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Prospective associations between sedentary behavior and physical activity in adolescence and sleep duration in adulthood

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Abstract

The purpose of this prospective study was to investigate whether sedentary screen time (SST) and physical activity in adolescence were related to sleep duration in adulthood and whether these associations varied by sex. We analyzed data from 9279 adolescents who participated in Waves I and V of the National Longitudinal Study of Adolescent Health (Add Health) in the United States. SST was measured by reported hours spent watching television/videos or playing video/computer games per week. Physical activity was measured with participation in school team club sports and frequency (times/week) of moderate to vigorous physical activity (MVPA). Results from multinomial regression models indicated that adolescents with more SST, particularly 15–21 h (Relative Risk Ratio [RRR] = 1.18, 95% CI: 1.02–1.36) or 22 or more hours (RRR = 1.19, 95% CI: 1.06–1.35) compared to 0–7 h per week SST, had significantly higher relative risk of short sleep (six or fewer hours) in adulthood, after controlling for demographic characteristics, socioeconomic status and health behaviors at Waves I and V, sleep duration at Wave I, and SST and MVPA at Wave V. The association between 22 or more hours per week SST in adolescence and later short sleep varied by sex (RRR = 0.75, 95% CI: 0.58–0.95) and was significantly stronger among males. Measures of physical activity in adolescence did not predict sleep duration. Decreasing adolescents' SST to prevent suboptimal sleep later in development may be a target for further investigation, particularly for males.

Keywords

Sedentary screen time; Exercise; Sleep duration; Sex differences; Adolescence

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Declaration of Competing Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data
Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2021.106812.

1. Introduction

Sleep is essential for physical functioning and well-being. Increasingly, researchers have connected short sleep duration (less than 7 h per 24-h period) to chronic health conditions such as diabetes, obesity, heart disease, and cognitive impairment, and also to longevity (Bruce et al., 2017; Grandner et al., 2016; Kripke et al., 2002; Ruan et al., 2015; St-Onge et al., 2016). Even as the importance of sleep for well-being has become well documented and publicized, self-reports of short sleep duration have increased in recent years among adolescents and adults (Keyes et al., 2015; Sheehan et al., 2019), heightening the importance of understanding the shifting determinants of sleep. Among various factors, studies have stressed active lifestyle and healthy behaviors. For example, cross-sectional and longitudinal cohort studies have consistently linked reported and device-based greater physical activity (Farnsworth et al., 2015; Kim et al., 2016; Kredlow et al., 2015; Xu et al., 2019) and lower sedentary behavior (Buman et al., 2015; Kakinami et al., 2017; Kim et al., 2016; Xu et al., 2019; Yang et al., 2017) with optimal sleep in adolescents and adults. However, research has indicated that sleep is predicted not only by current daily or weekly factors, but also by factors and experiences that occur throughout the life span (Johnson et al., 2004; Sheehan et al., 2020). Here we use a longitudinal nationally representative sample of American adolescents, the National Longitudinal Study of Adolescent Health (hereafter Add Health), to analyze whether sedentary behavior and physical activity in adolescence are associated with sleep duration in adulthood. In doing so, we account for important demographic, socioeconomic, and behavioral health (including sleep in adolescence and sedentary behavior and physical activity in adulthood) characteristics in adolescence and adulthood, and test for sex differences.

Adolescence, which occurs between ages 10 and 19, is a period when gradual, nonlinear, and indelible psychological, social, biological, and neural changes occur as one transitions from childhood to adulthood (Brand and Kirov, 2011; Jaworska and MacQueen, 2015). During adolescence, individuals begin to establish behavioral patterns and personal lifestyle choices, which are likely to become habitual and carry over into adulthood (Kumar et al., 2015; Ortega et al., 2013; Telama, 2009; Telama et al., 2005). Levels of sedentary behavior, for example, tend to be stable or increase from adolescence through adulthood (Hanson et al., 2019; Ortega et al., 2013). Similarly, despite a decreasing trend, physical activity shows low-to-moderate rank-order stability from adolescence to adulthood (Hayes et al., 2019; Telama et al., 2005). Additionally, it is becoming increasingly clear that many chronic diseases and psychiatric illnesses begin to develop in childhood and adolescence, highlighting the importance of understanding how behaviors in these ages can shape health and well-being throughout adulthood (Biddle et al., 2004; Kessler et al., 2005). Regular physical activity and low sedentary time could be such behaviors in adolescence that help limit the development of adverse outcomes such as short sleep later in life (Johnson et al., 2004; Sacker and Cable, 2006). Yet, we were unaware of any previous research that has analyzed how physical activity and sedentary behavior in adolescence are related to sleep in adulthood (for the exception for television viewing see Johnson et al. (2004)), which is surprising given that cross-sectional and short-term longitudinal studies suggest that physical activity and sedentary behavior are related to sleep (Kredlow et al., 2015; Yang et al., 2017).

While Johnson et al. (2004) found that watching television three or more hours per day in adolescence was related to increased risk of sleep problems in adulthood, they used only a regional sample and did not account for physical activity. Given that high physical activity and high sedentary behavior can be observed in the same person (e.g., one may exercise vigorously and then be sedentary for the rest of the day) and are differentially associated with sleep (Chen et al., 2018; Kim et al., 2016; Xu et al., 2019), it is important to understand their unique, longitudinal associations with sleep.

Sex differences have been reported in physical activity and sedentary behavior, with males (on average) being more likely to participate in physical activity but also having more hours of sedentary behavior (Chen et al., 2018; Nuutinen et al., 2013; Xu et al., 2019). Importantly, there is some evidence that the associations of physical activity and sedentary behavior with sleep vary by sex, but findings of the patterns are mixed (Lin et al., 2018; McClain et al., 2014; Xu et al., 2019) and thus additional work is warranted. In this study, we analyze if there are associations between sedentary behavior and physical activity in adolescence and self-reported sleep duration in adulthood and test for sex differences.

2. Data and methods

2.1. Data

We analyzed a prospective sample from Add Health (see https://addhealth.cpc.unc.edu for more details). Add Health employed a school-based sampling design to enroll a nationally representative sample of adolescents in grades 7–12 in the United States and then followed them from adolescence through adulthood (Harris, 2013). During 1994 and 1995, over 90,000 students from 145 middle, junior, and high schools completed in-school questionnaires, and 20,745 of them were selected to participate in the Wave I in-home interview. The Wave I in-home sample was followed in 1996 (Wave II, $N = 14,738$), 2001–2002 (Wave III, $N = 15,197$), 2008–2009 (Wave IV, $N = 15,701$), and 2016–2018 (Wave V, $N = 12,300$). Our sample includes 9279 individuals who provided responses regarding physical activity from the in-school questionnaires and participated in Waves I and V in-home interviews. Add Health was approved by the Institutional Review Board (IRB) at the University of North Carolina at Chapel Hill. The permission to conduct secondary analyses was approved by the IRB at Arizona State University.

2.2. Measures

2.2.1. Sleep duration—Participants reported their sleep duration (in hours) in response to one question in the Wave V in-home interview: "*How many hours of sleep do you usually get per day/night?*" In accord with sleep duration recommendations by the American Academy of Sleep Medicine (Consensus Conference Panel et al., 2015), we categorized participants as short sleepers (six or fewer hours), optimal sleepers (seven to eight hours), and long sleepers (nine or more hours). Additional specifications in which we coded short, optimal, and long sleep duration of adults as six or fewer hours, seven to nine hours, and ten or more hours, respectively, yielded substantively similar results.

2.2.2. Sedentary behavior—Screen time, one component of sedentary behavior, was assessed in the Wave I in-home interview using three questions: "*How many hours a week do you watch television*?" "*How many hours a week do you watch videos*?" and "*How many hours a week do you play video or computer games*?" Hours given in the three responses were summed to create a measure of non–school related sedentary screen time (SST) per week. The distribution of the sum scores is presented in Supplemental Table 1. Based on the Canadian 24-h movement guidelines, individuals aged 5–17 years should limit recreational screen time to no more than 2 h per day (Tremblay et al., 2016). In addition to the 2-h cut-point, previous studies also stressed the 1-h and 3-h per-day cut-points (Carson et al., 2016). Therefore, we categorized the sum into very low (0–7 h/week), low (8–14 h/week), medium (15–21 h/week), and high (22+ hours/week) SST. Importantly, we also investigated four alternative specifications, with SST being operationalized as a continuous variable (specification A with raw scores of SST and specification B with outliers exceeding 3 SD above the mean being assigned values at 3 SD above the mean), a dichotomous variable of meeting the 2-h per day SST recommendation (0–14 h/week) or not (15+ hours/week) (specification C; Tremblay et al., 2016), and a categorical variable using the 10th and 90th percentiles as cutoffs (specification D). Each specification provided substantively similar results as those provided in the text, please see Supplemental Table 2 for more information.

2.2.3. Physical activity—Adolescents reported their participation in team club sports in school using one question in the in-school questionnaires: "*Are you participating/Do you plan to participate in the following clubs, organizations and teams?*" Team club sports included cheerleading/dance team, baseball/softball, basketball, field hockey, football, ice hockey, soccer, swimming, tennis, track, volleyball, wrestling, and other sport. Participation in any of these team club sports was coded as 1, and nonparticipation in all of them as 0.

In the Wave I in-home interview, adolescents reported their participation in moderate to vigorous physical activity (MVPA) during the past seven days in response to three questions: "*During the past week, how many times did you go roller-blading, roller-skating, skate-boarding, or bicycling?*" "*During the past week, how many times did you play an active sport, such as baseball, softball, basketball, soccer, swimming, or football?*" "*During the past week, how many times did you exercise, such as jogging, walking, karate, jumping rope, gymnastics or dancing*?" Responses ranged from *not at all* to *five or more times* and were scored as 0 times = *not at all*, 1.5 times = *1 or 2 times*, 3.5 times = *3 or 4 times*, and 6 times = *5 or more times* (Bazaco et al., 2016). Responses to the three questions were summed to create a measure of total times of MVPA each week, classified as no (*0 times*), some (*1–4 times*), and high (*5 or more times*) MVPA per week (Bazaco et al., 2016; Ford et al., 2008).

2.2.4. Covariates—Covariates included demographic variables, socioeconomic status (SES), health behaviors, and sleep duration at Wave I, and SES, health behaviors, MVPA, and SST at Wave V. Demographic characteristics included age at Wave I, biological sex, race/ethnicity, and nationality. Among the Wave I (M_{age} = 16) covariates, SES included household income, highest education of either of the parents, and neighborhood safety. Health behaviors included smoking in the past 30 days, drinking in the past 12 months, body mass index, self-rated health, and physical limitation. Among the Wave V (M_{age} =

38) covariates, SES consisted of household income, participants' education, homeownership, and employment. All measures of health behaviors at Wave I were included at Wave V, with the addition of chronic conditions. MVPA and SST at Wave V were coded consistently with Wave I. Detailed descriptions of measures and/or the exact coding of the categories for each covariate are presented in the supplementary material.

2.3. Data analytic plan

We fit a series of hierarchical multinomial regression models, with optimal sleep duration set as the referent category. Multinomial regression models are an appropriate regression approach for polytomous outcomes (i.e., optimal, short, and long sleep duration; Hoffmann, 2004). The models were calculated in Stata 16.1, and the results are presented in the form of Relative Risk Ratios (hereafter RRR). In Model 1, we included measures of SST and physical activity in adolescence (Wave I). In Model 2, we added demographic characteristics and measures of SES, health behaviors, and sleep duration in adolescence (Wave I). In Model 3, we added measures of SES, health behaviors, MVPA, and SST in adulthood (Wave V). We also investigated whether the associations of physical activity and SST with sleep duration varied significantly by sex, by fitting a model interacting the measures of SST and physical activity with sex. To clarify these interactions we calculated the predicted probability using the *margins* command which calculated for the predicted probability of short sleep duration by sex and SST level with the covariates held at their mean values (Williams, 2012). Missing data (see Supplemental Table 3 for missing rates of variables) were handled with Stata's multiple imputation suite using chained equations (Bartlett and Morris, 2015). We generated 40 imputed datasets and parameter estimates across datasets were pooled using Rubin's rule. Detailed information regarding the imputation process is presented in Supplemental Table 4.

3. Results

Descriptive statistics for the full sample and subsamples of males and females are presented in Table 1. At Wave V (M_{age} = 38), 54% of the sample reported optimal sleep duration (7–8 h), 42% reported short sleep duration (six or fewer hours), and 4% reported long sleep duration (nine or more hours). At Wave I (M_{age} = 16), 22% reported very low (0–7 h/week), 24% low (8–14 h/week), 16% medium (15–21 h/week), and 38% high (22+ hours/week) SST. Also, at Wave I, 57% of the sample participated in team club sports, 30% of the sample reported some (1–4 times/week) MVPA, and 65% reported five or more times of MVPA.

3.1. The associations of SST and physical activity with sleep duration

3.1.1. Short sleep duration—RRRs and their 95% CIs from multinomial regression models predicting sleep duration are presented in Table 2. In Model 1, compared to those who had the least SST, those with medium (RRR = 1.17, 95% CI: 1.02–1.34) or high (RRR = 1.37, 95% CI: 1.22–1.53) SST had significantly higher relative risk of reporting short sleep duration. Participation in team club sports during adolescence was associated with lower risk of short sleep duration (RRR = 0.86, 95% CI: 0.79–0.94) in adulthood. Model 2 included demographic characteristics and covariates at Wave I, and when these controls were included, participation in team club sports was no longer significant. However, even after we adjusted for these characteristics, those with medium (RRR = 1.16, 95% CI: 1.01–1.34) or high (RRR = 1.22, 95% CI: 1.08–1.37) SST had significantly higher relative risk of short sleep duration than those with the lowest SST. The substantive results remained similar when covariates at Wave V were included (Model 3). In sum, those who engaged in medium or high SST in adolescence had significantly higher risk of short sleep in adulthood, more than two decades later—even after we accounted for important covariates, including sleep duration in adolescence and MVPA and SST in adulthood. In sensitivity analyses (see Supplemental Table 2), we compared the fully adjusted models with and without SST at Wave I and found that the Akaike Information Criterion decreased across all specifications of SST when including SST at Wave I, suggesting that adding SST at Wave I improved the model fit (Akaike, 1973). In another sensitivity analyses with complete cases only (*N* = 6249), we still obtained significant prediction from high SST but not medium SST in all models.

3.1.2. Long sleep duration—

Participation in team club sports was associated with lower risk of long sleep duration in Model 1 (RRR = 0.75, 95% CI: 0.61–0.93), but this association was no longer significant when demographic characteristics and covariates at Wave I were included in Model 2.

3.2. Sex differences

To examine sex differences, we fit a fully adjusted model (i.e., a model with all the covariates) with interaction terms between the measures of physical activity and SST with sex (see Supplemental Table 5). The results indicated that there was a significant interaction between high SST and sex (RRR = 0.75, 95% CI: 0.58–0.95) on short sleep, as the relationship was significantly stronger for males. We present the predicted probabilities by sex from the interaction model in Fig. 1. Fig. 1 indicates that there is a step-wise association between higher SST and the predicted probability of short sleep for males.

4. Discussion

Utilizing a 22-year prospective sample, we investigated the unique associations between SST and physical activity during adolescence and sleep duration during adulthood. Our primary findings suggest that more SST in adolescence, especially high (22+ hours/week) SST as compared to very low (0–7 h/week) SST, was associated with higher risk of short sleep duration in adulthood, even after accounting for covariates in adolescence (including sleep duration) and adulthood (including MVPA and SST). These nationally representative results are consistent with studies of regional samples (Johnson et al., 2004; Kakinami et al., 2017; Nuutinen et al., 2013) suggesting the importance of sedentary behavior in determining sleep quality and duration throughout the life course. Our study extended prior research by utilizing a long-term prospective, nationally representative sample, accounting for important covariates, and providing evidence for the "long arm" of sedentary behavior in adolescence for sleep in adulthood.

The long-term association between high SST and elevated risk for short sleep duration was evident. Future studies should further investigate the pathways that might explain the long-term association. For example, it is possible that SST observed in adolescence is likely to carry over and persist into adulthood and is, therefore, prospectively associated with short sleep during adulthood (Falbe et al., 2015; Hanson et al., 2019; Hysing et al., 2015). Indeed, physical activity, sedentary behavior, and sleep time, which are co-dependent within 24-h and weekly time frames (Pedišić, 2014), may be structured in a certain pattern during adolescence and carry over to adulthood (Hanson et al., 2019; Hayes et al., 2019; Ortega et al., 2013; Telama et al., 2005). Additionally, adolescents who have high SST are at increased risk of sleep disorders, which may subsequently be associated with short sleep duration (Grandner and Kripke, 2004; Yang et al., 2017). Likewise, high SST in adolescence may be related to negative physical (e.g., obesity) and psychosocial (e.g., depression, loneliness) outcomes that also likely increase the risk of sleep disorders and short sleep in adulthood (Buman et al., 2011; Tremblay et al., 2010; Vancampfort et al., 2019).

Our results also indicated that the association between SST and sleep duration varied by sex: the association between high SST in adolescence and short sleep in adulthood was significantly stronger among males than females. We were unable to statistically explain why the differences exist, but male and female adolescents may watch different television programs or videos and play different video/computer games. Females are less likely to engage in video games than males, especially competitive and violent video games (Hartmann and Klimmt, 2006). Playing video games, particularly those involving violent elements, may negatively influence sleep (King et al., 2013). It is also plausible that males and females differ in patterns of sedentary behavior. For example, women experience interruptions in sedentary time more often than men do (Bellettiere et al., 2015), and more interruptions in sedentary time are related to more optimal health outcomes (Sardinha et al., 2015). Given that males tend to have longer and more continuous hours of sedentary behavior than females (Bellettiere et al., 2015; Chen et al., 2018; Nuutinen et al., 2013; Xu et al., 2019), males may be at particularly high risk of short sleep duration and these behavior patterns formed in adolescence may carry over into adulthood (Hanson et al., 2019; Ortega et al., 2013).

Physical activity during adolescence, including participation in school team club sports and frequency of MVPA per week, was not related to risk of short or long sleep duration in adulthood in the fully adjusted model. This finding is consistent with one cross-sectional study indicating that when both sedentary behavior and self-reported physical activity were included in models, only sedentary behavior was related to sleep in young adults (Kakinami et al., 2017). These results are not surprising, given that physical activities investigated in this study were likely to occur in the daytime, so that they might have greater influence on sleep quality than on sleep duration (Kredlow et al., 2015). By contrast, sedentary behaviors are not restricted to particular times and are likely to become habitual (Hanson et al., 2019), which could lead to long-term influences on sleep duration.

5. Limitations

This study has some limitations. First, the self-reports of sedentary behavior, physical activity, and sleep duration could suffer from measurement error and social desirability bias. Future studies should use device-based measurements. Of course, given the expensive and often intrusive techniques needed to measure physical activity and sleep, these studies will likely lack the external generalizability that studies using self-reports can provide. Second, sedentary behavior at Wave I was assessed during 1996. Given that the prevalence and conditions in which sedentary behaviors occur have changed in the last two decades, findings of this study are not generalizable but portend poorly for the sleep in adulthood of contemporary cohorts of adolescents who are likely to have increased SST and decreased sleep compared to those analyzed in this study (Matricciani et al., 2012; Yang et al., 2019). Third, Add Health used limited measures of physical activity and sedentary behavior, which did not allow us to test other specifications such as the energy expenditure of MVPA and breaks in SST. Future studies should collect more detailed data on these variables and examine how different specifications are related to sleep. Fourth, given that time of physical activity, sedentary behavior, and sleep may be co-dependent within 24-h or weekly time frames (Pedišić, 2014), future studies should analyze the dynamic balance among these behaviors and how the balance is related to subsequent outcomes. Finally, our missing data were handled with multiple imputation under the assumption of missing at random. It is possible that data were missing not at random, which might lead to biased estimates (Carreras et al., 2021).

6. Conclusion

This study suggests that adolescents, especially adolescent males, who have more SST, particularly high (22+ hours/week) as compared to very low (0–7 h/week) SST, are more likely to get insufficient sleep (six or fewer hours) once they reach adulthood. Given the detrimental effects of insufficient sleep on health and well-being, it is important to investigate whether decreasing adolescents' SST might promote healthy sleep behaviors and thus greater well-being throughout the life course.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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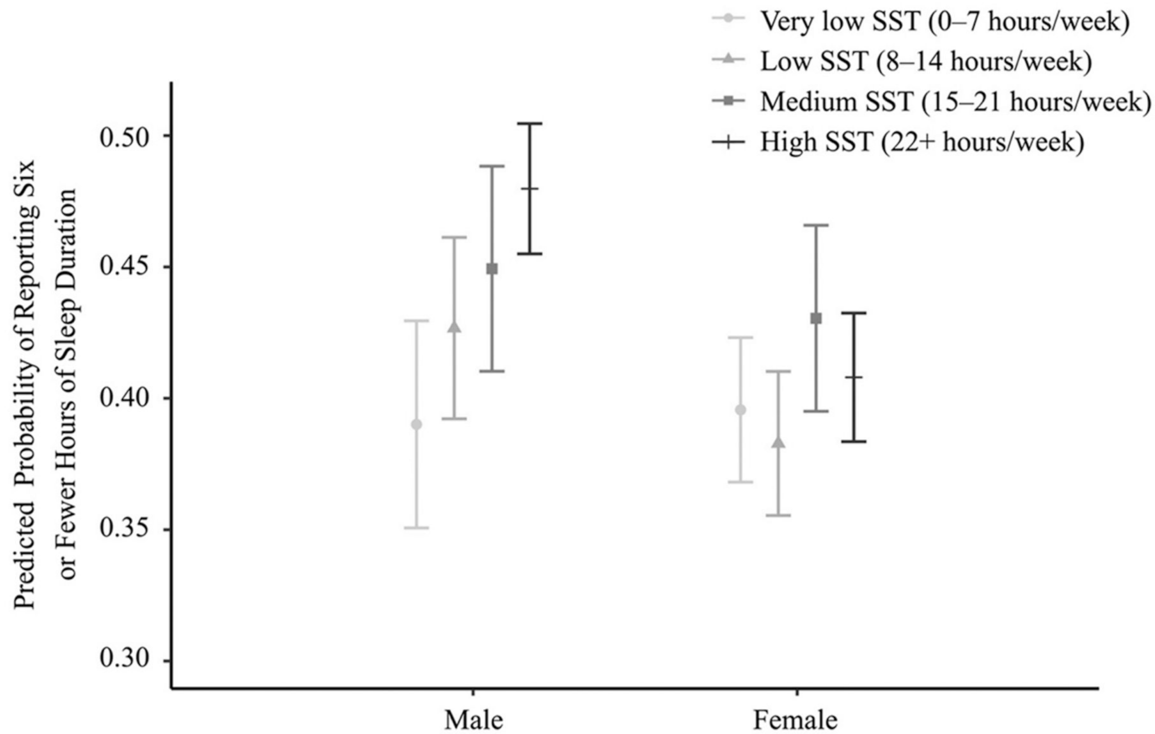

Fig. 1.

Predicted probability of reporting six or fewer hours of sleep duration (per 24-h period) in male (N = 3989) and female (N = 5290) adults.

Note. SST = sedentary screen time. Error bars represent 95% confidence intervals of estimates.

Table 1

Descriptive statistics of sleep duration, sedentary behavior, physical activity, and covariates from the national longitudinal study of adolescent to adult health (add health; *N* = 9279).

Variables	Full sample (*N* = 9279)		Male sample (*N* = 3989)		Female sample (*N* = 5290)	
	N	Proportion or *M* (*SE*)	*N*	Proportion or *M* (*SE*)	*N*	Proportion or *M* (*SE*)
Sleep duration						
W1 sleep duration		7.75 (0.01)		7.79 (0.02)		7.72 (0.02)
Short (e.g., 0–7 h for adolescents aged 13–18)	3550	0.38	1491	0.37	2059	0.39
Optimal (e.g., 8–9 h for adolescents aged 13–18)	4877	0.53	2120	0.53	2756	0.52
Long (e.g., 10+ hours for adolescents aged 13–18)	852	0.09	378	0.09	474	0.09
W5 sleep duration		6.73 (0.01)		6.66 (0.02)		6.79 (0.02)
Short (0–6 h)	3907	0.42	1772	0.44	2135	0.40
Optimal (7–8 h)	4991	0.54	2093	0.52	2898	0.55
Long (9+ hours)	380	0.04	123	0.03	257	0.05
Sedentary behavior						
W1 sedentary screen time (hours/week)		22.45 (0.22)		25.27 (0.36)		20.32 (0.28)
0–7 h/week	2022	0.22	650	0.16	1372	0.26
8–14 h/week	2200	0.24	874	0.22	1326	0.25
15–21 h/week	1508	0.16	689	0.17	819	0.15
22+ hours/week	3549	0.38	1776	0.45	1773	0.34
W5 sedentary screen time (hours/week)		13.02 (0.14)		14.19 (0.23)		12.15 (0.17)
0–7 h/week	3899	0.42	1466	0.37	2432	0.46
8–14 h/week	2528	0.27	1136	0.28	1392	0.26
15–21 h/week	1609	0.17	774	0.19	834	0.16
22+ hours/week	1244	0.13	613	0.15	631	0.12
Physical activity						
W1 participation in team Club sports	5328	0.57	2480	0.62	2848	0.54
W1 moderate to vigorous physical activity (times/week)		6.57 (0.04)		7.59 (0.07)		5.80 (0.05)
0 times	506	0.05	158	0.04	348	0.07
1–4 times	2773	0.30	896	0.22	1877	0.35
5+ times	6000	0.65	2935	0.74	3065	0.58

Variables	Full sample (N = 9279)		Male sample (N = 3989)		Female sample (N = 5290)	
	N	Proportion or *M* (*SE*)	*N*	Proportion or *M* (*SE*)	*N*	Proportion or *M* (*SE*)
W5 moderate to vigorous physical activity (times/week)		4.45 (0.05)		5.19 (0.08)		3.88 (0.06)
0 times	2227	0.24	723	0.18	1505	0.28
1–4 times	3500	0.38	1469	0.37	2030	0.38
5+ times	3552	0.38	1797	0.45	1755	0.33
Demographics						
W1 age		16.06 (0.02)		16.16 (0.03)		15.99 (0.02)
Female	5290	0.57	0	0	5290	1.00
US citizen	8690	0.94	3729	0.93	4961	0.94
Race/ethnicity						
Non-Hispanic white	5125	0.55	2292	0.57	2833	0.54
Non-Hispanic black	1807	0.19	661	0.17	1146	0.22
Hispanic	1328	0.14	573	0.14	755	0.14
Non-Hispanic other	1019	0.11	463	0.12	556	0.11
W1 socioeconomic status						
W1 household income						
Less than $39,999	4464	0.48	1823	0.46	2641	0.50
$40,000 to $74,999	3470	0.37	1555	0.39	1915	0.36
$75,000+	1344	0.14	610	0.15	734	0.14
W1 highest education of parents						
Below high school	1002	0.11	386	0.10	616	0.12
High school graduate to some college	4688	0.51	1968	0.49	2720	0.51
College graduate or higher	3589	0.39	1635	0.41	1953	0.37
W1 neighborhood safety	8270	0.89	3602	0.90	4668	0.88
W5 socioeconomic status						
W5 household income						
Less than $39,999	2306	0.25	813	0.20	1493	0.28
$40,000 to $74,999	2277	0.25	1009	0.25	1268	0.24
$75,000+	4695	0.51	2167	0.54	2528	0.48
W5 education						
Below high school	307	0.03	161	0.04	146	0.03

Variables	Full sample (N = 9279)		Male sample (N = 3989)		Female sample (N = 5290)	
	N	Proportion or *M* (*SE*)	*N*	Proportion or *M* (*SE*)	*N*	Proportion or *M* (*SE*)
High school graduate to some college	4959	0.53	2296	0.58	2662	0.50
College graduate or higher	4013	0.43	1532	0.38	2481	0.47
W5 home ownership	8085	0.87	3399	0.85	4686	0.89
W5 employment	7864	0.85	3564	0.89	4300	0.81
W1 health behaviors						
W1 smoke	2197	0.24	950	0.24	1247	0.24
W1 alcohol	2638	0.28	1203	0.30	1435	0.27
W1 body mass index						
Underweight	272	0.03	129	0.03	144	0.03
Normal weight/overweight	8028	0.87	3366	0.84	4662	0.88
Obese	978	0.11	494	0.12	484	0.09
W1 self-rated health						
Good, very good, or excellent	8722	0.94	3811	0.96	4911	0.93
W1 physical limitation	246	0.03	104	0.03	142	0.03
W5 health behaviors						
W5 smoke	2160	0.23	1055	0.26	1105	0.21
W5 alcohol	6767	0.73	3065	0.77	3703	0.70
W5 body mass index						
Underweight	88	0.01	19	0.00	69	0.01
Normal weight/overweight	5440	0.59	2441	0.61	2999	0.57
Obese	3751	0.40	1529	0.38	2222	0.42
W5 self-rated health						
Good, very good, or excellent	8071	0.87	3460	0.87	4610	0.87
W5 chronic conditions	4878	0.53	2039	0.51	2840	0.54
W5 physical limitation	438	0.05	147	0.04	290	0.05

Note. W1 = Wave I (M_{age} = 16), W5 = Wave V (M_{age} = 38).

Table 2

Multinomial logistic regression models predicting short (six or fewer hours per 24-h period) and long sleep duration (nine or more hours per 24-h period) compared to optimal sleep duration (seven to eight hours per 24-h period) ($N = 9279$).

	Short vs. optimal			Long vs. optimal		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	RRR [95% CI]	RRR [95% CI]	RRR [95% CI]	RRR [95% CI]	RRR [95% CI]	RRR [95% CI]
W1 sedentary screen time (reference: 0–7 h/week)						
8–14 h/week	1.02 [0.90, 1.16]	1.01 [0.89, 1.15]	1.02 [0.90, 1.17]	1.04 [0.76, 1.41]	1.06 [0.78, 1.45]	1.12 [0.81, 1.53]
15–21 h/week	1.17 [1.02, 1.34]	1.16 [1.01, 1.34]	1.18 [1.02, 1.36]	0.97 [0.68, 1.38]	1.01 [0.71, 1.43]	1.05 [0.73, 1.50]
22+ hours/week	1.37 [1.22, 1.53]	1.22 [1.08, 1.37]	1.19 [1.06, 1.35]	1.18 [0.89, 1.56]	1.16 [0.87, 1.55]	1.12 [0.83, 1.50]
W1 participation in team Club sports	0.86 [0.79, 0.94]	0.92 [0.84, 1.01]	0.97 [0.89, 1.07]	0.75 [0.61, 0.93]	0.82 [0.66, 1.02]	0.92 [0.73, 1.15]
W1 moderate to vigorous physical activity (reference: No times)						
1–4 times/week	0.95 [0.78, 1.16]	0.98 [0.80, 1.20]	0.99 [0.81, 1.22]	0.91 [0.59, 1.42]	0.92 [0.59, 1.44]	0.96 [0.61, 1.50]
5+ times/week	1.03 [0.85, 1.25]	1.10 [0.90, 1.34]	1.12 [0.92, 1.37]	0.79 [0.51, 1.22]	0.89 [0.57, 1.38]	0.92 [0.59, 1.44]
W1 age		1.02 [0.99, 1.05]	1.02 [1.00, 1.05]		1.01 [0.95, 1.08]	1.01 [0.95, 1.09]
Female		0.85 [0.78, 0.93]	0.86 [0.79, 0.95]		1.45 [1.15, 1.82]	1.31 [1.03, 1.67]
US citizen		1.34 [1.10, 1.63]	1.23 [1.01, 1.50]		1.16 [0.70, 1.93]	1.04 [0.62, 1.74]
Race/ethnicity (reference: Non-Hispanic white)						
Non-Hispanic black		1.99 [1.77, 2.25]	1.85 [1.63, 2.09]		1.22 [0.91, 1.64]	1.07 [0.79, 1.45]
Hispanic		1.29 [1.12, 1.48]	1.31 [1.14, 1.51]		0.81 [0.57, 1.16]	0.87 [0.61, 1.25]
Non-Hispanic other		1.66 [1.43, 1.93]	1.67 [1.43, 1.94]		0.88 [0.58, 1.33]	0.88 [0.58, 1.33]
W1 household income (reference: Less than $39,999)						
$40,000 to $74,999		0.83 [0.74, 0.93]	0.90 [0.80, 1.02]		0.83 [0.64, 1.09]	0.99 [0.75, 1.30]
$75,000+		0.73 [0.62, 0.87]	0.84 [0.70, 1.00]		0.77 [0.52, 1.15]	0.98 [0.65, 1.49]
W1 highest education of parents (reference: Below high school)						
High school graduate to some college		1.12 [0.96, 1.31]	1.16 [0.99, 1.36]		0.69 [0.49, 0.96]	0.76 [0.54, 1.08]
College graduate or higher		0.95 [0.80, 1.13]	1.07 [0.89, 1.28]		0.66 [0.45, 0.97]	0.81 [0.55, 1.21]
W1 neighborhood safety		0.89 [0.78, 1.03]	0.94 [0.82, 1.09]		0.86 [0.62, 1.21]	0.94 [0.67, 1.32]
W1 smoke		1.20 [1.07, 1.34]	1.06 [0.94, 1.20]		1.26 [0.97, 1.65]	1.11 [0.84, 1.47]
W1 alcohol		0.87 [0.78, 0.97]	0.89 [0.79, 0.99]		1.03 [0.79, 1.33]	1.09 [0.84, 1.42]
W1 body mass index (reference: Normal weight/overweight)						

	Short vs. optimal			Long vs. optimal		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	RRR [95% CI]	RRR [95% CI]	RRR [95% CI]	RRR [95% CI]	RRR [95% CI]	RRR [95% CI]
Underweight		0.85 [0.65, 1.12]	0.92 [0.70, 1.21]		1.95 [1.21, 3.12]	2.11 [1.29, 3.46]
Obese		1.30 [1.13, 1.51]	1.07 [0.92, 1.25]		0.96 [0.65, 1.40]	0.80 [0.54, 1.20]
W1 self-rated good, very good, or excellent health		1.03 [0.85, 1.24]	1.22 [1.01, 1.48]		0.69 [0.47, 1.02]	0.87 [0.58, 1.29]
W1 physical limitation		1.53 [1.17, 2.00]	1.38 [1.05, 1.82]		1.26 [0.68, 2.33]	1.08 [0.58, 2.01]
W1 sleep duration (reference: Optimal)						
Short		1.43 [1.31, 1.57]	1.44 [1.31, 1.59]		0.82 [0.64, 1.04]	0.83 [0.65, 1.07]
Long		0.84 [0.71, 0.98]	0.79 [0.67, 0.93]		1.51 [1.11, 2.05]	1.36 [0.99, 1.87]
W5 household income (reference: Less than $39,999)						
$40,000 to $74,999			0.87 [0.76, 1.00]			0.78 [0.58, 1.06]
$75,000+			0.81 [0.71, 0.92]			0.68 [0.50, 0.92]
W5 education (reference: Below high school)						
High school graduate to some college			1.30 [1.01, 1.69]			0.92 [0.57, 1.49]
College graduate or higher			1.07 [0.82, 1.41]			0.88 [0.52, 1.51]
W5 home ownership			0.92 [0.80, 1.05]			0.82 [0.61, 1.10]
W5 employment			1.22 [1.06, 1.40]			0.44 [0.34, 0.57]
W5 smoke			1.29 [1.15, 1.44]			1.09 [0.83, 1.42]
W5 alcohol			0.98 [0.88, 1.08]			0.75 [0.59, 0.94]
W5 body mass index (reference: Normal weight/overweight)						
Underweight			0.93 [0.58, 1.51]			0.73 [0.27, 1.92]
Obese			1.21 [1.09, 1.33]			1.16 [0.91, 1.48]
W5 self-rated good, very good, or excellent health			0.72 [0.62, 0.83]			0.78 [0.56, 1.07]
W5 chronic conditions			1.25 [1.14, 1.36]			1.19 [0.95, 1.49]
W5 physical limitation			1.50 [1.19, 1.89]			1.00 [0.63, 1.59]
W5 sedentary screen time (reference: 0–7 h/week)						
8–14 h/week			0.94 [0.84, 1.04]			0.82 [0.61, 1.09]
15–21 h/week			0.91 [0.80, 1.03]			1.06 [0.78, 1.45]
22+ hours/week			1.06 [0.91, 1.22]			1.31 [0.96, 1.80]
W5 moderate to vigorous physical activity (reference: No times)						
1–4 times/week			0.93 [0.83, 1.04]			0.84 [0.64, 1.09]

	Short vs. optimal			**Long vs. optimal**		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
	RRR [95% CI]	**RRR [95% CI]**	**RRR [95% CI]**	**RRR [95% CI]**	**RRR [95% CI]**	**RRR [95% CI]**
5+ times/week			0.93 [0.82, 1.05]			0.78 [0.59, 1.04]
Akaike's information criterion	15,337.80	14,966.06	14,696.14	15,337.80	14,966.06	14,696.14

Note. Relative Risk Ratios (RRR) and 95% Confidence Intervals (CI) are shown. W1 = Wave I, W5 = Wave V. Bold indicates statistically significant results ($p < .05$).