Research Square

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Associations Between Physical Activity and Sedentary Time with Sleep Duration and Sleep Quality in Adolescents

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Abstract

Background: To examine the cross-sectional associations between objectively assessed physical activity and sedentary time, and both objectively and subjectively assessed sleep parameters (e.g., duration and quality) among Australian adolescents, including weekdays and weekends.

Methods: Baseline data from the TransformUs Secondary effectiveness trial involved 193 adolescents (mean age 14.8 years) from Victoria, Australia. Participants self-reported bedtime and wake-up times on school nights and weekends, as well as sleep quality using the Adolescent Sleep Wake Scale. The wrist-worn ActiGraph GT9X was used to collect 24-hour activity data for over 1 week (minimum of 16 hours, at least 3 days) to assess moderate-to-vigorous physical activity (MVPA), light physical activity (LPA), sedentary time, and sleep parameters, including total sleep time (TST), sleep efficiency, sleep latency, and wake after sleep onset (WASO). Linear regression models examined associations between physical activity, sedentary time, and sleep parameters.

Results: Sedentary time was inversely associated with self-reported sleep quality, and with objectively assessed weekday sleep duration and TST. No significant associations were observed between LPA, MVPA, and sleep parameters.

Conclusions: These findings highlight the detrimental link between higher sedentary time and poor sleep quality and duration among adolescents, reinforcing the need to reduce sedentary behavior as a key intervention strategy for improving sleep health. Future prospective studies are needed to better understand temporal associations and the types of behaviour adolescents are engaging in when they are sedentary.

Background

Adolescence is a developmental period characterized by physiological, psychological, and social changes (1). Sleep plays a fundamental role in adolescent development, supporting cognitive function, emotional regulation, physical growth, and mental health (2–4). However, insufficient sleep and poor sleep quality are increasingly prevalent in this age group; contributing to greater risk of metabolic dysfunction (5, 6), reduced academic performance (7, 8), and psychological distress, including anxiety and depression (4).

Australia has developed a much-needed 24-hour movement guidelines that recommend 8–10 hours of sleep per night for 14–17-year-olds (9). National data show that up to half of older adolescents in Australia do not achieve recommended sleep on school nights, with adolescent girls especially at risk (10). A national survey of over 9,000 Australian adolescents found that 67% met sleep duration recommendations, with little change over the past decade (11). The reasons for poor sleep are likely to be varied. Biological changes during puberty, including delayed circadian rhythms (12) and changes in melatonin production (13, 14) along with extrinsic factors such as early school start times (15) contribute to delayed sleep onset and insufficient sleep.

Modifiable daily behaviors, including physical activity and sedentary time, may significantly influence adolescent sleep (16). Physical activity may promote sleep by supporting the circadian rhythm (i.e., light exposure timing, hormonal modulation) (17–19), and by inducing a drop in core body temperature after exercise (20), which can promote earlier sleep onset and improved sleep quality (21, 22). While a systematic review reported that physical activity is associated with improved sleep quality, shorter sleep latency, and fewer nighttime awakenings among children and adolescents (21), other evidence suggests no significant effect of physical activity on sleep quality (23). Conversely, sedentary time among adolescents, particularly screen-based activities, has been associated with delayed sleep onset and disrupted sleep (24, 25), and reduced total sleep time (26). These associations are likely explained by physiological (e.g., melatonin suppression) (13), cognitive (e.g., emotional arousal) (27), and temporal (e.g., sleep displacement) mechanisms among adolescents (28).

However, important gaps remain. Most studies focus primarily on sleep duration, with fewer studies including multi-dimensional indicators of sleep quality, such as sleep latency, sleep efficiency, and wake after sleep onset (WASO) (29). These parameters offer a more comprehensive understanding of sleep health, recognizing that adequate duration does not necessarily mean restorative sleep (30). Many studies rely solely on self-report measures of sleep or physical activity, which may limit accuracy and underestimate associations (3, 23, 28). Studies combining self-report and device-based measures of sleep duration, sleep quality, and physical activity are limited in this age group (3, 31). Furthermore, adolescents' routines differ markedly between school days and weekends, yet few studies examine whether associations vary across these contexts, despite their relevance for targeted intervention.

To address these gaps, this study aimed to examine associations between device-measured physical activity and sedentary time with both device-measured and self-reported sleep duration and sleep quality (i.e., sleep latency, WASO, sleep efficiency, awakenings) in a sample of Australian adolescents. A secondary aim was to investigate how these behaviors relate to meeting age-specific sleep duration guidelines.

Methods

Study design and participants

This cross-sectional study used baseline data (August 2023 - March 2025) as part of the *TransformUs Secondary* real-world effectiveness trial, with full trial details published elsewhere (32). TransformUs is a school-based intervention designed to promote healthy movement behaviors such as increasing physical activity and reducing sedentary time among children and adolescents through curriculum integration and environmental strategies (33, 34). Seven secondary schools in Victoria, Australia, were recruited using targeted convenience sampling to ensure diversity in school type (Government, Independent, or Catholic), geographic location (metropolitan and regional), socioeconomic status (as indicated by the socioeconomic indexes for areas), and school size (enrolment of > 200 students). A total of 545 students in Years 7–10 (approximately aged 13–17 years) were invited to participate, and

193 students provided written informed consent from both caregivers and students (35.4% participation rate). All participants and their caregivers were fully informed about the study procedures prior to providing consent. Ethical approval was obtained from the Deakin University Human Research Ethics Committee (Project ID: 2021 – 269) and the Victorian Department of Education (Project ID: 2023_004712). All procedures were performed in accordance with relevant guidelines and regulations, including the Declaration of Helsinki.

Data collection and data management

Demographic characteristics

At the schools, students completed a Qualtrics survey capturing demographics including date of birth, gender, year level, language spoken at home, and country of birth. Age was calculated to one decimal place by subtracting the self-reported date of birth from the date of data collection. Gender was self-reported with inclusive options (i.e., prefer not to say, other).

Self-reported sleep duration and quality

Typical bedtime and wake time on school nights and weekends (hh:mm AM/PM format) and typical sleep duration were assessed by questionnaire (35). Times were converted to a 24-hour time format, and if calculated sleep time crossed midnight (i.e., negative duration), 24 hours were added to obtain the correct duration.

Self-reported sleep quality over the past month was evaluated using the short Adolescent Sleep-Wake Scale (ASWS), a validated self-report 10-item questionnaire assessing three subscales: going to bed, falling asleep/reinitiating sleep, and returning to wakefulness (36). Participants reported using a 5-point Likert scale, ranging from 1 (“Never”) to 5 (“Always”). Negatively worded items were reverse coded, and total and mean domain scores were calculated, with higher scores indicating better perceived sleep quality. The ASWS has been psychometrically tested and is validated for use with adolescents with good internal consistency coefficients ranging from 0.64 to 0.82 (36, 37).

Device-measured physical activity, sedentary time, and sleep

Participants wore an ActiGraph GT9X accelerometer (Pensacola, FL, USA) on their non-dominant wrist for seven consecutive days, 24 hours a day, to measure physical activity, sedentary time, and sleep duration. Accelerometers were initialized using ActiLife software (version 6.13.4) at a sampling frequency of 30 Hz, and raw data were downloaded in .gt3x format. Data processing was conducted in R using the GGIR package (version 2.6-0), which includes autocalibration, detection of non-wear time, imputation of invalid data, and identification of sleep periods (38, 39). A valid day was defined as ≥ 10 hours of wear time, beginning at midnight and spanning a full 24-hour period. Participants were excluded

if they failed to provide at least 10 hours/day of valid wear time on at least 3 days, or if post-calibration error exceeded 10 mg (38). Non-wear time was estimated based on a criterion involving standard deviation and value range of acceleration across 15-minute epochs within 60-minute moving windows (40).

Physical activity intensity was classified using age-specific Euclidean Norm Minus One (ENMO) thresholds: sedentary time < 35.6 mg; light physical activity (LPA) 35.6-201.4 mg; moderate physical activity 201.4–707.0 mg; and vigorous physical activity > 707.7 mg (41, 42). Minutes spent in sedentary time and physical activity intensities were averaged across valid days.

Sleep was estimated using GGIR's automated heuristic algorithm, which identifies sleep period time (SPT) based on sustained inactivity and low wrist movement variability (39). Within this window, total sleep time (TST) was determined as the total time spent in sustained inactivity, expressed in minutes. Sleep efficiency was determined as the percentage of the SPT-window spent in sleep (recommended ≥ 85% per night) (29). Sleep latency was defined as the time between the start of the algorithm-detected SPT window and the onset of sustained inactivity, identified as five consecutive 30-second epochs with acceleration ≤ 10 mg (recommended 15–50 minutes). WASO was defined as the total duration of wake-like movement within the SPT-window following sleep onset (recommended 20–40 minutes) (29).

Statistical analysis

All statistical analyses were conducted using R (version 2024.04.2), with statistical significance of $p < 0.05$. Descriptive statistics (means, standard deviations, frequencies, and percentages) were calculated to summarize participant characteristics, physical activity, sedentary time, and sleep variables. Sleep duration and efficiency were categorized based on recommended cut-offs (e.g., 8–10 hours for sleep duration; ≥85% for sleep efficiency). A Spearman's correlation was performed to explore agreement between device-measured and self-reported total sleep duration. Multiple linear regression models were used to determine associations between accelerometer measured physical activity and sedentary time with self-reported (i.e., ASWS) and sleep duration, and device-measured sleep parameters (TST (minutes), sleep latency (minutes), sleep efficiency (percentage), number of awakenings, and WASO (minutes)), adjusting for gender, age, and school fixed effects to account for shared school-level environment. Meeting sleep duration guidelines was defined for device-measured total sleep time and self-reported sleep duration.

Results

Sample characteristics

Of the 193 adolescents who consented to participate, five (2.6%) were excluded for malfunctioning or missing accelerometers, 34 (17.6%) were excluded for insufficient wear time (i.e., less than 16 hours), and an additional 30 (15.6%) were excluded for wear time of less than 3 valid days. The final analytical

sample comprised of 124 participants (64.2% retention), with a mean age of just under 15 years (Table 1) and approximately equal proportions of males (49.2%) and females (46.0%). Over half the participants were enrolled in Year 7, and the majority were born in Australia and spoke English at home.

Table 1
Descriptive characteristics of participants

Variables	Mean ± SD/N (%)
Age (year)	14.8 ± 1.0
Gender	
Male	80 (49.2%)
Female	67 (46.0%)
Other	2 (1.6%)
Prefer not to say	5 (3.2%)
School Year	
Year 7	64 (51.6%)
Year 8	37 (29.8%)
Year 9	22 (17.7%)
Year 10	1 (0.9%)
Country of birth	
Australia	99 (79.8%)
Other	25 (20.2%)
Language spoken at home	
English	101 (81.5%)
Other	23 (18.5%)
Self-reported sleep characteristics	
Weekday bedtime	22:10 ± 01:10
Weekend bedtime	23:30 ± 01:36
Weekday wake up time	07:04 ± 00:49
Weekend wake up time	08:50 ± 01:36
Typical sleep duration	9.0 ± 1.3
ASWS Sleep quality (1–5 range) [α]	

[α] Scores calculated as a mean score from each subscale of Adolescent Sleep Wake Scale (ASWS), ranging from 1 to 6. Higher scores indicate better sleep quality. [β] Derived from actigraphy. TST: total sleep time; WASO: wake after sleep onset; ST: sedentary time; LPA: light physical activity; MVPA: moderate to vigorous physical activity. [γ] National Sleep Foundation guidelines (29)

Variables	Mean ± SD/N (%)
Total sleep quality score	3.5 ± 0.9
Going to bed	3.4 ± 1.1
Falling asleep and reinitiating sleep	3.9 ± 1.4
Returning to wakefulness	3.5 ± 1.5
Device-measured sleep characteristics [β]	
TST (h)	7.8 ± 1.2
Number of awakenings (n)	2.2 ± 1.8
WASO (min)	10.8 ± 9.1
Sleep efficiency (%)	83.3 ± 6.5
Sleep latency (min)	22.8 ± 1.3
Meeting sleep recommendations (device-measured) [γ]	
Yes	70 (56.4%)
No	54 (43.6%)
Meeting sleep recommendations (self-report) [γ]	
Yes	74 (59.7%)
No	50 (40.3%)
Activity level[β]	
ST (min/day)	683.4 ± 92.8
LPA (min/day)	253.1 ± 47.2
MVPA (min/day)	42.0 ± 26.1

[α] Scores calculated as a mean score from each subscale of Adolescent Sleep Wake Scale (ASWS), ranging from 1 to 6. Higher scores indicate better sleep quality. [β] Derived from actigraphy. TST: total sleep time; WASO: wake after sleep onset; ST: sedentary time; LPA: light physical activity; MVPA: moderate to vigorous physical activity. [γ] National Sleep Foundation guidelines (29)

Bedtime and wake-up time

On average, adolescents reported a weekday bedtime of around 10:00 pm and a weekend bedtime of 11:30 pm. Wake-up times were earlier on weekdays (7:00 am) compared to weekends (8:50 am).

Self-reported sleep quality and duration

Adolescents reported moderate to high self-reported sleep quality, with a mean total ASWS sleep quality score of 3.5 out of 5. Among the three ASWS subdomains, the highest scores were observed for falling asleep and reinitiating sleep, followed by returning to wakefulness, and going to bed. Self-reported mean sleep duration was within the recommended range for this age group.

Device-measured sleep parameters

Among those included in the sample, the average number of valid accelerometer days was 6.0 days (SD = 1.5, range = 3–9). Average TST was just under 8 hours per night, and just over half of the participants met the recommended 8–10 hours of sleep per night. Participants' device-based measures showed two awakenings per night on average, which is below the National Sleep Foundation's threshold for concern (> 4 awakenings per night), although the number of awakenings ranged between 0 and 8 across participants. The mean WASO duration was just over 10 minutes, suggesting relatively undisturbed sleep although WASO ranged between 0 and 40 minutes. The mean sleep efficiency was 83%, falling just below the recommended 85% threshold indicative of good quality sleep. Sleep efficiency ranged between 62% and 96%. Sleep latency averaged 23 minutes, which is within recommended range of ≤ 30 minutes and ranged between 20 and 29 minutes. Spearman's correlation showed a weak significant positive correlation of 0.287 ($p < 0.05$) between self-reported sleep duration and device-measured TST (see Supplementary File 1 for Bland-Altman plot).

Device-measured sedentary time and physical activity

On average, adolescents spent 11 hours in sedentary time, four hours in LPA, and just over half-an-hour in moderate to vigorous physical activity (MVPA) per day.

Associations between physical activity, sedentary time and sleep parameters

Associations between physical activity, sedentary time and device-measured sleep parameters are shown in Table 2. Higher sedentary time was consistently associated with several indicators of poorer sleep quality, including shorter sleep time, lower WASO, longer sleep latency but fewer number of awakenings. Specifically, each additional minute of sedentary time per day was associated with half a minute less TST, equating to approximately 34 minutes of shorter TST for every hour of sedentary time. No significant associations were found between LPA, MVPA, and any of the sleep parameters.

Table 2
Linear regression models of associations between physical activity, sedentary time and device-measured sleep parameters

Variables	ST		LPA		MVPA	
	β	95% CI	β	95% CI	β	95% CI
TST	**-0.577**	**-0.656; -0.498***	-0.165	-0.665; 0.335	-0.048	-1.001; 0.898
WASO	**-0.047**	**-0.086; -0.043***	0.004	-0.044; 0.057	0.036	-0.048; 0.147
Sleep efficiency	-0.004	-0.019; 0.011	-0.018	-0.613; 0.244	-0.007	-0.047; 0.331
Sleep latency	**0.006**	**0.003; 0.009***	0.002	-0.007; 0.010	0.003	-0.007; 0.012
Awakenings	**-0.009**	**-0.013; -0.006***	0.001	-0.006; 0.008	0.007	-0.007; 0.021

*p-value < 0.0001. Abbreviations: TST: total sleep time; WASO: wake after sleep onset; ST: sedentary time; LPA: light physical activity; MVPA: moderate to vigorous physical activity. All the models were adjusted for age and gender and clustered by school.

Moreover, in logistic regression models adjusted for age and gender and school fixed effects, higher time spent sedentary was significantly associated with lower odds (OR: 0.983; 95% CI: 0.978; 0.988, p = 0.000) of meeting the 8–10-hour sleep guidelines derived from accelerometer measures. In contrast, LPA and MVPA were not significantly related to sleep guideline compliance.

Associations between physical activity, sedentary time and self-reported sleep quality and duration

Sedentary time was negatively associated with the total ASWS sleep quality score (Table 3). LPA was positively associated with the total ASWS score and the going to bed subscale. No other significant associations were found between LPA, MVPA, and ASWS domains. Sedentary time and physical activity were not associated with self-reported sleep duration.

Table 3
Linear regression models of associations between sedentary time, physical activity and self-reported sleep quality scores and duration

Subscales	ST (min/day)		LPA (min/day)		MVPA (min/day)	
	β	95% CI	β	95% CI	β	95% CI
ASWS total	**-0.002**	**-0.003; -0.000***	**0.004**	**0.000; 0.007***	0.003	-0.005; 0.011
Going to bed	-0.003	-0.007; 0.001	**0.006**	**0.001; 0.010***	0.002	-0.010; 0.014
Falling asleep	-0.002	-0.004; 0.001	0.004	-0.004; 0.012	-0.001	-0.010; 0.008
Returning to wakefulness	0.001	-0.003; 0.005	0.002	-0.006; 0.010	0.004	-0.007; 0.014
Sleep duration	-0.112	-0.283; 0.058	-0.104	-0.417; 0.210	-0.291	-0.849; 0.266

*p-value < 0.05. Abbreviations: ASWS: Adolescent Sleep Wake Scale; ST: sedentary time; LPA: light physical activity; MVPA: moderate to vigorous physical activity. Adjusted for age and gender and clustered by schools.

When sleep guideline adherence was derived from self-reported sleep duration, greater LPA was associated with higher odds of meeting self-reported sleep guidelines (OR = 1.795; 95% CI: 1.068; 3.015), while MVPA and sedentary time showed no significant association.

Discussion

This study investigated associations between device-measured physical activity and sedentary time with multiple sleep parameters in Australian adolescents, using both device-based and self-reported indicators. Across analyses, higher sedentary time was consistently associated with poorer sleep outcomes, including shorter TST, longer sleep latency, and lower self-reported sleep quality. Importantly, sedentary time was also associated with lower odds of meeting age-specific sleep duration guidelines when using device-based measure, highlighting its potential role in achieving sufficient sleep.

The strong and consistent associations observed for sedentary time align with previous research linking sedentary time, particularly screen-based activities, to delayed sleep onset, reduced TST, and poorer subjective sleep quality (24, 26). Several mechanisms may explain these effects, including melatonin suppression from evening screen exposure, cognitive and emotional arousal, and behavioral displacement where time spent sedentary reduces the time available for sleep (43–46). In the current study, sedentary time was also associated with lower WASO and fewer awakenings, likely reflecting the reduced sleep opportunity among adolescents with high sedentary time (47). With less total time spent asleep, there is less opportunity to accumulate long periods of wakefulness or frequent awakenings

across the night, which may explain the negative associations observed (47). The association between sedentary time and poorer self-reported sleep initiation (i.e., going to bed) is consistent with previous evidence of the detrimental effects of screen time before bedtime (48). However, this study did not capture what sedentary behaviors were undertaken by adolescents during sedentary time. Overall, the findings suggest that sedentary behaviour may have a stronger influence on adolescent sleep than physical activity, particularly in relation to sleep duration.

In the Australian context, national self-reported data from the Longitudinal Study of Australian Children showed that 52% of older adolescents (aged 16–17) did not meet school-night sleep recommendations (10). Using device-based sleep, the proportion of adolescents in the present sample meeting sleep duration guidelines was higher than estimates reported in comparable device-based studies from New Zealand (44%) (49) and Brazil (33%) (50). Moreover, compared to international estimates (≥ 85%) (51), this study found a slightly lower prevalence of adolescents meeting device-measured sleep efficiency recommendations (44%). Differences in the prevalence of guideline adherence across studies may reflect variation in sample characteristics and representativeness, as well as methodological differences. The present study found weak correlations between self-reported and device-measured sleep duration, indicating limited agreement between assessment methods in adolescents. Without a purposefully designed validation study, it is uncertain which measure most accurately reflects sleep behaviour in this population. Overall, these findings highlight the ongoing need for strategies and interventions to improve sleep guideline compliance in Australian adolescents.

Neither LPA nor MVPA was consistently associated with device-based or self-reported sleep parameters, including sleep guideline adherence. Similar null or inconsistent findings for physical activity have been reported elsewhere (23), despite theoretical pathways linking physical activity to improved sleep through greater homeostatic sleep pressure, thermoregulatory cooling, and circadian synchronisation (21, 22). One explanation may be that timing of physical activity, rather than overall volume, may influence sleep differently, with morning or evening activity showing different effects, a possible factor that could not be examined in the present study. Notably, greater LPA was associated with the going to bed subscale, suggesting that lighter forms of physical activity across the day may support sleep initiation. In adolescents, LPA may reflect behaviors such as active transport, informal movement, and household tasks (52). These behaviors may be relevant in the evening, as replacing sedentary screen-based activities with light movement may support transitions to sleep and given that LPA and sedentary time are often strongly inversely related, this finding may also partly reflect the benefits of less sedentary behavior. Future research should examine the patterns and timing of sedentary behavior, LPA, and MVPA across the day, as well as their associations with sleep parameters.

Strengths of this study include the use of validated accelerometer methods to assess both movement behaviors and sleep, the inclusion of multiple sleep quality indicators, and the use of device-based and self-reported sleep measures. The use of school fixed effects provides additional control for contextual variations between schools. However, the study has several limitations. The cross-sectional design limits causal inference. The accelerometer-derived sleep algorithm may misclassify sleep latency and

awakenings relative to polysomnography. Sedentary time was not categorised by type (e.g., screen-based or study-related), limiting contextual interpretation. The sample size, although adequate for main effects, may reduce power to detect small but meaningful associations for physical activity, and convenience sampling limits population-level inferences. The accelerometer inclusion criteria saw 30% of the available sample excluded; nevertheless, sensitivity analyses using less strict inclusion criteria showed consistent associations. Finally, self-reported sleep duration and bedtimes and wake time may also be subject to recall bias (53).

Conclusions

In conclusion, the study highlights the importance of addressing sedentary time in adolescent populations, as it was consistently negatively associated with both device-based and self-reported sleep outcomes, including shorter TST (sleep duration), and poorer self-reported sleep quality, particularly regarding going to bed and falling asleep. While physical activity, particularly MVPA, was not associated with either sleep duration or quality in adjusted models, findings suggest some associations with LPA and adolescent sleep health. Future longitudinal studies are needed to clarify directionality and causality of associations between adolescent physical activity, sedentary time and sleep duration and quality. A better understanding of how the timing and context of physical activity and sedentary time relate to sleep duration and quality across the week is needed to inform the development of interventions.

Abbreviations

WASO	Wake After Sleep Onset
ASWS	Adolescent Sleep Wake Scale
ENMO	Euclidean Norm Minus One
LPA	Light Physical Activity
MVPA	Moderate to Vigorous Physical Activity
SPT	Sleep Period Time
TST	Total Sleep Time
ST	Sedentary Time

Declarations

Ethics approval: Ethical approval was obtained from the Deakin University Human Research Ethics Committee (Project ID: 2021-269) and the Victorian Department of Education (Project ID: 2023_004712). All procedures were performed in accordance with relevant guidelines and regulations, including the

Declaration of Helsinki. Written informed consent was obtained from all participants and their caregivers prior to participation.

Consent for publication: Not applicable.

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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