Preventive Medicine 56 (2013) 112–117

Contents lists available at SciVerse ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Maintaining recommended sleep throughout the week is associated with increased physical activity in children

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ARTICLE INFO

Available online 29 November 2012

Keywords:
ActiGraph
Accelerometer
Child
Health
Obesity
Physical activity
Sleep

ABSTRACT

Objective. Given evidence of weekday–weekend variability in children's sleep and associations with obesity there is rationale for exploring sleep in relation to weekday and weekend physical activity (PA) and examining whether weekday–weekend variations in sleep impact physical activity.

Methods. Children's ($n=856$) physical activity was measured using accelerometry (Toronto; 2010–2011). Sleep was assessed via parental report and collapsed into three categories (<9 h; 9–10 h; ≥10 h) and differences in anthropometric and physical activity characteristics were assessed. Data were compared to determine whether sleep increased, decreased or was maintained across the week and relationships with activity and overweight/obesity were explored (cross-sectional analysis) after controlling for confounders.

Results. On weekdays, children who slept the least (<9 h) were less active in terms of overall intensity than those attaining ≥10 h, and more were overweight/obese ($p<0.05$). On weekends, differences in light physical activity occurred at lower sleep levels. Weekday–weekend sleep regularity mattered; overall intensity was higher among those maintaining recommended sleep (>9 h) compared to those engaging in weekend-catch-up-sleep.

Conclusion. While sleep is associated with obesity and activity in children, relationships vary by day. Recommended weekday–weekend sleep (regularity) supports healthy activity and should be an important health-promoting strategy. Future studies using longitudinal designs (to establish causality) are recommended.
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Introduction

Maintaining recommended levels of sleep and physical activity should be considered important components of a healthy lifestyle in children. In the prevention/treatment of childhood obesity, the function of sleep and physical activity in metabolic control is well documented (Riddell and Iscoe, 2006; Trenell et al., 2007). While there is consistent evidence of a positive relationship between short sleep duration and weight gain in children (Magee and Hale, 2012; Patel and Hu, 2008), fewer studies have examined the relationships of sleep with physical activity and sedentary behaviour, particularly through an objective measurement of physical activity (accelerometry). One exception is a study of Estonian and Swedish youth using accelerometry and self-reported sleep (Ortega et al., 2011). They found that those sleeping>10 h engaged in greater physical activity and spent less time sedentary than those sleeping<10 h. However, associations became non-significant after adjusting for age and sexual maturation. Further research using comparable measures is required to confirm this novel finding and the possibility that there is no link between sleep duration and physical activity.

Improving our understanding of this relationship is important for weight management in children, and has implications regarding clinical guidelines. The National Sleep Foundation (http://www.sleepfoundation.org/) recommends regular physical activity to improve sleep quantity and quality, yet currently, evidence to support an association is mixed (Hense et al., 2011; Olds et al., 2011; Ortega et al., 2011). Typically, weekday and weekend physical activity data are collapsed. Given evidence of variability in children's sleep on school days and weekends and associations with obesity (Spruyt et al., 2011) there is rationale for exploring weekday *and* weekend characteristics of accelerometer data in relation to sleep. Children may have more discretionary time on the weekend, and there is evidence of weekday–weekend differences in activity, with activity dropping off on the weekend and overweight/obese children attaining less activity compared to normal-weight peers (Stone et al., 2009a). Whether lower weekend activity is related to less sleep and overweight/obesity is an interesting possibility, and to the authors' knowledge has not been investigated. Reflecting the call for further research on the relationship between sleep and physical activity (Ortega et al., 2011), the objectives of the

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http://dx.doi.org/10.1016/j.ypmed.2012.11.015

Table 1a
Differences in anthropometrics by sleep duration; weekdays (Toronto, Ontario, Canada; 2010–2011).

Characteristics	<9 h (a) ($n=194$)	9 to 10 h (b) ($n=319$)	≥10 h (c) ($n=343$)	*P*	Pairwise comparisons[a]		
					a–b	a–c	b–c
Age (years)	11.1 (0.6)	11.0 (0.6)	11.0 (0.6)	ns			
Height (cm)	147.6 (7.3)	147.4 (9.8)	147.1 (8.1)	ns			
Weight (kg)	42.6 (10.4)	42.1 (10.7)	40.4 (9.1)	$p<0.05$	ns	>	ns
BMI (kg/m^2)	19.4 (3.7)	19.1 (3.8)	18.5 (3.2)	$p<0.05$	ns	>	ns
BMI category (%)							
Normal weight	63.9	69.3	73.4	$p<0.05$	ns	<	ns
Overweight/obese	36.1	30.7	23.6	$p<0.05$	ns	>	ns

[a] Pairwise comparisons: the symbol > in the column a-c, for instance, indicates a significant difference ($p<0.05$; $p<0.01$) in the direction a > c; ns = non-significant.

present study were to examine weekday and weekend characteristics of accelerometer data in relation to sleep, and, explore whether variations in weekday–weekend sleep patterns were differentially associated with physical activity behaviour.

Methods

Experimental design: project BEAT

The results of this study are based on data collected from a cohort of children in Toronto, Canada (Stone et al., in press). Approval from the University of Toronto Ethics Committee and Toronto District School Board was granted. Written consent was obtained from individual schools, parents and students.

Participants

Height and weight measurements were taken and body mass index (BMI) was calculated on 1001 children, aged 10 to 12 years. Accelerometer-measured physical activity data were collected for seven days (ActiGraph GT1M; Pensacola, FL). For inclusion in data analysis, each child required a minimum of 10 h of accelerometer wear time for at least three weekdays and one weekend day; 85.5% met these criteria ($n=856$; boys = 389, girls = 467). This article is therefore based on 856 participants (aged 11.1 ± 0.6 years) who met inclusion parameters. Using age- and sex-specific BMI cut-points (Cole et al., 2000), participants were classified as: normal weight, overweight or obese (Tables 1–4).

Physical activity

Physical activity variables included total physical activity (counts/day), mean counts (counts/min) and time spent in various levels of movement intensity. These were classified according to published thresholds (Stone et al., 2009b) and used to determine minutes of sedentary behaviour, light physical activity and moderate-to-vigorous physical activity (MVPA). Total physical activity (counts/day) is the total amount of physical activity accumulated per day; mean counts (counts/min) is the daily intensity of physical activity; minutes of sedentary behaviour, light and moderate-to-vigorous activity have been determined using published thresholds which correspond with MET values of 1.5, 3.0, and 4.5, respectively. Percent time (%) spent sedentary was calculated using wear time data. Characteristics of activity were computed for weekdays and weekend days.

Sleep

The ActiGraph GT1M accelerometer is not capable of assessing sleep. Therefore, sleep duration was assessed via parental report. Parents recorded the number of hours of sleep their child attains for a typical weekday and weekend day. Good correspondence between objective measures of sleep (as measured using actigraphy) and parents' perceptions of sleep latency and sleep duration exists (Holley et al., 2010). The National Sleep Foundation defines optimal sleep in children as sleeping > 9 h, however sleep needs may be higher (10 + h) (http://www.sleepfoundation.org/). Therefore, participants were categorized into three groups: a) <9 h, b) 9 to 10 h, c) 10 + h.

Confounders

Age, sex, weight status classification (normal weight, overweight/obese), socioeconomic status (SES; based on median household income reported in the 2006 Canadian Census) and TV viewing (hours/day) were explored as potential confounders.

Statistical analyses

Bivariate correlations among main study variables and confounders were performed to examine associations between sleep and physical activity. These analyses enabled the determination of whether potential confounders were correlated with main study variables and should be accounted for in subsequent analyses. Differences in demographic, anthropometric and physical activity characteristics by sleep category were assessed in analysis of variance (ANOVA) and covariance (ANCOVA) tests (continuous variables), and chi-squared (categorical variables) tests, with and without adjustment for confounders. Weekday and weekend sleep data were compared to determine whether sleep time increased, decreased or showed no change from the weekday to the weekend, and relationships with activity and overweight/obesity were explored. We were specifically interested in determining whether children who did not attain recommended sleep across the school week yet caught up on sleep over the weekend were able to accumulate similar levels of weekend activity and have similar body weight classifications as those who maintained recommended sleep. To determine whether the maintenance of inadequate sleep across the

Table 1b
Differences in anthropometrics by sleep duration; weekends (Toronto, Ontario, Canada; 2010–2011).

Characteristics	<9 h (a) ($n=138$)	9 to 10 h (b) ($n=232$)	≥10 h (c) ($n=486$)	*P*	Pairwise comparisons[a]		
					a–b	a–c	b–c
Age (years)	11.1 (0.6)	11.0 (0.6)	11.1 (0.6)	ns			
Height (cm)	147.4 (8.0)	146.9 (7.3)	147.5 (9.3)	ns			
Weight (kg)	44.0 (11.1)	40.3 (9.8)	41.4 (9.7)	$p<0.01$	>	>	ns
BMI (kg/m^2)	20.1 (4.0)	18.5 (3.4)	18.8 (3.4)	$p<0.01$	>	>	ns
BMI category (%)							
Normal weight	53.6	76.3	73.3	$p<0.01$	<	<	ns
Overweight/Obese	46.4	23.7	26.7	$p<0.01$	>	>	ns

[a] Pairwise comparisons: the symbol > in the column a-c, for instance, indicates a significant difference ($p<0.05$; $p<0.01$) in the direction a > c; ns = non-significant.

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