Waking Activities and Sleep: Analysis of UK Adolescents' Daily Time-Use Diaries

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Abbreviations: MCS – Millennium Cohort Study; NSF – National Sleep Foundation; TUD – Time-Use Diary; NS-SEC – National Statistics Socioeconomic Classification; CLS – Centre for Longitudinal studies; MD – Mean Difference; CI – Confidence Intervals; RRR – Relative Risk Ratio.

Abstract

Purpose: To investigate waking activities associated with risks of short and long sleep in a representative cohort of UK adolescents.

Methods: Data from 14-year-olds participating in the UK Millennium Cohort Study were used. Daily time-use diaries were completed by adolescents on two randomly selected days (one weekday and one weekend) to capture their activities within a 24h period from 4am of each selected day. Short and long sleep duration categories were computed by using the National Sleep Foundation's age-specific non-recommended sleep duration thresholds.

Results: Approximately 8% and 6% were short sleepers on weekdays and weekends, respectively. On average, adolescents spent 33% of their time awake per weekend day on recreational digital media activities. Compared to those with optimal sleep on weekdays, short sleepers spent more time on personal care (Mean Difference, MD = +56min; 95% CI: 21; 92) and less time on exercise activities (MD = -15min; 95% CI: -27; -3). 10-minute increase in daily digital media activity was associated with 2% (95% CI: 1.01; 1.03) higher relative risk (RR) of adolescents being short sleepers on weekdays. RR of short sleeping was 1.03 (95% CI: 1.01; 1.04) times higher for every 10-minute daily increase in travel time on weekdays.

Conclusions: Adolescents spend up to a-third of their time awake per day on digital media. However, more time spent on personal care and travel on weekdays and weekends is associated with increased risk of short sleep. These findings permit a reflection on appropriate interventions needed to improve sleep duration in sleep-deprived teens.

Keywords: Sleep duration; waking activities; adolescence; sleep deprivation; excessive sleep; time-use; Millennium Cohort Study.

Implications and Contribution Statement

Adolescents spend up to a-third of their time awake per day on digital media. More time on daily digital media, travel and personal care is associated with higher risk of adolescents being short sleepers relative to being optimal sleepers. This study provides information to improve future interventions of adolescents' sleep.

Introduction

Sleep plays a crucial role in the continuous physiological and psychological development of children. From a developmental perspective, sleep duration requirements physiologically reduce with increasing age as a result of adjustments in circadian regulation and sleep homeostasis, especially from childhood to adolescence[1,2]. However, there are growing concerns about sociological and lifestyle-related declines in sleep duration and increasing levels sleep deprivation among adolescents[3]. Evidence from analysis of large datasets revealed a historical shift in sleep duration over the past decades in several countries[4] and historical increase in the risk of short sleep among adolescents[5].

Sleep duration problems are not limited to short or insufficient sleep duration but also, long sleep duration, which has been linked with adverse health outcomes. Among adults, short and long sleep duration have been shown to be associated with increased risk cardiovascular disease[6,7], diabetes[8,9], and all-cause mortality[10,11]. Among adolescents, a similar U-shaped relationship with the risk of obesity – a leading public health problem – has been reported[12]. Sleep problems have also been shown to be associated with poor mental health[13] and academic performance among adolescents[14,15]. Although sleep is potentially modifiable, there is very little evidence of effective interventions that improve sleep duration of adolescents[16]. In order to develop effective interventions, it is important to understand what waking activities compete for adolescents' sleep duration in a 24h period. The epidemic of sleep insufficiency and deprivation in adolescents have been attributed to a number of social and lifestyle factors, in particular, early school start times[17,18], and increasing exposure and use of screen-based media devices[19,20]. The delayed sleep onset as a result of exposure to screen-based media devices means adolescents are sleeping later than normal[20] and waking up early for school. However, within a 24h period, other waking activities may also compete for sleep time in a typical adolescent's life. Understanding how

time spent on waking activities by short and long sleepers differ from those with optimal sleep is key to designing policies and interventions aimed at improving sleep among adolescents.

This research paper provides insights into the amount of time adolescents spend on various activities in a day and examines which daily waking activities compete for adolescents' sleep time. The paper also investigates waking activities that are associated with risks of short sleep and long sleep. The data analysed in this paper is drawn from daily time-use activity diaries (TUDs) from a large population-based cohort of adolescents in the United Kingdom.

Methods

Participants

Participants included adolescents participating in the UK Millennium Cohort Study (MCS), a nationally representative prospective cohort study of infants born between September 2000 and January 2002. The MCS used a stratified, clustered random sample design to oversample hard-to-reach populations including ethnic minorities and those living in disadvantaged areas. Detailed sampling strategy and profile of the MCS are explained elsewhere[21]. Briefly, the MCS sample is drawn from 398 electoral wards nested in 9 sampling strata i.e. two strata (advantage and disadvantaged) for each of the four nations of the UK and an extra ethnic minority stratum for England. The disadvantaged, smaller nations (Scotland, Wales and Northern Ireland) and ethnic minorities were proportionally oversampled. Participants in the MCS have been followed from infancy through adolescence. To date, there have been six sweeps - the most recent occurring when most of the participants were 14 years old (01/2015 – 04/2016). The present study uses data from this sixth sweep of MCS (MCS6) since it is the only sweep when TUDs were provided [22]. At MCS6, 61% of

the original sample participated. In this article, sample and attrition weights generated by the MCS were applied in all analyses to account for the sub-group oversampling in the design and attrition. By accounting for survey weights, bias in estimates of parameters are minimised.

Time-use data

Participants completed TUDs which included information about their daily activities and the amount of time they spent engaging in those activities in real time. The TUDs were completed on two randomly selected days (one weekday and one weekend) within 3 to 10 days after parents' consent. The days for completing the diaries were randomly generated by a computer-assisted personal interview programme. Participants completed TUDs using one of three methods – online diary (entered in a web form); app diary (entered in a smartphone or tablet application); and paper diary (entered in a paper form). In all, participants were given a list of 44 pre-coded specific diary activities (tier 2) that were nested in 12 general activity categories (tier 1) as shown in the appendix, Table A1.

Participants were encouraged to use the electronic methods but were offered the paper version, if they refused. For the electronic options, participants were given leaflets with instructions to download app or visit website as well as unique login details to access the TUD. Checks were programmed into the electronic diaries to ensure data quality. There were no restrictions for participants to complete the TUDs during or at the end of the day of assessment. The online and paper diaries requested for time spent on activities within the 24h period in 10-minute slots beginning at 4am on the selected day while the app diary required the participant to assign a start and end time for their activity. Therefore, Saturday refers to the period from 4 am Saturday until 4am Sunday; Sunday refers to the period from 4 am Sunday until 4am Monday, etc. Where consent was obtained, participants received text messages to remind them to complete the TUDs on the day prior to, and the morning of each

diary day. The Centre for Longitudinal studies (CLS) in the University College London (UCL) harmonized data from the different diary methods into 10-minute slots and made it publicly available via UK Data Service [22]. CLS, Ipsos MORI and the Centre for Time Use Research at the University of Oxford designed the materials used in the MCS TUD[23].

Sociodemographic data

Sociodemographic variables that were deemed to be potentially associated with time spent on daily activities were selected *a priori* from MCS household and parent-derived datasets[22]. Specifically, adolescent's age, sex, ethnicity, parental socioeconomic status, and number of people in household were selected as potential confounders for our analysis. The National Statistics Socioeconomic Classification (NS-SEC) level (3-group version) of the main respondent parent was used to classify the parental socioeconomic status. Except for age (continuous variable), all other variables were categorised – sex (boys/ girls), ethnicity (white/ non-white); and the total number of people in household (< 5 people / ≥ 5 people).

Data processing and statistical analysis

Incomplete daily diaries were excluded during the data cleaning process. Except for two tier-2 activities – sleep and personal care – all other activity variables used in the analysis were tier-1 activities. Thus, in total, 13 activities were considered, and all analyses were run separately for weekdays and weekends. Hereafter, all activities except sleep are referred to as waking activities. The overall analytical sample was 4029 adolescents with all survey characteristics from whom 7082 completed TUD days were obtained.

First, descriptive analyses were performed to show the weighted daily average time adolescents spent on activities on weekdays and weekends. Sleep duration was computed from the total time that adolescents reported sleeping per day between 4am of the TUD start day and 4am of the following day. Sleep duration was used as continuous variable in

descriptive analysis but was converted to a categorical variable to reflect short sleep, optimal sleep, and long sleep categories in inferential analyses. The United States National Sleep Foundation's (NSF) recommended age-specific sleep durations were used to create sleep categories[24]. To account for potential over or under reporting of sleep duration, non-recommended (extreme) sleep duration thresholds were used to define short sleep (<7h for all) and long sleep (>12h for under-14-year-olds and >11h for ≥ 14 -year-olds). Optimal sleep was therefore conservatively defined as neither short nor long sleep.

Second, covariance between the sleep duration categories and time spent on waking activities were explored. Precisely, the adjusted mean difference in the time spent on each waking activity between both short sleepers and long sleepers compared to optimal sleepers was investigated using multiple linear regressions. Third, multinomial logistic regressions were used to investigate waking activities that are associated with sleep duration categories whereby adolescents with optimal sleep duration were the reference outcome group. Linear and multinomial logistic regression models were adjusted for sex, ethnicity, age, parental socioeconomic status and number of people in household. The analyses were not stratified by sex because exploratory analyses did not show sex-waking activity interactions in relation to the relative risk of short or long sleep. Since data on whether weekday was a school day was a holiday or not, two sensitivity analyses were performed. The first excluded data collected in the month of August since this the summer holiday period that is common among all pupils in the UK. The second sensitivity analyses were multinomial logistic regressions on a sub-cohort of adolescents who reported some in-class activity (tier 2) on Weekdays. The assumption was that, reporting in-class activity was indicative of being in school on the day of the assessment.

Statistical analyses were performed using by using Stata MP/13.1 (Stata Corp, College Station, TX). Weights were used in all analyses to account for non-response and

oversampling of disadvantaged and minority groups. The survey data commands in Stata were used to account for clustering and stratification within the MCS and applied a finite population correction factor. Statistical significance was defined as $P < .05$.

Ethical considerations

Parents/guardians provided written consent for children to participate in the TUD component of the MCS, and adolescents provided verbal consent before starting the TUD-part of the study. Ethical approval for MCS6, including subsequent amendments, was obtained from National Research Ethics Service (NRES) Research Ethics Committee London by CLS (REC ref: 13/LO/1786)[23]. The MCS dataset is publicly available on the UK Data Service website to registered users. The present project received governance approval from the University of Lincoln Research Ethics Committee (ref: 2019-1093).

Results

In total, 7,088 of 8,625 daily TUDs were fully completed by adolescents (82.2% completion). Of the completed TUDs, 73.8% were completed on the app diary, 23.6% on the online diary, and 2.7% on the paper diary. Figure 1 shows a flow chart of TUD completion by adolescents. Complete TUDs for both randomly selected days were provided by 3056 adolescents while 495 completed diaries only on a weekday and 487 completed only on a weekend.

Survey characteristics were missing for 3 of the 4032 adolescents who completed TUD on at least one day. Of the 4029 adolescents (53% girls), 20.7% were not 14 years old yet and 37.7% lived in a household with more than 5 members (including themselves). The prevalence of short sleep was approximately 8% on weekdays and 6% on weekends. The prevalence of long sleep doubled on weekends compared to weekdays (29.2% v 12.8%, respectively – Table 1).

Figures 2 and 3 show the correlation matrices of the survey-weighted time spent on each pair of the 14 major (tier 1) activities on weekdays and weekends, respectively. Weighted daily averages of the duration of adolescents' activities are presented in the appendix, Table A2. As shown in Table 2, mean sleep duration (standard error, *SE*) was 9.4 h (0.05) and 10.2 h (0.05) on weekdays and weekends, respectively. On weekdays, *M* (*SE*) sleep duration for short sleepers, optimal sleepers, and long sleepers was 5.0 h (0.13), 9.1 h (0.03), and 13.4 h (0.15), respectively. On weekends, *M* (*SE*) sleep duration for short sleepers, optimal sleepers, and long sleepers was 4.8 h (0.03), 9.7 h (0.18), and 12.6 h (0.06), respectively. On average, adolescents spent 22% and 33% of their daily time awake on digital media activities on weekdays and weekends, respectively. There was a statistically significant difference in the average time spent on most activities between boys and girls on weekdays and weekends (Table 2). Specifically, on weekdays, boys spent significantly more time on sleep, digital media and physical exercise activities whereas girls spent significantly more time on social events, personal care, eating and drinking, travel, hobbies and house chores. This pattern of sex-difference in time spent on activities persisted on weekends except for sleep, eating and drinking, and travel time (which was not different between boys and girls on weekends). Overall, the average time spent on each of the activities (except personal care) was significantly different between weekdays and weekends. Sensitivity analysis on weekday activity for adolescents who reported some time spent on in-class activity (tier-2) showed that sleep average sleep duration of this group was 8.7 h (0.04) and average time spent on education-related activities was 6.8 h (0.04) (Table A3).

Figure 4 shows the adjusted daily mean difference (MD) and corresponding 95% confidence interval (CI) in the time spent on waking activities between both short and long sleepers, and optimal sleepers on weekends. As expected, long sleepers spent significantly less time on several waking activities (e.g. social events, digital media, travel, personal care, physical

exercise) compared to those who had optimal sleep on weekends – the highest difference was for time spent on digital media (MD = -50 min; 95% CI: -68; -32). Digital media in this paper refers only to time spent on recreational digital media activities and not use for academic or communication purposes. Contrarily, except for personal care (MD = +79 min; 95% CI: 42; 116), the adjusted daily average time spent on most weekend activities by short sleepers was not statistically significantly different from activities of optimal sleepers (Table A4). On weekdays, however, short sleepers spent significantly more daily time on social events (MD = +36 min (95% CI: 9; 63), and personal care (MD = +56 min; 95% CI: 21; 92), and spent significantly less time on physical exercise activities (MD = -15 min; 95% CI: -27; -3) compared to the optimal sleep group (Table 3). Likewise, long sleepers relatively spent significantly more time on eating and drinking, and house chores but less time on travelling, personal care, and education-related activities on weekdays (Figure A1).

Table 4 shows results of multinomial logistic regression models on weekdays (N = 2800) and weekends (N = 2805): the risk of an adolescent being a short sleeper or a long sleeper relative to the risk of being an optimal sleeper. The results revealed that, after adjusting for confounding variables, a 10-minute increase in the daily time spent on digital media weekdays was associated with 2% (95% CI: 1.01; 1.03) increased relative risk of an adolescent being a short sleeper. However, increase in time spent on digital media activities on weekends was not associated with increased relative risk of an adolescents being a short sleeper. Likewise, relative risk ratio (RRR) for a 10-minute increase in daily time spent on personal care activities and travelling for short sleepers compared to optimal sleepers was 1.05 (95% CI: 1.03; 1.07) and 1.03 (95% CI: 1.01; 1.04), respectively. Conversely, a 10-minute increase in the daily time spent on personal care and travel was associated with 4% (95% CI: 0.93; 1.00) and 8% (95% CI: 0.89; 0.96) less relative risk of an adolescent being a long sleeper on weekdays. On weekends, the relative risk of an adolescent being a long

sleeper was 1.02 (95% CI: 1.01; 1.02), 1.03 (95% CI: 1.01; 1.05) and 1.06 (95% CI: 1.04; 1.09) times more likely for a 10-minute increase in daily time spent on travelling, house chores and personal care, respectively.

Sensitivity analysis excluding the data collected in the month of August did not produce varying results from that obtained from the entire cohort (not shown). However, when the multinomial logistic regression analysis was performed for a sub-cohort of adolescents who reported some in-class activity on weekday, the results showed that a 10-minute increase in education-related activity was associated with increased relative risk of adolescents being short sleepers (RRR= 1.04, 95% CI: 1.02; 1.06) and a reduced risk of being longer sleepers (RRR= 0.96, 95% CI: 0.92; 1.01) (see Figure 5). The association between increasing weekday digital media time, and personal activity time, and increased risk of short sleep remained significant in the sub-cohort.

Discussion

In this large and contemporary cohort of UK adolescents, the results show that, adolescents spent up to a-third of their daily time awake on digital media. Also, every 10-minute increase in daily time spent on travelling and personal care was associated with higher relative risk of short sleep and a lower risk of long sleep on both weekdays and weekends. These two waking activities showed the most consistent association with the risk of short and long sleep on both weekdays and weekends. Time spent on other waking activities such digital media and eating, and drinking was only associated with higher relative risk of short sleep on weekdays but not on weekends. Among adolescents who reported in-class activity, more time spent on personal care, education-related activities, digital media, eating and drinking, and social events were associated with increased relative risk of short sleep on weekdays.

To my knowledge, this study is the first to investigate the link between time spent on daily waking activities and the relative risks of short and long sleep using TUDs from a large cohort of adolescents. Time spent on digital media was ranked third to sleep and education on weekdays and came second to sleep, on weekends. This highlights the significance of digital media in displacing time spent on other favourable activities such as physical activity and socialising by the digital media use[25,26]. Spending more time on digital media was associated with higher relative risk of short sleep on weekdays. This is coherent with the expanding literature on media device use and sleep among adolescents which appears to consistently show worse sleep among heavy users of digital media[20,27–29]. Although daily digital media time took a significant proportion of adolescents' time awake, there was little variation in the digital media time between short and optimal sleepers. This may explain the rather small additional relative risk (2%) of being a short sleeper for a 10-minute increase in digital media time; this is consistent with a recent findings using the same data that reported very small inverse association between bedtime use of digital media and sleep duration[30]. These findings imply that whereas blanket-approach interventions on reducing digital media time may have benefits for sleep duration in the general adolescent population, targeted interventions on reducing digital media time to average levels among sleep deprived adolescents may be less feasible and less likely to produce large improvements in sleep time. Thus, targeted interventions on improving sleep time for sleep deprived adolescents may also consider a reduction in time spent on other activities such as personal care and travel.

Several studies have investigated emerging hypothesis that short sleep duration in adolescence is associated with the higher risks of obesity and overweight[31–35]. Although these studies account for physical activity, none has investigated an interaction between physical activity and short sleep on the risk of obesity. In the present study, although short sleepers spent more time on each waking activity compared to optimal sleepers, short

sleepers spent 15 min less time daily on physical exercise activities on weekdays, which implies that short sleepers are also likely to be less physically active. The association between short sleep and obesity is often explained by potentially higher intake of high-density sugary foods, late night eating and poor dietary choices among short sleepers compared to optimal sleepers [34–36]. However, a recent study among 66,817 adolescents revealed that both short-sleeping and long-sleeping adolescents had increased risk of obesity compared to optimal sleepers[12]. In the present study, long sleepers relatively spent more time eating and drinking while spending relatively less time on other waking activities including physical activity.

In the present study, the waking activities that showed consistent difference in activity time between short sleepers and optimal sleepers for both weekend and weekdays were travelling and personal care. Previous time-use research among adults showed that longer commute time to work was associate with higher risk of short sleep[37]. Longer travel time between home and school, other public amenities or friend's home may contribute to higher risk of short sleep in this cohort. Also, adolescents who spent more time spent on personal care activities including shower, bath, grooming, getting dressed, and make-up had a higher risk of being short sleepers.

This study has several strengths including the use of a large representative sample of UK adolescents and as a result, sufficient power to detect associations after adjusting for potential confounders. Compared to other TUD surveys such as the American Time Use Survey which collects data on a randomly selected weekday or weekend[38], the MCS collect data from the same participants on a randomly selected weekday and weekend which allows weekday and weekend comparison of time spent on activities. The study, however, has a few limitations. First, sleep duration computed from the TUDs may overestimate the actual sleep time of adolescents in the cohort as has been reported in previous time-use studies[37] and in

comparison to other large adolescent cohorts in the UK [27,39]. Adolescents who were in bed while sick may have included this time as part of their sleep duration which leads to an overestimation. In the MCS time use data, we could not identify those who were sick during the TUD data collection. Also, sleep duration was defined as sleep activities over the 24 h period and not overnight sleep. Although overestimated sleep time unquestionably implies underestimated waking activity times, any potential misclassification bias in sleep duration is likely to be non-differential to specific waking activity times. Also, potential over- or underestimation in sleep time was accounted for when defining optimal sleep by shifting the boundaries of the NSF recommended sleep durations by 1 hour on each end. Second, although this study identified waking activities that competed for sleep time of adolescents, it was equipped to identify the intensity and content of such activities which could have repercussions on adolescents' sleep. Third, weekday daily activities do not reflect school day activities and as a result, caution is required in interpreting findings. As mentioned in the results, long sleepers tended to have substantial less time on education-related activities on weekdays indicating that some adolescents completed the TUD on weekday when they were absent from school and had minimal school-related activities. Thus, the study could not reveal the role of school start times on student sleep times compared to free days. MCS TUDs were collected during school and holiday periods. This explains the wide variation in time spent on education-related activities on weekdays between long sleepers and optimal sleepers. However, sensitivity analysis excluding August data (common holiday month across the UK) made no significant differences to the results while sensitivity analysis focusing on those who reported in-class activity time showed that increased time on education-related activities may also increase the risk of short sleep on weekdays. Activities are usually pre-categorised in a tier system in TUDs including the MCS. This categorisation of activities could in some instances lead to misclassification or misinterpretation of findings.

Furthermore, whereas TUDs involving data collection over a 24 h period from 4am presents difficulty in accurately measuring continuous overnight sleep in a day, the potential of seasonal variation in time use and sleep should not be overlooked [40]. In addition, potential late bedtimes on Friday nights and early bedtimes on Sunday nights are likely to underestimate weekday sleep duration and overestimate weekend sleep duration, respectively.

Conclusions

This study shows that adolescents spend up to a-third of their time awake per day on digital media. The study provides evidence that spending more time on personal care and travel per day on weekdays and weekends is associated with higher relative risk of short sleep and lower relative risk of long sleep among adolescents. The findings of the study permit a reflection on appropriate interventions techniques need to reduce improve sleep duration among sleep deficient teenagers.

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Figure legends

Figure 1. Flowchart of complete and incomplete time-use activity data obtained from MCS participants

Figure 2. Correlation matrix for pairwise weighted-Pearson's correlations of time spent on various activities on Weekdays. Red indicates a negative correlation while blue indicates a positive correlation. Statistically significant correlations ($p < .05$) are in bold.

Figure 3. Correlation matrix for pairwise weighted-Pearson's correlations of time spent on various activities on Weekends. Red indicates a negative correlation while blue indicates a positive correlation. Statistically significant correlations ($p < .05$) are in bold.

Figure 4. Adjusted daily mean difference in time spent on waking activities on weekends between both short and long sleepers and optimal sleepers

Note: All estimates are weighted for MCS design characteristics and adjusted for sex, ethnicity, age, parental socioeconomic status and number of people in household.

Figure 5. Relative risk ratios (95% CI) of short and long sleep among UK adolescents for 10-minute increments of daily waking activities on weekdays for sub-cohort who reported in-class activity ($N= 1868$). Estimates are weighted for MCS design characteristics and adjusted for sex, ethnicity, age, parental socioeconomic status and number of people in household.

Appendix figure:

Figure A1. Adjusted daily mean difference in time spent on waking activities on weekdays between both short and long sleepers and optimal sleepers

Note: All estimates are weighted for MCS design characteristics and adjusted for sex, ethnicity, age, parental socioeconomic status and number of people in household.

Table 1. Characteristics of MCS participants who completed the time use diary on at least one day

Characteristics	Number (N= 4032) ^a	Weighted percentage
Age (years), mean (standard error)	4029	14.3 (0.0)
< 14 y	851	20.7
≥ 14 y	3178	79.3
Sex		
Boys	1805	47.0
Girls	2224	53.0
Ethnicity		
White	3389	85.0
Non-white	619	15.0
Household size		
< 5 people	2497	62.3
≥ 5 people	1532	37.7
SES of main respondent parent		
Managerial/Professional occupations	1367	37.3
Intermediate occupations	1036	33.3
Routine/ Manual occupations	781	29.4
Sleep category on a weekday		
Short sleepers	270	7.9
Optimal sleepers	2822	79.3
Long sleepers	456	12.8
Sleep category on a weekend		
Short sleepers	214	6.4
Optimal sleepers	2227	64.4
Long sleepers	1093	29.2

^a Includes 3 participants with missing survey characteristics.

The socioeconomic status (SES) is based on the National Statistics Socioeconomic Classification (NS-SEC) level (three-class version) of the main parent or guardian respondent.

Table 2. Weighted daily average duration of activities in minutes (linearised standard error) on weekdays and weekends by UK adolescents

Activities	Weekday (<i>N</i> = 3,351)				Weekend (<i>N</i> = 3,537)				<i>P</i> ^a
	Total	Boys	Girls	<i>P</i>	Total	Boys	Girls	<i>P</i>	
Sleeping	561.5 (2.9)	567.9 (4.5)	555.7 (4.0)	.048	613.6 (2.9)	614.5 (4.5)	612.7 (3.8)	.762	<.001
Education-related	272.2 (4.7)	275.7 (6.6)	269.0 (6.3)	.444	34.1 (2.1)	28.7 (2.6)	38.9 (3.3)	.015	<.001
Digital media	184.2 (3.7)	218.8 (5.6)	153.0 (3.8)	<.001	257.4 (4.6)	306.8 (7.9)	213.8 (5.1)	<.001	<.001
Social events	72.7 (2.1)	63.1 (3.3)	81.3 (2.8)	<.001	119.4 (3.2)	96.6 (4.8)	139.5 (4.1)	<.001	<.001
Eating and drinking	70.2 (1.5)	66.4 (2.4)	73.7 (1.7)	.012	84.0 (2.0)	80.5 (2.2)	87.0 (3.0)	.069	<.001
Travelling	66.0 (1.8)	61.1 (2.6)	70.5 (2.5)	.009	53.2 (2.2)	52.1 (3.7)	54.2 (2.5)	.640	<.001
Personal care	54.3 (1.3)	39.3 (1.9)	67.9 (1.8)	<.001	54.1 (1.6)	40.4 (2.4)	66.1 (2.0)	<.001	.751
Physical exercise	51.6 (1.8)	61.2 (3.2)	43.0 (2.2)	<.001	65.3 (2.3)	81.7 (3.9)	50.8 (2.6)	<.001	<.001
Hobbies incl. relaxing	41.4 (1.9)	33.4 (2.5)	48.6 (2.7)	<.001	54.5 (2.2)	45.1 (3.1)	62.7 (3.2)	<.001	<.001
House chores	23.0 (1.4)	15.3 (1.6)	29.9 (2.2)	<.001	35.8 (2.0)	27.7 (2.2)	43.0 (3.2)	<.001	<.001
Work	6.2 (0.9)	7.5 (1.7)	5.1 (0.9)	.233	11.1 (1.4)	11.3 (1.5)	10.9 (2.1)	.890	.010
Volunteering & Spiritual	3.4 (0.6)	3.6 (0.9)	3.2 (0.7)	.669	7.9 (0.8)	6.6 (1.0)	9.1 (1.2)	.101	<.001
Other	33.2 (1.8)	26.6 (2.2)	39.1 (2.6)	<.001	49.8 (2.4)	48.0 (3.9)	51.3 (3.2)	.532	<.001

^a *P* from paired comparison of total activity time on weekdays and weekends (*N* = 3053, 3 dropped because of missing survey data)

Table 3. Adjusted daily mean difference (MD) in time spent on waking activities on weekdays between both short and long sleepers and optimal sleepers

Waking activities	MD (95% CI) in minutes	
	Short sleepers	Long sleepers
Education-related	+13 (-37; 62)	-243 (-263; -222) [#]
Digital media	+29 (-5; 63)	+3 (-18; 25)
Social events	+36 (9; 63) [*]	-9 (-23; 5)
Eating and drinking	+41 (8; 75) [*]	+11 (2; 20) [*]
Travelling	+20 (-6; 46)	-36 (-44; -28) [#]
Personal care	+56 (21; 92) [*]	-12 (-18; -6) [#]
Physical exercise	-15 (-27; -3) [*]	+19 (0; 38)
Hobbies incl. relaxing	+11 (-11; 33)	-5 (-18; 9)
House chores	+13 (-1; 28)	+14 (3; 25) [*]
Work	+3 (-5; 12)	-3 (-7; 1)
Volunteering & Spiritual	+4 (-6; 14)	-1 (-2; 0)
Other	+32 (4; 60) [*]	+3 (-6; 11)

Note: All estimates are weighted for MCS design characteristics

[#] $P < .001$; ^{*} $P < .01$; ^{*} $P < .05$.

Reference category was the optimal sleep duration on weekdays.

Models were adjusted for sex, ethnicity, age, parental socioeconomic status and number of people in household.

Table 4. Relative risk ratios (95% CI) of short and long sleep among UK adolescents for 10-minute increments of daily waking activities on weekdays (*N*=2800) and weekends (*N*=2805)

Waking activities	Adjusted multinomial logistic model results			
	Weekdays		Weekends	
	Short sleeper	Long sleeper	Short sleeper	Long sleeper
Education-related	1.00 (1.00; 1.01)	0.94 (0.93; 0.95) [#]	1.00 (0.98; 1.03)	1.01 (1.00; 1.02)
Digital media	1.02 (1.01; 1.03) [#]	1.01 (1.00; 1.02) [*]	1.00 (0.99; 1.01)	0.99 (0.98; 1.00) [#]
Social events	1.01 (1.00; 1.02)	1.01 (1.00; 1.02)	1.02 (1.01; 1.03) [#]	0.99 (0.98; 1.00) [*]
Eating and drinking	1.02 (1.01; 1.04) [#]	1.02 (1.01; 1.04) [‡]	1.02 (1.0; 1.04)	1.00 (0.98; 1.01)
Travelling	1.03 (1.01; 1.04) [#]	0.92 (0.89; 0.96) [#]	1.02 (1.01; 1.02) [‡]	0.95 (0.94; 0.96) [#]
Personal care	1.05 (1.03; 1.07) [#]	0.96 (0.93; 1.00) [*]	1.06 (1.04; 1.09) [#]	0.98 (0.96; 1.00) [*]
Physical exercise	0.98 (0.97; 1.00) [*]	1.02 (1.00; 1.03) [*]	1.00 (0.99; 1.02)	0.98 (0.97; 0.99) [#]
Hobbies incl. relaxing	1.01 (1.00; 1.03)	1.01 (0.99; 1.02)	1.00 (0.99; 1.02)	0.99 (0.98; 1.00) [*]
House chores	1.00 (0.97; 1.03)	1.04 (1.01; 1.06) [‡]	1.03 (1.01; 1.05) [‡]	1.01 (1.00; 1.03)
Work	1.03 (0.99; 1.07)	1.01 (0.98; 1.04)	1.02 (1.00; 1.04) [*]	0.99 (0.98; 1.01)
Volunteering & Spiritual	1.03 (0.99; 1.06)	0.96 (0.91; 1.01)	0.98 (0.94; 1.03)	0.97 (0.95; 0.99) [‡]
Other	1.02 (1.01; 1.03) [‡]	1.00 (0.99-1.01)	1.02 (1.01; 1.03) [‡]	0.98 (0.97; 0.99) [#]

Note: All estimates are weighted for MCS design characteristics

[#]*P* < .001; ^{*}*P* < .01; [‡]*P* < .05.

Reference category was the optimal sleep duration on weekdays.

Models were adjusted for sex, ethnicity, age, parental socioeconomic status and number of people in household.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.