft and editing. Mingren Zhao is responsible for study design, manuscript draft and editing.

Declaration of competing interest

The authors declare no conflicting interest.

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