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Sleep Is Inversely Associated With Sedentary Time Among Youth With Obesity

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Abstract

Objective: Pathways underlying the sleep-obesity relationship in youth are poorly understood. This study aimed to examine associations of sleep with sedentary time and moderate-to-vigorous physical activity (MVPA) among youth, stratified by weight category (obesity versus no obesity). A sub-aim examined whether controlling for screen time changed the sleep-sedentary time association.

Methods: Methods entailed secondary analysis of baseline data collected June–August 2014–2017 during a school-based healthy weight management trial in Minneapolis/St. Paul Minnesota. Participants ($N = 114$) were 8-to-12 years old with BMI $\geq 75^{\text{th}}$ percentile, most of whom were members of racial/ethnic minority groups (57%) or from households receiving economic assistance (55%). Mean nightly sleep duration and daily screen time were measured by survey, MVPA and sedentary time by accelerometer, and height and weight by research staff. Multivariate linear regression examined associations of sleep with sedentary time and MVPA.

Results: Sleep was inversely associated with hours of sedentary time ($\beta = -1.34 [-2.11, -0.58]$ $p = .001$) and percent of time spent sedentary ($\beta = -2.92 [-4.83, -1.01]$ $p = .004$), for youth with obesity only. The association was unchanged by screen time. Sleep was not significantly associated with MVPA in total sample or stratified models.

Conclusions: Associations among sleep, activity levels, and obesity may differ based upon movement type (sedentary time versus MVPA) and weight category (obesity versus no obesity).

Keywords

exercise; pediatric obesity; screen time; sedentary behavior; sleep

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Human Subjects Statement

University of Minnesota and Temple University Institutional Review Boards approved the study; all participants provided informed parent consent and child assent.

Conflict of Interest Statement

All authors of this article declare they have no conflicts of interest.

Sleep duration is inversely associated with obesity in youth.¹⁻⁴ Mechanisms linking reduced sleep and childhood obesity are complex and include behavioral and physiological underpinnings.¹⁻⁵ For example, inadequate sleep may negatively impact dietary quality (eg, fatigued youth eat more calories and food with less favorable glycemic load), decrease energy expenditure, and raise levels of ghrelin, a hunger-inducing hormone.¹⁻⁵ Research disentangling the pathways underlying the sleep-obesity association in youth is needed to inform future studies, clinical care, and public health interventions, particularly among populations at greatest risk of poor health outcomes such as youth with obesity.⁶

Physical behaviors, defined as moderate-to-vigorous physical activity (MVPA), sedentary time, and sleep, are one pathway that may underlie the sleep-obesity relationship. Inadequate sleep may lead to daytime fatigue that decreases MVPA, increases sedentary time, and/or increases screen time. However, evidence is limited and, at times, contradictory.^{1,5-7} The relationship between sleep and MVPA is mixed,⁶ with some studies finding positive or inverse associations⁸⁻¹⁰ and others no association.¹¹ Evidence for an inverse association of sleep with sedentary time is growing but also mixed.^{3,6,8,10-14} Most studies demonstrate that shorter and poorer quality sleep is associated with more screen time, but how screen time impacts sleep's association with total sedentary time is unclear.⁶ Moreover, most research has not compared differences between youth with and without obesity, nor focused on priority populations such as preadolescents at the top quartile of the body mass index (BMI) chart.¹⁵⁻¹⁷ Youth with BMI ≥ 75 percentile are at risk for excess weight gain, making research focused on this population particularly important.¹⁵⁻¹⁷ Further, adolescents are more likely to have severe obesity - for which lifestyle modification is less likely to be effective - thus intervening to promote a healthy weight during preadolescence is indicated.^{18,19} Also, limited research has used rigorous measures of MVPA and sedentary time measurement such as accelerometry, and few studies have comprehensively considered physical behaviors defined as MVPA, sedentary time, screen time, and sleep.^{1,5-7}

Purpose

A better understanding of physical behaviors underlying the sleep-obesity association can inform efforts to reduce obesity and improve well-being among youth. This study examined associations of sleep with sedentary time and MVPA among 8-12 year old youth with BMI ≥ 75th percentile, stratified by weight category (obesity versus no obesity). A sub-aim examined whether controlling for screen time changed the sleep-sedentary time association. We hypothesized that there would be an inverse association of sleep with sedentary time, a positive association of sleep with MVPA, and that the association of sleep with sedentary time would reduce in magnitude after controlling for screen time.

METHODS

Study methods entailed secondary analysis of baseline data collected from June to August 2014 to 2017 for the Students, Nurses, and Parents Seeking Healthy Options Together (SNAPSHOT) study, a randomized controlled trial of a school-based healthy weight management intervention conducted in the Minneapolis/Saint Paul metropolitan area (N =

132). Child eligibility criteria included BMI 75 percentile; 8–12 years old; able to read, write, and speak English; and living with participating parent most of the time. Exclusion criteria included parents' plans to move outside the school district within the next 12 months and child with food allergies, physical limitations or medical conditions that would limit ability to participate in physical activity, or emotional health conditions that would limit ability to participate in group activities. Participants were recruited using flyers, school and district website announcements, in-person presentations at school events, and general mailings. Intervention details are reported elsewhere.²⁰ University of Minnesota and Temple University Institutional Review Boards approved the study; all parents provided informed consent for self and child and children provided assent.

Outcome Measures

Parents reported their child's demographic characteristics and usual bedtime and wake time for weekdays and weekends via paper survey, using questions adapted from a validated instrument.^{21,22} Sleep duration in hours per day was calculated for weekdays, weekends, and typical day (eg, weighted average of weekday and weekend). Mean weekday and weekend sleep duration differed by only 6 minutes, so weighted average sleep duration was used for analyses. Youth reported screen time via paper survey, using a question adapted from a reliable tool.^{23,24} The question asked "On a typical weekday (Monday through Friday), how many hours do you spend..." with 6 options for screen time including texting, watching TV, watching DVD's or videos, playing games with a phone or hand-held device (DS, PSP, iPad, Kindle), playing video games (X-box, Play Station), or using the computer (Internet, Facebook, playing games on the computer). Response options ranged from 0 to more than 5 hours. The same question was asked for weekend screen time and the average hours for a typical day was calculated. Youth's height and weight were measured by trained study staff using standard procedures,²⁵ with BMI percentiles calculated using Centers for Disease Control and Prevention growth charts.²⁶ Obesity was defined as BMI 95th percentile for age and sex.²⁷

ActiGraph uniaxial GT3X+ accelerometers,²⁸ validated for use in youth,^{29–31} were used for measurement of sedentary time and MVPA. Sedentary time and MVPA were measured 2 ways: 1) hours per day and 2) percent of total time spent in each category (eg, percent of all movement that was sedentary, percent of all movement that was moderate-to-vigorous). Participants were asked to wear the ActiGraph on their right hip for one continuous week, except during sleep and activities when the ActiGraph could get fully wet such as swimming or bathing. ActiGraph data were collected in 15-second epochs, downloaded using ActiLife software (ActiGraph, Pensacola, FL),³² and processed using R including previously published procedures to reduce missingness.³³ The data analysis reported here included child participants with sedentary time and MVPA data for at least 2 of 7 days of baseline measurement (N = 114). Established Evenson cutpoints^{33–35} were used to categorize ActiGraph count values into intensity categories.

Statistical Analyses

Participant demographics and daily hours of sleep, screen time, sedentary time, and MVPA were summarized using descriptive statistics. Multivariate linear regression was used to

examine associations of daily hours of sleep (independent variable) with sedentary time (model 1 dependent variable) and MVPA (model 2 dependent variable). Two post hoc exploratory models were run with percent of time spent sedentary (model 3 dependent variable) and percent of time spent in MVPA (model 4 dependent variable). The purpose of the post hoc models were to explore whether associations were similar for both overall duration and percent of time, which controls for differences in total wear time of the ActiGraph. Models were first run for the total sample then stratified by obesity versus no obesity, in order to examine if the associations differed by weight category. Due to previously observed associations with the dependent variables,^{36–40} model covariates included age in years (continuous), sex (male/female), race/ethnicity (member of minority group yes/no), and household receipt of economic assistance (yes/no). In addition, models controlled for mean daily hours spent in other intensity categories (light PA and MVPA for models 1 and 3; light PA and sedentary time for models 2 and 4). An additional multivariate linear regression model examined whether adding screen time as a covariate changed the association of hours of sleep with sedentary time. Lack of collinearity between screen time and sedentary time was confirmed prior to running the model. Analyses were conducted using SAS 9.4.⁴¹ Statistical significance was assessed at a p-value of .05.

RESULTS

Sample demographic characteristics (N = 114) are summarized in Table 1. Half of participating youth were girls, 57% were members of racial or ethnic minority groups, and 55% were from households receiving economic assistance. About half (49%) met criteria for obesity. Youth slept 10.3 ± 0.8 hours per night, within guidelines of 9–12 hours.⁴² Per day, youth engaged in 6.8 ± 5.2 hours of screen time, 8.3 ± 2.1 hours of total sedentary time, and 0.7 ± 0.3 hours of MVPA. Most ($62.8 \pm 9.1\%$) of their time was spent sedentary, with $5.1 \pm 2.5\%$ being in MVPA.

Findings are summarized in Tables 2–3. For every increased hour of sleep, youth engaged in 30 fewer minutes of sedentary time ($\beta = -0.55 [-1.03, -0.07]$ $p = .02$). Stratified analysis demonstrated the association was driven by youth with obesity ($\beta = -1.34 [-2.11, -0.58]$ $p = .001$), with no significant association for youth without obesity ($\beta = 0.21 [-0.36, 0.80]$ $p = .46$). The association between sleep and hours of sedentary time did not meaningfully change after controlling for screen time; further, screen time was not significant in the model (data not shown). There was no significant association of sleep with hours of MVPA for the total sample ($\beta = -0.03 [-0.11, 0.05]$ $p = .42$) nor in stratified models. Models testing associations between percent of time spent sedentary and in MVPA showed a similar pattern, with a significant inverse association between sleep and percent of time spent sedentary for children with obesity only ($\beta = -2.92 [-4.83, -1.01]$ $p = .004$) and no significant association between sleep and percent of time in MVPA.

DISCUSSION

This study found that, among 8–12 year old youth with BMI $\geq 75^{\text{th}}$ percentile, more sleep was significantly associated with less sedentary time but only for youth with obesity, partially supporting our hypothesis of an inverse association between sleep and sedentary

time. Contrary to our hypotheses, controlling for screen time did not change the association between sleep and sedentary time and there was no significant association of sleep with MVPA. Study results are consistent with emerging evidence about an inverse relationship between sleep and sedentary time,^{3,6,8,10–14} and add to growing but conflicting evidence about the MVPA-sleep association.^{6,8–11} Importantly, study findings contribute knowledge about potential physical behavior pathways underlying the sleep-obesity relationship in a high risk population of mostly minority and low income youth with obesity or at risk of developing obesity.

Our study findings highlight the importance of considering differences in physical behavior patterns between youth with and without obesity. Overall, youth engaged in 3 hours more sedentary time,⁴³ approximately 2 hours more screen time,⁴⁴ and half as much MVPA compared to similar-aged peers nationally. However, youth with obesity were more sedentary and less active than youth without obesity, a finding consistent with weight category differences in other studies.⁴⁵ Further, a sleep-sedentary time association existed for youth with obesity only. Such findings highlight the need for targeted, tailored, and intensive intervention for youth with obesity. Obesity reduction efforts focused on sedentary time and MVPA are particularly important during preadolescence, before the increase in sedentary time decline in MVPA that typically occur during adolescence (especially among girls).^{46–49} Future research, such as time use studies, with parents and preadolescents with obesity can inform a deeper understanding of physical behavior in this population. Experimental studies examining how manipulating sleep impacts desire for sedentary time are particularly needed.⁶ Studies using qualitative methods can provide additional insight by exploring preadolescents' perspectives on how sleep and screen time affect their ability to be active, if and how they think about managing their screen and sedentary time, and what would increase their interest in and motivation for healthier physical behaviors. Collectively, such evidence can inform interventions to reduce excess weight gain and prevent development of severe obesity during the preadolescent period.

Considering the physical behaviors of sedentary time, screen time, MVPA, and sleep as distinct but interrelated components of an overall pattern is consistent with a growing evidence^{50–53} and emerging approaches to guidelines, such as Canada's 24 Hour Movement Guidelines which encourage youth to "Sweat, Step, Sleep and Sit the right amounts each day."^{54,55} Such approaches consider MVPA, light activity, sedentary time, and sleep as part of a collective pattern of behaviors, and acknowledge the natural relationship among the behaviors across a 24 hour cycle.⁵⁵ Sleep is considered a component of the cycle, rather than isolated from what is typically thought of as activity (eg, MVPA, light activity, and sedentary time).⁵⁵ Sedentary time and MVPA are unique phenomena, considered distinct but interrelated. However, youth often engage in both types of behavior throughout the day. Similarly, screen time is a type of sedentary behavior. Many sedentary behaviors (eg, reading, school work) may not involve screens, though given societal shifts and technological advances, screen use will likely continue to increase (eg, reading book on e-reader, school work on iPad). Future work in this area will be affected by ongoing trends in technology.

Of note, this study focused on 8–12 year old youth - a population at a key developmental stage for developing life-long health behavior habits. While some studies have examined associations between sleep, MVPA, and sedentary time during isolated time points of preadolescence,^{3,9,11,13,14} to our knowledge none have included youth across 8–12 years of age; thus this study adds new knowledge about potential physical behavior pathways underlying sleep-activity associations during this important developmental stage. For many preadolescents, parents dictate bedtime/waketime though this may change as youth progress into adolescence. However, parents may less directly control their children's MVPA and sedentary time because parent influence on these behaviors is complex and often mediated through support, facilitation, and encouragement.^{56–62} In addition, many adults are sedentary, which impacts their self-efficacy and ability to role model an active lifestyle for their children.^{63,64} Efforts to promote healthy physical behaviors in preadolescent youth will likely benefit from a family-focused approach that engages parents and children to promote less sedentary time and more MVPA.

Strengths and Limitations

Study strengths include objectively measured MVPA and sedentary time, an analytic approach that considered comprehensive physical behaviors (MVPA, sedentary time, screen time, and sleep) and measurement approaches (total time and percent time), and a focus on an understudied population of youth at risk for excess weight gain. Limitations include that sleep and screen time were measured by parent-report and self-report, respectively, which likely limited their accuracy as compared to objective measurement; however, questions used were drawn from valid and reliable tools. The cross-sectional design prohibited inference of causality or exploration of the temporal nature of relationships. Further, findings are drawn from a small sample of youth enrolled in a healthy weight management intervention from one Midwestern metropolitan area. While the sample was racially and economically diverse, the results may not be generalizable to other populations or settings. Future studies can use larger samples, longitudinal designs, and objective measures of sleep and sedentary time to help further illuminate how physical behavior patterns influence the sleep-obesity relationship.

Conclusion

This study suggests that future research focused on physical behaviors and obesity should consider differences by movement intensity (sedentary time versus MVPA) and weight category (obesity versus no obesity). A growing evidence base about the pathways underlying the sleep-obesity association can inform clinical practice and public health interventions that aim to support youth to achieve and maintain a healthy weight and improve well-being.

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Characteristics, by Weight Category, of 8–12 Year Old Youth with BMI 75th Percentile, Metropolitan Minnesota, 2014–2017

Table 1

Characteristic	Total Sample (N = 114)	No obesity: BMI 75 th to <95 th percentile (N = 58)	Obesity: BMI 95 th percentile (N = 56)	p value
Age in years (mean±SD)	9.4±0.9	9.5±1.0	9.2±0.8	.11
Female (n [%])	58 (50.1)	30 (51.7)	28 (48.3)	.85
Household economic assistance (n [%])				
Yes	63 (55.3)	29 (56.9)	29 (46.0)	
No	51 (44.7)	22 (43.1)	34 (54.0)	.25
Race/ethnicity (n [%])				
White	48 (42.1)	27 (46.6)	21 (37.5)	.71
Hispanic	25 (21.9)	13 (22.4)	12 (21.4)	
Other	21 (18.4)	9 (15.5)	12 (21.4)	
Black	20 (17.5)	9 (15.5)	11 (19.6)	
BMI z-score (mean±SD)	1.6±0.7	1.1±0.4	2.1±0.3	<.001
Weight category (n [%])				
Obesity: 95 th Percentile	56 (49.1)	n/a	n/a	
No obesity: BMI 75 th - <95 th Percentile	58 (50.9)	n/a	n/a	n/a
Hours of sleep per day (mean±SD) ^a	10.3±0.8	10.2±0.8	10.3±0.8	.84
Hours of sedentary time per day (mean±SD) ^b	8.3±2.1	7.9±1.7	8.8±2.3	.02
Percent of time spent sedentary (mean±SD) ^b	62.8±9.1	62.2±9.7	63.4±8.4	.49
Hours of screen time per day (mean±SD) ^c	6.8±5.2	6.5±5.4	7.1±5.0	.59
Hours of MVPA per day (mean±SD) ^b	0.7±0.3	0.7±0.4	0.6±0.3	.003
Percent of time in MVPA (mean±SD) ^b	5.1±2.5	5.9±2.6	4.3±2.2	.0006

Note.

BMI = Body mass index. MVPA = Moderate-to-vigorous physical activity.

^aMeasured via parent-reported typical bed time and wake time.^bMeasured via Actigraph uniaxial GT3X+ accelerometer.^cMeasured via child-report hours of texting, watching television, watching DVDs or videos, playing video games on phone or hand-held device, using computer, playing video games.

Table 2

Associations of Sleep with Hours of Sedentary Time and MVPA, by Weight Category, among 8–12 Year Old youth with BMI 75th Percentile, Metropolitan Minnesota, 2014–2017

Domain	Total Sample (N = 114)	No obesity: BMI 75 th to <95 th percentile (N = 58)	Obesity: BMI 95 th percentile (N = 56)	
	β (95% CI)	p-value ^a	β (95% CI)	p-value ^a
Model 1 outcome: Hours of sedentary time ^b				
Intercept	10.84 (4.06, 17.63)	.002	5.49 (−1.94, 12.92)	.14
Sleep in hours ^c	−0.55 (−1.03, −0.07)	.02	0.21 (−0.36, 0.80)	.46
Age in years	0.43 (0.01, 0.85)	.04	0.28 (−0.16, 0.73)	.21
Female (ref: male)	0.18 (−0.60, 0.95)	.65	−0.48 (−1.37, 0.42)	.29
White (ref: minority) ^d	−0.20 (−1.00, 0.60)	.63	−0.15 (−1.08, 0.78)	.74
Economic assistance (ref: no)	−0.80 (−1.61, 0.02)	.06	1.35 (−2.30, −0.39)	.007
Obese (ref: not obese) ^e	0.62 (−0.16, 1.40)	.12	n/a	n/a
MVPA in hours ^b	−1.58 (−2.78, −0.37)	.01	−1.08 (−2.48, 0.33)	.13
Light activity in hours ^b	0.03 (−0.22, 0.28)	.81	−0.17 (−0.51, 0.17)	.32
Model 2 outcome: Hours of MVPA ^b				
Intercept	1.09 (−0.00, 2.18)	.05	0.92 (−0.56, 2.40)	.22
Sleep in hours ^c	−0.03 (−0.11, 0.05)	.42	−0.02 (−0.13, 0.09)	.71
Age in years	0.02 (−0.04, 0.09)	.47	0.01 (−0.08, 0.10)	.75
Female (ref: male)	−0.12 (−0.24, −0.00)	.05	−0.16 (−0.34, 0.01)	.06
White (ref: minority) ^d	−0.02 (−0.15, 0.10)	.74	−0.03 (−0.21, 0.16)	.76
Economic assistance (ref: no)	−0.14 (−0.26, −0.01)	.04	−0.18 (−0.38, 0.01)	.07
Obese (ref: not obese) ^e	−0.18 (−0.29, −0.06)	.004	n/a	n/a
Light activity in hours ^b	0.05 (0.01, 0.08)	.02	0.10 (0.04, 0.17)	.001
Sedentary time in hours ^b	−0.04 (−0.07, −0.01)	.01	−0.04 (−0.10, 0.01)	.13

Note.

BMI = Body mass index. MVPA = Moderate-to-vigorous physical activity.

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^b Multivariate linear regression was used to assess statistical significance.

^b Measured via Actigraph uniaxial GT3X+ accelerometer.

^c Measured via parent-reported typical bed time and wake time.

^d Racial/ethnic minority defined as Black or African American, Asian or Pacific Islander, American Indian, more than one race, or Hispanic

^e Obesity defined as BMI ≥ 95th percentile

Table 3

Associations of Sleep with Percent of Time Spent Sedentary and in Moderate-to-Vigorous, by Weight Category, among 8–12 Year Old Youth with BMI 75th Percentile, Metropolitan Minnesota, 2014–2017

Domain	Total Sample (N = 114)	No obesity: BMI 75 th to <95 th percentile (N = 58)	Obesity: BMI 95 th percentile (N = 56)	
	β (95% CI)	p-value ^a	β (95% CI)	p-value ^a
Model 1 outcome: Percent of time spent sedentary^b				
Intercept	83.65 (64.48, 101.83)	<.0001	71.40 (48.43, 94.37)	<.0001
Sleep in hours ^c	-1.18 (-2.45, 0.10)	.07	0.40 (-1.36, 2.15)	.65
Age in years	1.69 (0.57, 2.81)	.004	1.52 (0.15, 2.90)	.03
Female (ref: male)	0.10 (-2.19, 1.98)	.92	-1.88 (-4.66, 0.89)	.18
White (ref: minority) ^d	-1.18 (-3.32, 0.97)	.28	-1.33 (-4.21, -1.54)	.36
Economic assistance (ref: no)	-2.23 (-4.42, -0.04)	.05	-3.88 (-6.84, -0.92)	.01
Obese (ref: not obese)	1.10 (-0.99, 3.18)	.30	n/a	n/a
MVPA in hours ^b	-9.89 (-13.10, -6.67)	<.0001	-8.73 (-13.06, -4.40)	.002
Light activity in hours ^b	-4.03 (-4.71, -3.36)	<.0001	-4.35 (-5.40, -3.31)	<.0001
Model 2 outcome: Percent of time in moderate-to-vigorous^b				
Intercept	13.99 (6.33, 21.66)	.0005	13.60 (2.88, 24.32)	.01
Sleep in hours ^c	-0.32 (-0.85, 0.22)	.24	-0.19 (-1.01, 0.63)	.64
Age in years	-0.03 (-0.44, 0.50)	.90	0.04 (-0.61, 0.69)	.91
Female (ref: male)	-0.69 (-1.53, 0.15)	.11	-1.19 (-2.45, 0.06)	.06
White (ref: minority) ^d	-0.07 (-0.95, 0.81)	.88	-0.03 (-1.36, 1.30)	.96
Economic assistance (ref: no)	-0.81 (-1.70, 0.09)	.08	-1.23 (-2.66, 0.20)	.09
Obese (ref: not obese) ^e	-1.18 (-2.01, -0.34)	.006	n/a	n/a
Light activity in hours ^b	0.04 (-0.23, 0.31)	.77	0.26 (-0.18, 0.70)	.25
Sedentary time in hours ^b	-0.58 (-0.79, -0.37)	<.0001	-0.75 (-1.15, -0.36)	.0004

Note.

BMI = Body mass index. MVPA = Moderate-to-vigorous physical activity.

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- ^b Multivariate linear regression was used to assess statistical significance.
- ^c Measured via Actigraph uniaxial GT3X+ accelerometer.
- ^c Measured via parent-reported typical bed time and wake time.
- ^d Racial/ethnic minority defined as Black or African American, Asian or Pacific Islander, American Indian, more than one race, or Hispanic
- ^e Obesity defined as BMI ≥ 95th percentile