Night-time screen-based media device use and adolescents' sleep and health-related quality of life

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Short title: **Night-time screen-based devices use and adolescent sleep and wellbeing**

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Abstract

Objective

The present study investigates the relationship between night-time screen-based media devices (SBMD) use, which refers to use within one hour before sleep, in both light and dark rooms, and sleep outcomes and health-related quality of life (HRQoL) among 11 to 12-year-olds.

Methods

We analysed baselined data from a large cohort of 6,616 adolescents from 39 schools in and around London, United Kingdom, participating in the Study of Cognition Adolescents and Mobile Phone (SCAMP). Adolescents self-reported their use of any SBMD (mobile phone, tablet, laptop, television etc.). Sleep variables were derived from self-reported weekday and/or weekend bedtime, sleep onset latency (SOL) and wake time. Sleep quality was assessed using four standardised dimensions from the Swiss Health Survey. HRQoL was estimated using the KIDSCREEN-10 questionnaire.

Results

Over two-thirds (71.5%) of adolescents reported using at least one SBMD at night-time, and about a third (32.2%) reported using mobile phones at night-time in darkness. Night-time mobile phone and television use was associated with higher odds of insufficient sleep duration on weekdays (Odds Ratio, OR= 1.82, 95% Confidence Interval, CI [1.59, 2.07] and OR=1.40, 95% CI [1.23, 1.60], respectively). Adolescents who used mobile phones in a room with light were more likely to have insufficient sleep (OR=1.32, 95% CI [1.10, 1.60]) and later sleep midpoint (OR=1.64, 95% CI [1.37, 1.95]) on weekends compared to non-users. The magnitude of these associations was even stronger for those who used mobile phones in darkness for insufficient sleep duration on weekdays (OR=2.13, 95% CI [1.79, 2.54]) and for later sleep midpoint on weekdays (OR=3.88, 95% CI [3.25, 4.62]) compared to non-users. Night-time use of mobile phones in light was not associated with HRQoL but use in darkness was associated with a lower KIDSCREEN-10 score (β= -1.19, 95% CI [-1.83, -0.56]) compared to no use.

Conclusions

We found consistent associations between night-time SBMD use and poor sleep outcomes and worse HRQoL in adolescents. The magnitude of these associations was stronger when SBMD use occurred in a dark room versus a lit room.

Keywords: screen-based media; mobile phone; television; children; sleep; quality of life

1. Introduction

It is estimated that humans spend a third of their lifetime sleeping or attempting to do so (Colten et al., 2006). Sufficient sleep duration and quality are vital, especially for children and adolescents to maintain their ongoing physical and mental development (Brand and Kirov, 2011). Good sleep hygiene is crucial for cognitive processes, including sustained attention and memory (Lim and Dinge[1]s, 2010). Among adolescents, poor sleep hygiene is associated with poor academic performance (Dewald et al., 2010). Indeed, insufficient sleep has also been shown to be associated with impaired cellular immune responses, depression, anxiety and obesity in children and adolescents (Roberts et al., 2009; Seegers et al., 2011; Spiegel et al., 2002). The United States National Sleep Foundation (NSF) recommends a sleep duration of 9 to 11 hours for school-aged children (6 to 13-year-old) (Hirshkowitz et al., 2015).

Despite the importance of sleep in optimal adolescent health and development, sleep deficits are prevalent in this age group (Gradisar et al., 2011). An analysis of the Youth Risk Behavior Surveillance System data (Basch et al., 2014) revealed that more than 90% of high school students slept less than the recommended 9 hours. A recent meta-analysis investigating global sleep patterns among adolescents also reported that on average, children are sleeping less than 9 hours on school-nights and thus instigating attempted catch-up sleep during weekend nights (Gradisar et al., 2011). A trend towards later bed times and fixed school/workday wake times has been suggested to explain the one hour per night reduction in sleep duration over the past century (Matricciani et al., 2012). In addition to insufficient sleep duration, other sleep problems such as delayed sleep onset, poor sleep quality, and restless

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Abbreviations: SBMD – Screen-based media device; HRQoL – Health-related quality of life; SCAMP – Study of Cognition Adolescents and Mobile Phones; SOL – Sleep onset latency; DAG – Directed acyclic graph; BMI – Body mass index sleep are also prevalent among adolescents (Fricke-Oerkermann et al., 2007; Hochadel et al., 2014; Zhang et al., 2011).

Although delays in sleep pattern are expected to occur as part of the physiological effect of pubertal development and resulting changes in circadian regulation of sleep (Colten et al., 2006), lifestyle influences from increasing access and use of screen-based media devices (SBMD) have been shown to contribute heavily to the detrimental sleep hygiene of adolescents (Carter et al., 2016; Colten et al., 2006). SBMD are common among adolescents and the use of these devices during the night remains high. In the UK, 12 to 15-year-olds are known to be the largest users of SBMD among children ("Children and parents: media use and attitudes report 2016 - Ofcom," 2017). It is estimated that 98% of UK adolescents aged 12 to 15-years-old watch television and over 90% of them use mobile phones at home ("Children and parents: media use and attitudes report 2016 - Ofcom," 2017).

Earlier studies have shown traditional non-portable SBMD such as televisions, video game consoles and desktop computers to be associated with insufficient sleep duration and quality (Hale and Guan, 2015; Kenney and Gortmaker, 2017), although a recent study found no such effect of computer use (Li et al., 2007). The use of portable SBMD devices such as mobile phones and tablets has also been associated with adverse adolescent sleep outcomes. However, many of the studies to date have only focused on a single device (Schweizer et al., 2017), general (day and night) SBMD use (Foerster and Röösli, 2017; Schweizer et al., 2017), one sleep outcome (Lange et al., 2017), or not separated weekday and weekend sleep habits (Fobian et al., 2016). As a consequence of poor sleep hygiene among adolescents, the use of SBMD either throughout the day or at night has also been shown in some studies to be associated with poor health related quality of life (HRQoL) among adolescents (Foerster and Röösli, 2017; Schoeni et al., 2015). SBMD use, including the use of mobile phones at night, may reduce physical wellbeing among adolescents via symptoms such as headaches, tinnitus, stomach ache, back ache or high body mass index (BMI) (Hutter et al., 2010; Lajunen et al., 2007). Although the advent of SBMD such as televisions was expected to increase family cohesion and social connection (Rothschild and Morgan, 1987), recent literature shows that increased SBMD use is associated with increased likelihood of social isolation and peer victimization among adolescents (Pagani et al., 2016). Further, a recent study of a cohort of Japanese adolescents revealed that SBMD use after lights out was associated with increased risk of suicidal thoughts, self-harm and poor mental health (Oshima et al., 2012). However, research on associations between night-time SBMD use composite HRQoL measures is scanty.

We have recently set up the Study of Cognition Adolescents and Mobile Phones (SCAMP), a cohort of adolescents from diverse ethnic and socio-economic backgrounds. SCAMP is the largest cohort of its kind in the world, set up specially to focus in detail on use of SBMD and, in particular, mobile phones and a wide range of cognitive, behavioural, health, and educational outcomes. In this study, we investigate the association between SBMD use within the hour before sleep (termed *night-time)* and a number of HRQoL and sleep outcomes, separately for weekdays and weekends, in the SCAMP cohort. We also examine these associations taking into account the presence or absence of room light when the device is being used.

2. Methods

2.1 Study design and participants

The present study is a cross-sectional analysis of the baseline data from the SCAMP study (Toledano et al., 2018). SCAMP is a large prospective cohort study investigating whether adolescents' use of mobile phones and other wireless devices influences their cognitive, educational, behavioural, physical and mental health outcomes. Baseline data were collected between November 2014 and July 2016 from adolescents in Year 7 (aged 11 to 12 years) from 39 schools in and around London, United Kingdom. The adolescents completed a computer-based assessment and provided self-report data on their SBMD use and the aforementioned behavioural and health-related outcomes. In total, 6,616 adolescents (52.4% females), representing 89.7% of the expected number according to school registers, took part in the SCAMP study. Details of participation rate and general characteristics of the cohort are published elsewhere (Toledano et al., 2018).

2.2 Exposures

Adolescents were asked if they usually use any of the following SBMD: mobile phone, tablet, eBook reader, laptop, portable media player, portable video game console, desktop computer, television or video game console, within one hour before sleep. If adolescents responded positively to this question they were subsequently asked, for each type of device, if they usually use it with the light on in the room or in darkness.

2.3 Outcomes

2.3.1 Sleep outcome measures

Adolescents reported when they usually got into bed, how long it took them to fall asleep (i.e. sleep onset latency, SOL) and what time they usually woke up using options provided in the questionnaire. These responses were recorded separately for weekdays and weekends. Weekday and weekend wake times were provided as 30-min interval categories (e.g. 06:00-06:30 a.m.) anchored at “before 06:00 a.m.” and “later than 02:00 p.m.”. Similar 30-minute interval categories were used for bedtimes anchored at “before 08:30 p.m.” and “later than 03:00 a.m.” for weekday nights and “before 08:00 p.m.” and “later than 03:00 a.m.” for weekend nights. To derive sleep onset time and sleep duration, the lower boundaries of the provided categories were chosen. For SOL, the following response categories were provided: “I fall asleep as soon as I get into bed”, “about 5 min”, “about 15 min”, “about 30 min”, “about 45 min”, “1-2 hr”, “3 hr or more”. To be consistent, lower category boundaries were chosen, hence the categories were translated into “0 min”, “5 min”, “15 min”, “30 min”, “45 min”, “60 min”, and “180 min”, respectively.

Sleep onset time and sleep duration were estimated from SOL, bedtime and wake time. The midpoint of sleep was estimated by adding half the sleep duration to the sleep onset time. These variables were calculated separately for weekdays and weekends. Duration of social jetlag was defined as the difference between weekday and weekend midpoint of sleep, and catch-up sleep was defined as the difference between weekend and weekday sleep duration (Wittmann et al., 2006).

Based on the recommendations of the NSF (Hirshkowitz et al., 2015) and the normal school start times of adolescents in London, the following categorical variables were created to differentiate between poor and good sleep hygiene: **late weekday wake time** (weekday wake time later than 7:30 a.m.), **late weekend wake time** (weekend wake time later than 8:30 a.m.), **long SOL** (SOL longer than 45 min), **insufficient sleep duration** (sleep duration less than 9 hr), **late midpoint of sleep** (later than the median sleep midpoint), **abnormal catch-up sleep** (catch-up sleep exceeding 2 hr), and **social jetlag** (duration of social jetlag exceeding 1 hr).

Sleep quality was assessed using four standardised dimensions from the Swiss Health Survey: difficulty falling asleep, sleeping restlessly, waking up several times during the night and waking up too early in the morning (Schmitt et al., 2000). Adolescents were asked how often they had encountered these sleep quality problems during the last four weeks using a four-point Likert scale (*Never, Rarely, Sometimes, and Often*).

2.3.2 Health-related quality of life measure

HRQoL was estimated using the KIDSCREEN-10 (The Kidscreen Group Europe, 2006). The KIDSCREEN-10 is a unidimensional 10-item self-report instrument covering physical, psychological and social dimensions of wellbeing validated for use among children and adolescents aged 8 to 18-years-old (The Kidscreen Group Europe, 2006). Adolescents were asked to indicate the frequency or severity of each item, using a five-point Likert scale (1 = *never*, 2 = *almost never*, 3 = *sometimes*, 4 = *almost always*, and 5 = *always*) or (1 = *not at all*, 2 = *slightly*, 3 = *moderately*, 4 = *very*, and 5 = *extremely*). The total score (range: 18.5 – 83.8) for each participant was calculated as described elsewhere (The Kidscreen Group Europe, 2006) with higher values indicating better HRQoL.

2.4 Covariates

Sociodemographic and behavioural characteristics of the adolescents including age, sex, weight, height, ethnicity, caffeine consumption, alcohol consumption, smoking and exposure to second-hand smoking, parental occupation and parental level of education were collected during the computer-based school assessment. Directed acyclic graphs (DAGs) (Textor et al., 2011) were used to select potential confounders from the list of covariates mentioned above (Figure 2 in Mireku et al., 2018) . In the DAG, the direction of the arrow was assumed to move from SBMD use to sleep outcomes or HRQoL. DAGs provide a structural approach to examine the relationship between an exposure and outcome to avoid adjusting for variables that introduce biases into the association (Shrier and Platt, 2008). Parental occupation, parental education and school type were used as proxy data for socioeconomic status of the adolescent.

2.5 Statistical analysis

The distributions of variables were checked independently and descriptive analyses were performed for all relevant variables. Complete case analysis was employed in all statistical analyses. Chi-squared tests, Mann-Whitney U tests and two sample *t*-tests were performed (as appropriate) to compare all variables by sex. Three main statistical methods were used for inferential analysis:

(i) Unconditional logistic regression was used to examine the relationship between each of the SBMD exposure variables and the dichotomous sleep outcomes.

(ii) Ordered logistic regression was performed to assess the relationship between each of the SBMD exposure variables and sleep quality items.

(iii) Linear regression was used to examine the association between each of the SBMD exposure variables and KIDSCREEN-10 score.

Crude models were run to show the unadjusted relationship between the exposures and outcomes. All models were then adjusted for ethnicity, age, sex, school type, parental education, and parental occupation (using the National Statistics Socio-Economic Classification with 3 categories) as potential confounders based on the DAG. This list of confounders is consistent with those used in other studies investigating the relationship between media use and sleep (Brunetti et al., 2016; Schweizer et al., 2017). Also, *post hoc* analyses using Wald test for equality of coefficients were performed to compare the coefficients obtained in the adjusted model for device use in a lit room and device use in a dark room.

As sensitivity analysis, the adjusted model was further adjusted for other covariates (BMI, second-hand smoking, and alcohol and caffeine consumption) in Model IIA. These covariates were not included in the adjusted model because of the uncertainty of the direction of the causal path with the exposure i.e. they could be potential mediators on the same pathway. For the linear regression models with KIDSCREEN-10 score as an outcome variable, further sensitivity analyses were conducted by excluding adolescents who self-reported any disability from the analysis (Model IIB).

All analyses were conducted using Stata version IC/13.1 for Windows (StataCorp, TX). Statistical significance was defined as $P < 0.05$.

2.6 Ethical approval

The North West Haydock Research Ethics Committee approved the SCAMP study protocol and subsequent amendments (ref 14/NW/0347). Head teachers of schools consented to participation in SCAMP. Parents and adolescents were provided in advance with written information about the study and were given the opportunity to opt out of the research. The adolescents were also provided with the opportunity to opt-out of participation on the day of the assessment. The opt-out recruitment approach was expected to improve participation in an ethnically diverse population, reduce selection bias, ensure feasibility of classroom-based assessment and ensure a cost-effective study (Toledano et al., 2018).The study was conducted in accordance with the Declaration of Helsinki.

3. Results

3.1 Study participants, sleep habits and night-time SBMD use

The median (interquartile range, IQR) age of our study sample was 12.1 (11.8-12.4) years for males and 12.0 (11.8-12.3) years for females (Table 1 in Mireku et al., 2018). The median (IQR) weekday sleep duration was 8.8 (8.0-9.4) hours and 8.9 (8.0-9.4) hours for male and female night-time SBMD users respectively compared to 9.3 (8.5-9.8) hours and 9.3 (8.8-9.9) hours for male and female non-SBMD users, respectively (Table 1). More than 70% of adolescents used at least one SBMD device within the hour before sleep (Table 2).

Although male and female adolescents had the same median sleep duration, slightly more females had an early wake time, normal SOL and an early midpoint of sleep on weekdays (Table 3). Midpoint of sleep was also more than 1 hour later on weekends compared to weekdays for both males and females (Table 3). Compared to males, social jetlag (weekend-weekday discrepancy in midpoint of sleep of 1hr or more) was more common among females (χ^2 (1) =41.23, p<0.01). More than a tenth of adolescents (17.6% males and 20.0% females) experienced abnormal sleep catch-up. With reference to sleep quality, more females than males reported having difficulty falling asleep, sleeping restlessly and waking up often during the night (see Table 2 in Mireku et al., 2018).

3.2 Night-time SBMD use and sleep outcomes

Even though night-time use of at least one SBMD, mobile phones or televisions was not associated with long SOL on weekdays, it was consistently associated with poor sleep quality on all dimensions including experiencing difficulty falling asleep and waking up too early (see Table 3 in Mireku et al., 2018). Further, night-time use of the most commonly used devices i.e. mobile phones and televisions was associated with higher odds of late wake time on weekdays (Odds Ratio, OR = 1.60, 95% Confidence Interval, CI [1.05, 2.44] and OR = 1.71, 95% CI [1.15, 2.55], respectively). Adolescents who used mobile phones, televisions or at least one SBMD during night-time had higher odds of insufficient sleep duration and late midpoint of sleep on weekdays (Table 4). Night-time use of mobile phones, television or at least one SBMD was associated with adverse outcomes for all the weekend sleep variables considered in this study. Adolescents who used at least one SBMD during night-time had higher odds of abnormal catch-up sleep and social jetlag (OR = 1.40, 95% CI [1.15, 1.71] and OR = 2.07, 95% CI [1.76, 2.43], respectively). Similar effects on catch-up sleep were observed for night-time use of phones and televisions. In the sensitivity analysis, after further adjusting for BMI, second-hand smoking, alcohol and caffeine consumption, the increased odds of adverse sleep outcomes (except for long SOL) among night-time SBMD users persisted (Table 4).

3.3 Night-time mobile phone and TV use in a room with the light on or off and sleep outcomes

The proportion of adolescents who reported adverse sleep outcomes was consistently higher among those who used mobile phones or televisions in darkness than those who used them in a room with the light on or did not use them at all (Figure 1 in this article and Figure 1 in Mireku et al., 2018). Further, there was a 31% increase in the odds of weekday insufficient sleep duration among adolescents who used mobile phones in a room with the light on compared to those who did not use mobile phones during night-time. However, the odds of insufficient sleep duration were 147% higher for adolescents who use mobile phones in a dark room in contrast to those who were not night-time users of mobile phones (Table 5). Whereas adolescents who used mobile phones in the dark were more likely to have long SOL on weekdays (OR = 1.41, 95% CI [1.11, 1.79]), those who used mobile phones in a room with the light on were less likely to experience long SOL on weekdays (OR = 0.74, 95% CI [0.56, 0.99]) compared to non-users of mobile phones. This inverse association between night-time mobile phone or television use in light and weekday SOL persisted even after further adjusting for BMI, second-hand smoking, alcohol and caffeine consumption in sensitivity analysis. However, adolescents who used mobile phones or television in darkness were more likely to have abnormal sleep catch-up (mobile phones: OR=1.73, 95% CI [1.42, 2.11]; television: OR=1.75, 95% CI [1.42, 2.16]) compared to those who did not use mobile phones or televisions during night-time. Except for weekday wake times, night-time mobile phone and television use in a dark room were consistently associated with higher odds of adverse sleep outcomes on weekdays and weekends after adjusting for potential confounding variables compared to mobile phone and television use in a lit room (Table 5).

As shown in Figure 2, mobile phone and television use in darkness was consistently associated with poor sleep quality (all four dimensions) but use in a room with the light on was consistently associated with only restless sleep. In general, adolescents who used mobile phones or televisions in a room with the light on reported worse sleep outcomes and poorer sleep quality than those who did not use phones or televisions at night-time however, this effect was even greater when phones or televisions were used in the dark.

3.4 Associations between night-time SBMD, mobile phone and television use and HRQoL

Adolescents who used at least one SBMD had significantly poorer HRQoL compared to those who did not use any SBMD during night-time (Table 6). Adolescents who used mobile phones during night-time reported lower HRQoL (β= -0.80, 95% CI [-0.24, -1.36]) compared to those who did not use mobile phones during night-time. The direction and significance of these associations persisted even after excluding children who had reported disabilities (Table 6). However, there was no statistically significant association between night-time television watching and HRQoL. Night-time use of mobile phones specifically in a light room was not associated with poor HRQoL but use in a dark room was associated with lower KIDSCREEN-10 score (β= -1.19, 95% CI [-1.83, -0.56]) (Table 4 in Mireku et al., 2018). In the sensitivity analysis (further adjusting for BMI, second-hand smoking, alcohol and caffeine consumption**),** watching television in darkness was associated with higher mean KIDSCREEN-10 score (β= 1.96, 95% CI [0.67, 3.25]) compared to no night-time television use.

4. Discussion

This study has shown that night-time use of at least one SBMD, and specifically mobile phones or televisions, was associated with adverse sleep outcomes, particularly insufficient sleep duration, late midpoint of sleep, abnormal catch-up sleep, abnormal social jetlag and poor sleep quality (sleep disturbance) among adolescents. The observed associations were consistent for sleep outcomes on weekdays and weekends. Although night-time use of mobile phones or televisions in a room with the light on was associated with insufficient sleep duration and late midpoint of sleep, the magnitude of the association was higher when night-time use of mobile phones or televisions occurred in darkness. Night-time use of at least one SBMD was also negatively associated with adolescent HRQoL and this association persisted even after excluding adolescents who report any disability. Night-time users of mobile phones in darkness reported worse HRQoL compared to those who did not use mobile phones during night-time.

The present study contributes to the growing literature highlighting the associations between SBMD use and both adolescent sleep outcomes and HRQoL. Night-time use of at least one SBMD was common with nearly three-quarters of adolescents reporting night-time SBMD use in this study and this is slightly higher than the prevalence of 60% reported in a UK-based study among adolescents of the same age range in 2010 (Arora et al., 2014).

Night-time use of mobile phones but not television was associated with long SOL on weekends in the SCAMP cohort. This is only partly consistent with previous research which found no significant association between television and mobile phone use and SOL (Arora et al., 2014). The lack of significant association between night-time television watching and weekday SOL is comparable to that reported by Gamble *et al.* (2014) although they found a significant dose response relationship between frequency of phone use and long SOL on both weekdays and weekends. In this present study, we did not assess the frequency of night-time SBMD use and this may have clarified the relationship between night-time SBMD use and long SOL on weekdays. Although the mechanism between SBMD use and long SOL is not well established, a number of previous studies have reported increased arousal and alertness from night-time use of SBMD. In particular, playing video games and engaging in stimulating tasks (puzzles) but not passive tasks (reading) on SBMD increased arousal (Fleming and Rick Wood, 2001; Ivarsson et al., 2009; Jones et al., 2018). Thus relative to passive engagement when watching television, mobile phones and video games require active engagement and alertness on the part of the user and could lengthen the time until sleep onset. Further, the portability of mobile phones implies that due to their continuous and consistent usage, the degree of exposure to light emitted and resulting ocular discomfort may be higher that from a traditional television screen which are non-portable and only occasionally used by adolescents (Kim et al., 2016).

In the present study, adolescents who usually used mobile phones, televisions or at least one SBMD at night-time were more likely to experience increasing frequency of sleep disturbance problems including difficulty falling asleep, restless sleep, waking up at night and waking up too early in the morning. Previous studies have explored the relationship between SBMD use and sleep quality using sleep quality dimensions similar to the ones used in this study (Gradisar et al., 2013) or validated sleep quality scales (Arora et al., 2014; Brockmann et al., 2016) or objective actigraphy data (Fobian et al., 2016). Regardless of how sleep quality was assessed in these studies, the inverse associations with night-time SBMD use persisted. The means by which SBMD devices affect sleep quality is not well understood but previous studies of children have revealed that those who had televisions in their rooms scored significantly higher on sleep terrors, nightmares, sleep walking and sleep talking and that sleep disturbance was significantly higher for those who watched television in the evening (Arora et al., 2014; Brockmann et al., 2016).

The weekday-weekend discordance in the observed associations between night-time SBMD use and wake time may be due to enforced school start times which implies that most adolescents force themselves to sleep once in bed in order to wake up in time for school. In fact, less than 5% of adolescents woke up later than 7:30 a.m. on weekdays which sharply contrasts with weekend sleep habits of nearly half of adolescents waking up later than 8:30 am. However, when specific SBMD were considered, we found significant associations between mobile phone use or television watching and late wake time on both weekdays and weekends which is similar to findings of previous studies that investigated wake time and specific SBMD such as computers, mobile phones and televisions (Amra et al., 2017; Gamble et al., 2014).

Sleep duration has been the most commonly researched sleep outcome in relation to SBMD use because adolescents are increasingly sleeping fewer hours during school nights. In fact, the American Academy of Pediatrics acknowledges insufficient sleep duration among adolescents as a major public health issue (Adolescent Sleep Working Group, 2014). In the present study, night-time use of mobile phones, televisions and at least one SBMD was consistently associated with insufficient sleep duration on both weekdays and weekends. These associations are congruent with the findings of a recent meta-analysis of 20 cross-sectional studies which reported that the odds of insufficient sleep is doubled for children who used portable SBMD around bedtime compared to those who did not use any portable SBMD (Carter et al., 2016). Other cross-sectional studies also found similar associations between portable and non-portable SBMD and adolescent insufficient sleep duration (Continente et al., 2017; Kenney and Gortmaker, 2017). Cain and Gradisar (2010) hypothesised that night-time use of SBMD displaces sleep time and other activities associated with good sleep hygiene and thus results in later bedtimes and shorter sleep duration. This hypothesis may explain the observed consistent association between night-time SBMD use and late midpoint of sleep and insufficient sleep duration on both weekdays and weekends.

Adolescents who used at least one SBMD or mobile phones at night had a poorer HRQoL compared to those who did not use any. The adjusted mean difference in HRQoL observed is equivalent to 20% of the mean difference in KIDSCREEN-10 scores between UK adolescents of normal and abnormal mental health status (Ravens-Sieberer et al., 2008). These findings are in line with many previous studies although different HRQoL scales were used (Foerster and Röösli, 2017; Lacy et al., 2012). First, spending more time on SBMD has been reported to be associated with increased consumption of sugar-sweetened beverages, increased risk of sedentary behaviour and decreased likelihood of physical activity among adolescents (Kenney and Gortmaker, 2017; Poulain et al., 2018) which are in turn directly associated with obesity (Robinson et al., 2017) and inversely associated with HRQoL in dose-response fashion (Wu et al., 2017). Using the extended KIDSCREEN-52 questionnaire, a previous study 10 to 17-year-olds found that high media device users reported the lowest scores for moods and emotions, self-perception, parents and home life, and school environment (Foerster and Röösli, 2017). Second, problematic mobile phone use has consistently been shown to be associated with unfavourable psychological outcomes including severity of anxiety and depression among teenagers (Elhai et al., 2017; Tamura et al., 2017) which may be explained by increasing mental fatigue arising from long-duration use (Ikeda and Nakamura, 2014). Although the aforementioned hypotheses and findings from previous research may explain the observed association in the SCAMP cohort, the present study is the only one to focus on night-time device use in lit and dark rooms and adolescents' HRQoL.

To our knowledge, this is the first study to investigate the effects of night-time mobile phone use or television watching taking into account the presence or absence of room light on sleep outcomes and HRQoL in an adolescent population. Night-time light exposure, especially short-wavelength ("blue") light emitted from SBMD, can suppress the onset of melatonin synthesis, followed by an alerting response and thus reduce sleepiness (Chang et al., 2015; Gooley et al., 2011). This arousal may become conditioned, by a learned association forming between bedtime and wakefulness (Gamble et al., 2014). In this study, adolescents who used mobile phones or watched television at night-time with the light on in the room experienced worse sleep outcomes than adolescents who did not use these devices at night-time. However, the effects were even greater when device use occurred in darkness. This observation might be due to factors associated with the large luminance difference between a dark room and the light from a SBMD. Thus, adolescents who use SBMD in darkness are likely to suffer from strained eyes because of sharp pupil adjustment to images from the only source of light, the screen of the media device. Also, in a dark environment, the pupils of the eye are usually dilated and thus the amount of blue light (peak emission ~450–470 nm) passing through the pupil and thus suppressing melatonin may be higher in darkness before the pupil adjusts to the light source (Tosini et al., 2016).

Although mostly cross-sectional, a number of studies have reported associations between chronotype and device use (Fossum et al., 2014; Randler et al., 2016). These studies reported that adolescents of 'Owl' chronotype are prone to increased device use and thus suggesting a potential reverse causation. On the contrary, a randomized crossover study by Chang et al (Chang et al., 2015) found a 55% decrease in melatonin suppression for participants who used the SBMD and no melatonin suppression for those who read a print-book under the same ambient light. This evidence supports the hypothesis of disrupted circadian rhythms and diminished melatonin secretion resulting from SBMD use. Moreover, we found the odds of long SOL, insufficient sleep duration, and late sleep midpoint, to all be greater for mobile phone use at night time in the dark versus TV use at night time in the dark. As TVs have lower blue light concentration than mobile phones, we would expect to see mobile phone users with poorer outcomes than TV users. Our findings thereby supporting the melatonin hypothesis.

Alternatively, the observed association may only be a reflection of potentially less discipline among adolescents who use devices in the dark. These adolescents may have used these devices secretively (without the knowledge of their parents) and thus could have done so for longer hours than those who use the devices in a light room until their parents tell them to turn the light off. Thus, the prolonged night-time use of the devices may have resulted in later sleep times and poorer sleep outcomes. Further, studies in animal models suggest that exposure to light at night increases the levels of oxidative stress markers and increase melatonin suppression (Ashkenazi and Haim, 2013). Stress induced by exposure to blue light in the dark could therefore alter sleep and HRQoL although little is known if the same effect occurs in humans.

In common with all cross-sectional studies, the present study lacks temporal information between exposures and outcomes and, therefore, cannot draw causal conclusions or exclude the potential for reverse causation. Although most studies within this field use cross-sectional data, and therefore lack temporal analysis, a longitudinal study of which approximately 1,800 children followed annually since age 6 months to 7 years found an increase of an hour per day in lifetime TV viewing to be associated with a reduction of 7 minutes in sleep duration per day (Cespedes et al., 2014). In our study, the use of questionnaires to collect information on SBMD use, sleep patterns and HRQoL may have resulted in social desirability and inaccurate reporting among adolescents. However, we have shown that our adolescents self-report their mobile phone usage through questionnaires fairly accurately (Mireku et al., 2017). Future studies with prospective measures of daily screen activity and sleep diary and/or objective measures of screen activity and sleep would help to tease out these complex relationships. Finally, exclusive SBMD use was not assessed therefore adolescents who reported using mobile phones could also use other SBMD devices.

Notwithstanding these limitations, the use of DAGs to choose confounders increases the internal validity of the study findings. As confounders cannot be in the causal pathway between the exposure and the outcome, the direction of association between the confounder and the exposure/outcome is highly important to avoid collider bias.

Future cohort and experimental studies are needed to corroborate our findings and to investigate whether induced pupil dilation during SBMD use in darkness and subsequent melatonin suppression explains the observed associations in darkness that were stronger than those observed when the light in the room was on. Prospective cohort studies including both children and adolescents would provide temporally defined data and also allow researchers to study how the association between SBMD and sleep or HRQoL varies by age, in order to create age-appropriate policy recommendations.

Conclusion

Overall, this study shows that night-time SBMD use is significantly associated with adverse sleep outcomes and poorer HRQoL among adolescents. Night-time use of mobile phones in a room with the light on is associated with some adverse sleep outcomes but the magnitude of the association is larger if use occurs in the dark. We recommend that parents, teachers, health professionals and adolescents be made aware of the associations between night-time SBMD use and sleep outcomes, as these may impact on cognitive function and educational attainment. In addition, interventions on healthy screen-based media use should include curtailed use within an hour before bedtime and particularly in darkness.

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Author contributions

M.O.M. coordinated the study, collected, cleaned and analysed the data, interpreted results, and wrote and revised the manuscript. M.M.B. analysed data, prepared table of results and revised the manuscript. J.M. collected and cleaned data, and revised the manuscript. I.D., M.S.C.T, M.R., and P.E.obtained funding for this study, interpreted results and revised the manuscript. M.B.T. conceived the study, obtained funding, interpreted results and revised the manuscript.

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Table 1. Sociodemographic and behavioural characteristics of adolescents, by night-time SBMD use in the SCAMP cohort

	SBMD Use		No SBMD Use	
	Males (n=2,234)	**Females (n=2,499)**	**Males (n=794)**	**Females (n=855)**
Age (years), median (IQR)[a]	12.1 (11.8-12.4)	12.1 (11.8-12.3)	12.1 (11.8-12.4)	12.0 (11.7-12.2)
BMI (Kg/m^2), median (IQR)[b]	17.5 (15.4-20.0)	17.3 (15.6-20.0)	17.4 (15.6-19.4)	16.7 (14.8-19.1)
Ethnicity				
White	947 (42.4)	1,021 (40.9)	352 (44.3)	327 (38.2)
Black	358 (16.0)	391 (15.6)	106 (13.4)	100 (11.7)
Asian	539 (24.1)	637 (25.5)	196 (24.7)	282 (33.0)
Mixed	239 (10.7)	251 (10.0)	95 (12.0)	89 (10.4)
Other	130 (5.8)	141 (5.6)	39 (4.9)	55 (6.4)
Missing	21 (0.9)	58 (2.3)	6 (0.8)	2 (0.2)
Disability				
Yes	309 (13.8)	266 (10.6)	121 (15.2)	96 (11.2)
No	1,742 (78.0)	2,010 (80.4)	622 (78.3)	686 (80.2)
Missing	1 (0.04)	0 (0.0)	1 (0.1)	0 (0.0)
School Type				
Independent	409 (18.3)	622 (24.9)	208 (26.2)	216 (25.3)
State	1,825 (81.7)	1,877 (75.1)	586 (73.8)	639 (74.7)
Parental Higher Education				
At least one	284 (12.7)	399 (15.9)	93 (11.7)	136 (15.9)
None	1,166 (52.2)	1,298 (51.9)	465 (58.6)	425 (49.7)
Missing	784 (35.1)	802 (32.1)	236 (29.7)	294 (34.4)
Parental Occupation				
Higher	1,104 (49.4)	1,280 (51.2)	450 (56.7)	436 (50.9)
Intermediate	526 (23.5)	550 (22.0)	139 (17.5)	179 (20.9)
Lower	342 (15.3)	389 (15.6)	104 (13.1)	130 (15.2)
Missing	262 (11.7)	280 (11.2)	101 (12.7)	110 (12.9)
Caffeine Consumption				
Yes	560 (25.1)	596 (23.8)	114 (14.4)	112 (13.1)
No	294 (13.2)	429 (17.2)	153 (19.3)	197 (23.0)
Missing	1,380 (61.8)	1,474 (59.0)	527 (66.4)	546 (63.9)
Alcohol Consumption				
At least once	256 (11.5)	190 (7.6)	61 (7.7)	41 (4.8)
Never	1,215 (54.4)	1,407 (56.3)	529 (66.6)	545 (63.7)
Missing	763 (34.2)	902 (36.1)	204 (25.7)	269 (31.5)
Smoking				
At least once	63 (2.8)	24 (1.0)	10 (1.3)	7 (0.8)
Never	1,410 (63.1)	1,568 (62.7)	581 (73.2)	580 (67.8)
Missing	761 (34.1)	907 (36.3)	203 (25.6)	268 (31.3)
Second-hand Smoking				
Yes	496 (22.2)	571 (22.8)	112 (14.1)	122 (14.3)
No	1,684 (75.4)	1,867 (74.7)	665 (83.8)	714 (83.5)
Missing	54 (2.4)	61 (2.4)	17 (2.1)	19 (2.2)

Weekday Sleep Duration (hours), median (IQR)[c]	8.8 (8.0-9.4)	8.9 (8.0-9.4)	9.3 (8.5-9.8)	9.3 (8.8-9.9)
Weekend Sleep Duration (hours), median (IQR)[d]	9.3 (8.0-10.3)	9.8 (8.8-10.6)	9.8 (8.8-10.4)	10.0 (9.3-10.9)
Weekday Midpoint of Sleep, median (IQR)[c]	2:15am (1:53-2:45am)	2:08am (1:47-2:38am)	2:00am (1:45-2:30am)	2:00am (1:33-2:17am)
Weekend Midpoint of Sleep, median (IQR)[d]	4am (3:08-5:15am)	4:00am (3:15-5:00am)	3:17am (2:38-4:08am)	3:17am (2:38-4:17am)
KIDSCREEN-10 Score, mean (SD)[e]	49.5 (8.5)	48.3 (8.1)	49.9 (8.8)	49.9 (9.3)

[a] *N*=6,379; [b] *N*=1,979; [c] *N*=6,382; [d] *N*=5,919; [e] *N*=5,735

SBMD – Screen-based media device; BMI – Body mass index; IQR – Inter quartile range; SD – Standard deviation

Unless otherwise stated, all figures are presented as number (percentage)

Table 2. Night-time use of screen-based media devices amongst the SCAMP cohort

	Males (n=3,147) n (%)	Females (n=3,469) n (%)	*P*
At least one SBMD			
Yes	2,234 (71.0)	2,499 (72.0)	0.506
No	794 (25.2)	855 (24.7)	
Missing	119 (3.8)	115 (3.3)	
Portable SBMD Use			
Phone			
Yes - Light	704 (22.4)	866 (25.0)	0.051
Yes - Dark	977 (31.1)	1,073 (30.9)	
No	1,336 (42.5)	1,409 (40.6)	
Missing[a]	130 (4.1)	121 (3.5)	
Tablet			
Yes - Light	667 (21.2)	878 (25.3)	<0.001
Yes - Dark	670 (21.3)	682 (19.7)	
No	1,680 (53.4)	1,788 (51.5)	
Laptop			
Yes - Light	680 (21.6)	834 (24.0)	0.017
Yes - Dark	384 (12.2)	366 (10.6)	
No	1,953 (62.1)	2,148 (61.9)	
Media Player			
Yes - Light	335 (10.7)	369 (10.6)	0.513
Yes - Dark	342 (10.9)	350 (10.1)	
No	2340 (74.4)	2629 (75.8)	
Portable Video Console			
Yes - Light	374 (11.9)	357 (10.3)	<0.001
Yes - Dark	402 (12.8)	250 (7.2)	
No	2,241 (71.2)	2,741 (79.0)	
Ebook (with light)			
Yes - Light	195 (6.2)	215 (6.2)	0.723
Yes - Dark	219 (7.0)	226 (6.5)	
No	2,603 (82.7)	2,907 (83.8)	
Ebook (without light)			
Yes - Light	210 (6.7)	255 (7.4)	<0.001
Yes - Dark	107 (3.4)	56 (1.6)	
No	2,700 (85.8)	3,037 (87.6)	
Non-portable SBMD Use			
Television			
Yes - Light	712 (22.6)	791 (22.8)	0.182
Yes - Dark	664 (21.1)	676 (19.5)	
No	1,641 (52.1)	1,881 (54.2)	
Non-portable Video Console			
Yes - Light	644 (20.5)	420 (12.1)	<0.001
Yes - Dark	586 (18.6)	167 (4.8)	
No	1,787 (56.8)	2,761 (79.6)	
Computer			
Yes - Light	488 (15.5)	527 (15.2)	<0.001
Yes - Dark	205 (6.5)	105 (3.0)	
No	2,324 (73.9)	2,716 (78.3)	

[a]Number (percentage) of missing data was the same for all portable and non-portable devices.
SBMD – Screen-based media device
Missing category was not used in statistical analysis

Table 3. Comparison of sleep outcomes on weekdays and weekends among males and females in the SCAMP cohort

	Males (n=3,147)	Females (n=3,469)	*P*
Weekdays			
Sleep duration (hours), median (IQR)[a]	8.9 (8.3-9.5)	8.9 (8.3-9.5)	0.110
Bed Time			
Early	2,434 (77.3)	2,826 (81.5)	<0.001
Late	604 (19.2)	535 (15.4)	
Missing	109 (3.5)	108 (3.1)	
Wake Time			
Early	2,911 (92.5)	3,286 (94.7)	<0.001
Late	132 (4.2)	83 (2.4)	
Missing	104 (3.3)	100 (2.9)	
SOL			
Normal	2,669 (84.8)	3,020 (87.1)	0.015
Long	362 (11.5)	337 (9.7)	
Missing	116 (3.7)	112 (3.2)	
Insufficient Sleep Duration			
Sufficient	1,492 (47.4)	1,674 (48.3)	0.262
Insufficient	1,539 (48.9)	1,683 (48.5)	
Missing	116 (3.7)	112 (3.2)	
Sleep Midpoint, median (IQR)[a]	2:08am (1:47-2:38am)	2:08am (1:45-2:33am)	<0.001
Sleep Midpoint			
Early	1,523 (48.4)	1,873 (54.0)	<0.001
Late	1,508 (47.9)	1,484 (42.8)	
Missing	116 (3.7)	112 (3.2)	
Weekends			
Sleep duration (hours), median (IQR)[a]	9.4 (8.3-10.3)	9.9 (8.9-10.8)	<0.001
Bed Time			
Early	1,925 (61.2)	2,320 (66.9)	<0.001
Late	1,113 (35.4)	1,041 (30.0)	
Missing	109 (3.5)	108 (3.11)	
Wake Time			
Early	1,723 (54.8)	1,671 (48.2)	<0.001
Late	1,320 (41.9)	1,698 (49.0)	
Missing	104 (3.3)	100 (2.9)	
SOL			
Normal	2,554 (81.2)	2,861 (82.5)	0.285
Long	477 (15.2)	496 (14.3)	
Missing	116 (3.7)	112 (3.2)	
Insufficient Sleep Duration			
Sufficient	1,709 (54.3)	2,281 (65.8)	<0.001
Insufficient	1,094 (34.8)	840 (24.2)	
Missing	344 (10.9)	348 (10.0)	
Midpoint of Sleep, median (IQR)	3:47am (3:00-4:53am)	3:53am (3:02-4:53am)	0.193
Midpoint of Sleep			
Early	1,496 (47.5)	1,629 (47.0)	0.365
Late	1,307 (41.5)	1,492 (43.0)	
Missing	344 (10.9)	348 (10.0)	
Weekdays + Weekends			
Catch-up Sleep			
Normal	2,248 (71.4)	2,428 (70.0)	0.023
Abnormal	555 (17.6)	693 (20.0)	
Missing	344 (10.9)	348 (10.0)	
Social Jetlag			
Yes	797 (25.3)	653 (18.8)	<0.001
No	2,337 (74.3)	2,807 (80.9)	
Missing	13 (0.4)	9 (0.3)	

[a] N=6388; IQR – Inter quartile range
Unless otherwise stated, all figures are presented as number (percentage)
Missing category was not used in statistical analysis

Table 4. Associations between night-time use of at least one SBMD, mobile phones and televisions and sleep outcomes in the SCAMP cohort

	SBMD OR (95% CI)	Mobile Phone OR (95% CI)	Television OR (95% CI)
<u>Weekdays</u>			
Late Wake Time			
Model I	1.06 (0.77, 1.45)	1.50 (1.13, 2.01)#	1.53 (1.16, 2.02)#
Model II	1.10 (0.70, 1.74)	1.60 (1.05, 2.44)*	1.71 (1.15, 2.55)#
Model IIA	1.04 (0.47, 2.33)	1.57 (0.74, 3.33)	2.38 (1.14, 4.96)*
Long SOL			
Model I	1.13 (0.94, 1.36)	1.35 (1.14, 1.59)‡	1.07 (0.91, 1.25)
Model II	0.99 (0.78, 1.25)	1.08 (0.87, 1.35)	0.87 (0.70, 1.08)
Model IIA	0.62 (0.42, 0.92)*	0.78 (0.53, 1.14)	0.67 (0.45, 0.98)*
Insufficient Sleep Duration			
Model I	2.02 (1.80, 2.26)‡	2.02 (1.83, 2.24)‡	1.64 (1.48, 1.81)‡
Model II	1.83 (1.58, 2.13)‡	1.82 (1.59, 2.07)‡	1.40 (1.23, 1.60)‡
Model IIA	1.81 (1.42, 2.32)‡	1.88 (1.50, 2.35)‡	1.45 (1.15, 1.82)#
Late Midpoint of Sleep			
Model I	1.90 (1.69, 2.13)‡	1.96 (1.77, 2.16)‡	1.63 (1.48, 1.80)‡
Model II	1.89 (1.62, 2.20)‡	1.95 (1.70, 2.24)‡	1.44 (1.26, 1.65)‡
Model IIA	1.55 (1.20, 2.00)#	1.81 (1.43, 2.29)‡	1.30 (1.03, 1.64)*
<u>Weekends</u>			
Late Wake Time			
Model I	1.75 (1.56, 1.97)‡	1.81 (1.63, 2.00)‡	1.63 (1.48, 1.80)‡
Model II	1.95 (1.67, 2.27)‡	1.86 (1.63, 2.14)‡	1.29 (1.11, 1.51)‡
Model IIA	2.39 (1.83, 3.12)‡	2.22 (1.76, 2.82)‡	1.65 (1.31, 2.07)‡
Long SOL			
Model I	1.63 (1.37, 1.93)‡	1.78 (1.54, 2.06)‡	1.33 (1.16, 1.52)‡
Model II	1.44 (1.15, 1.80)#	1.50 (1.24, 1.82)‡	1.09 (0.90, 1.31)
Model IIA	1.12 (0.79, 1.61)	1.29 (0.93, 1.79)	0.95 (0.69, 1.30)
Insufficient Sleep Duration			
Model I	1.79 (1.57, 2.05)‡	1.82 (1.62, 2.03)‡	1.61 (1.44, 1.79)‡
Model II	1.59 (1.34, 1.89)‡	1.72 (1.47, 2.00)‡	1.31 (1.13, 1.52)‡
Model IIA	1.39 (1.05, 1.86)*	1.56 (1.20, 2.02)#	1.26 (0.98, 1.63)
Late Midpoint of Sleep			
Model I	2.36 (2.09, 2.67)‡	2.62 (2.35, 2.91)‡	2.00 (1.80, 2.22)‡
Model II	2.56 (2.16, 3.04)‡	2.56 (2.22, 2.98)‡	1.78 (1.54, 2.05)‡
Model IIA	2.94 (2.19, 3.96)‡	2.94 (2.28, 3.80)‡	1.78 (1.39, 2.28)‡
<u>Weekdays + Weekends</u>			
Abnormal Catch-Up Sleep			
Model I	1.40 (1.21, 1.63)‡	1.54 (1.35, 1.75)‡	1.39 (1.23, 1.58)‡
Model II	1.40 (1.15, 1.71)#	1.42 (1.19, 1.69)‡	1.31 (1.11, 1.55)#
Model IIA	1.58 (1.10, 2.27)*	1.46 (1.07, 2.00)*	1.29 (0.95, 1.75)
Social Jetlag			
Model I	1.99 (1.75, 2.25)‡	2.00 (1.77, 2.25)‡	1.51 (1.34, 1.71)‡
Model II	2.07 (1.76, 2.43)‡	1.90 (1.63, 2.22)‡	1.49 (1.28, 1.75)‡
Model IIA	1.89 (1.46, 2.45)‡	1.82 (1.41, 2.35)‡	1.20 (0.93, 1.56)

Reference group for all models: no night-time use; $*P<0.05$, $\#P<0.01$, $‡P<0.001$

SBMD- Screen-based media device; SOL- Sleep onset latency

Model I: un-adjusted

Model II: adjusted for sex, age, ethnicity, school type, parental occupation, and parental education

Model IIA (sensitivity analysis): Model II further adjusted for BMI, second-hand smoking, alcohol and caffeine consumption

Table 5. Associations between night-time phone and television use (in a light/dark room) and sleep outcomes in the SCAMP cohort

	Night-time Phone Use		Night-time TV Use	
	Light OR (95% CI)	Dark OR (95% CI)	Light OR (95% CI)	Dark OR (95% CI)
Weekdays				
Late Wake Time				
Model I	1.37 (0.96, 1.96)	1.61 (1.17, 2.21)#	1.48 (1.07, 2.06)*	1.59 (1.14, 2.21)#
Model II	1.33 (0.79, 2.24)	1.81 (1.14, 2.87)*	1.74 (1.10, 2.78)*	1.68 (1.04, 2.72)*
Model IIA	1.12 (0.44, 2.86)	2.04 (0.89, 4.67)	2.52 (1.10, 5.73)*	2.20 (0.89, 5.43)
Long SOL				
Model I	0.96 (0.78, 1.20)	1.66 (1.39, 1.98)‡	0.79 (0.64, 0.97)*	1.40 (1.16, 1.69)‡
Model II	0.74 (0.56, 0.99)*	1.41 (1.11, 1.79)#c	0.71 (0.54, 0.94)*	1.07 (0.82, 1.40)a
Model IIA	0.53 (0.32, 0.87)*	1.09 (0.70, 1.69)	0.60 (0.37, 0.97)*	0.77 (0.46, 1.30)
Insufficient Sleep Duration				
Model I	1.42 (1.25, 1.61)‡	2.68 (2.38, 3.02)‡	1.30 (1.15, 1.46)‡	2.15 (1.88, 2.44)‡
Model II	1.31 (1.12, 1.54)#	2.47 (2.11, 2.90)‡c	1.16 (0.99, 1.36)	1.84 (1.54, 2.20)‡c
Model IIA	1.45 (1.11, 1.88)#	2.65 (1.98, 3.54)‡	1.15 (0.89, 1.50)	2.13 (1.53, 2.96)‡
Late Sleep Midpoint				
Model I	1.40 (1.23, 1.59)‡	2.54 (2.26, 2.86)‡	1.37 (1.21, 1.54)‡	1.99 (1.75, 2.26)‡
Model II	1.50 (1.27, 1.77)‡	2.48 (2.11, 2.91)‡c	1.20 (1.02, 1.41)*	1.84 (1.54, 2.19)‡c
Model IIA	1.53 (1.16, 2.02)#	2.22 (1.66, 2.98)‡	1.05 (0.80, 1.38)	1.82 (1.32, 2.51)‡
Weekends				
Late Wake Time				
Model I	1.34 (1.18, 1.52)‡	2.28 (2.03, 2.57)‡	1.29 (1.14, 1.46)‡	2.13 (1.87, 2.42)‡
Model II	1.41 (1.20, 1.66)‡	2.41 (2.05, 2.82)‡c	1.06 (0.89, 1.27)	1.69 (1.39, 2.05)‡c
Model IIA	1.78 (1.35, 2.34)‡	2.95 (2.20, 3.95)‡	1.25 (0.95, 1.64)	2.57 (1.86, 3.56)‡
Long SOL				
Model I	1.01 (0.83, 1.23)	2.46 (2.10, 2.87)‡	0.91 (0.76, 1.09)	1.86 (1.58, 2.18)‡
Model II	0.88 (0.68, 1.13)	2.14 (1.74, 2.64)‡c	0.76 (0.59, 0.97)*	1.55 (1.24, 1.94)‡c
Model IIA	0.79 (0.52, 1.21)	1.94 (1.34, 2.81)‡	0.74 (0.49, 1.11)	1.26 (0.84, 1.90)
Insufficient Sleep Duration				
Model I	1.28 (1.11, 1.48)#	2.33 (2.05, 2.64)‡	1.28 (1.12, 1.47)‡	2.04 (1.78, 2.34)‡
Model II	1.32 (1.10, 1.60)#	2.13 (1.79, 2.54)‡	1.15 (0.96, 1.37)	1.54 (1.28, 1.87)‡b
Model IIA	1.27 (0.93, 1.73)	1.96 (1.43, 2.69)‡	1.15 (0.85, 1.56)	1.44 (1.02, 2.04)*
Late Sleep Midpoint				
Model I	1.59 (1.39, 1.81)‡	3.91 (3.45, 4.43)‡	1.30 (1.15, 1.48)‡	3.33 (2.90, 3.83)‡
Model II	1.64 (1.37, 1.95)‡	3.88 (3.25, 4.62)‡c	1.17 (0.99, 1.39)	3.14 (2.58, 3.82)‡c
Model IIA	2.11 (1.57, 2.84)‡	4.41 (3.21, 6.05)‡	1.21 (0.91, 1.63)	3.28 (2.30, 4.68)‡
Weekdays + Weekends				
Abnormal Catch-Up Sleep				
Model I	1.22 (1.03, 1.44)*	1.80 (1.56, 2.08)‡	1.07 (0.91, 1.25)	1.80 (1.55, 2.10)‡
Model II	1.10 (0.89, 1.37)	1.73 (1.42, 2.11)‡c	1.01 (0.82, 1.25)	1.75 (1.42, 2.16)‡c
Model IIA	1.16 (0.80, 1.69)	1.87 (1.29, 2.70)#	1.06 (0.73, 1.54)	1.66 (1.12, 2.46)*
Abnormal Social Jetlag				
Model I	1.51 (1.31, 1.75)‡	2.57 (2.21, 2.98)‡	1.19 (1.04, 1.38)*	2.08 (1.75, 2.46)‡
Model II	1.46 (1.22, 1.75)‡	2.57 (2.11, 3.14)‡c	1.19 (1.00, 1.43)	2.21 (1.74, 2.81)‡c
Model IIA	1.46 (1.09, 1.95)*	2.58 (1.80, 3.70)‡	0.95 (0.71, 1.27)	2.00 (1.31, 3.05)#

Reference group for all models: no night-time use; *p<0.05, #p<0.01, ‡p<0.001 in comparison to reference category
[a]p<0.05, [b]p<0.01, [c]p<0.001 for the comparison of the observed measure of effect between device use in darkness and in a lit room
SOL- Sleep onset latency
Model I: un-adjusted
Model II: adjusted for sex, age, ethnicity, school type, parental occupation, and parental education
Model IIA (sensitivity analysis): Model II further adjusted for BMI, second-hand smoking, alcohol and caffeine consumption

Table 6. Associations between night-time use of at least one SBMD, mobile phones and televisions and HRQoL in the SCAMP cohort

	SBMD	Mobile Phone	Television
KIDSCREEN-10 Score, Beta (95% CI)			
Model I	-1.01 (-1.51, -0.51)‡	-0.87 (-1.32, -0.43)‡	-0.12 (-0.56, 0.33)
Model II	-0.98 (-1.60, -0.35)#	-0.80 (-1.36, -0.24)#	-0.09 (-0.66, 0.47)
Model IIA	0.37 (-0.60, 1.35)	0.28 (-0.64, 1.19)	1.01 (0.10, 1.93)*
Model IIB	-1.15 (-1.82, -0.48)#	-0.84 (-1.44, -0.24)#	-0.33 (-0.93, 0.28)

Reference group for all models: no night-time use; **p*<0.05, #*p*<0.01, ‡*p*<0.001

SBMD- Screen-based media device

Model I: un-adjusted

Model II: adjusted for sex, age, ethnicity, school type, parental occupation, and parental education

Model IIA: (Sensitivity analysis): Model II further adjusted for BMI, second-hand smoking, alcohol and caffeine consumption

Model IIB: (Sensitivity analysis): Model II excluding participants with disabilities

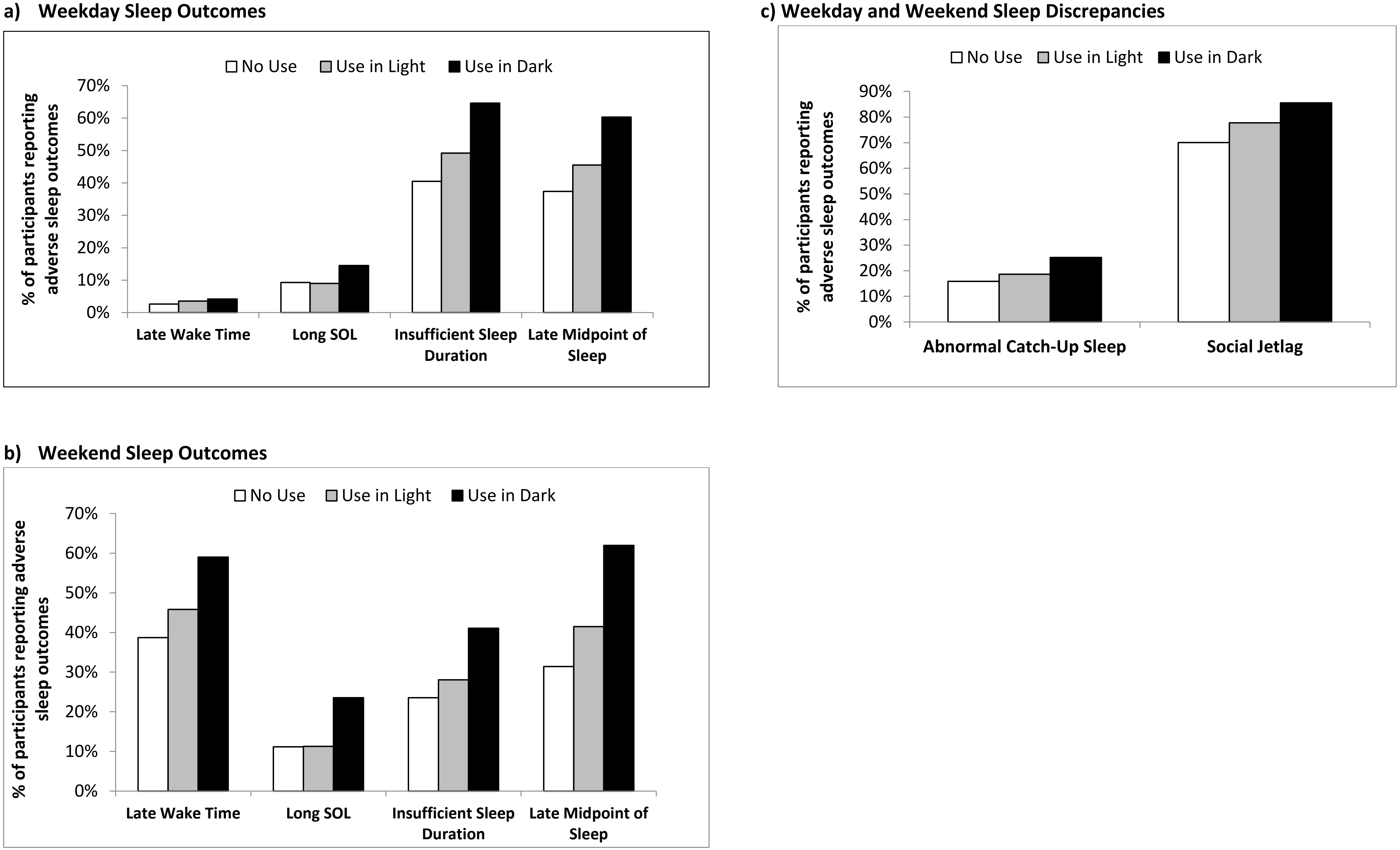
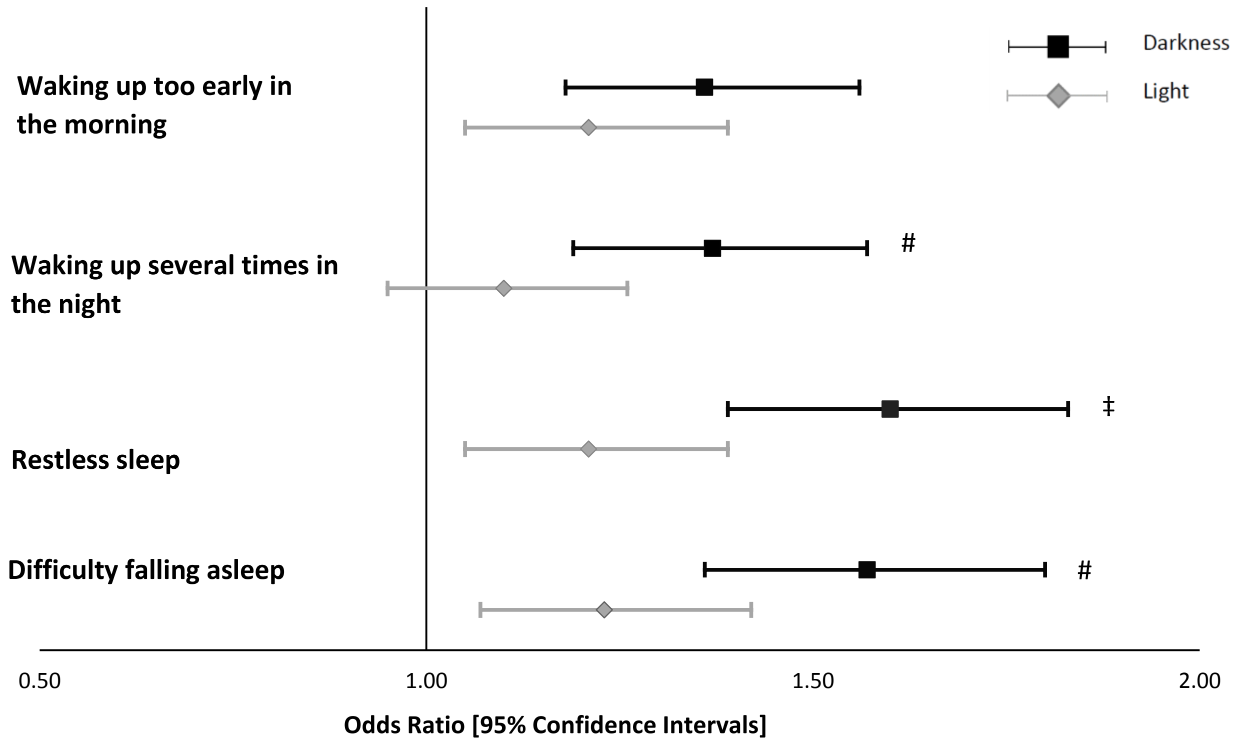


Figure 1. Proportion of adolescents reporting adverse sleep outcomes by night-time use of mobile phone (no use, use in light, use in darkness). Late wake time (later than 7:30 a.m. on weekdays and 8:30 a.m. on weekends); Long SOL (sleep onset latency > 45 min); Insufficient sleep duration (sleep duration < 9 hr); Late

midpoint of sleep (sleep midpoint later than 2:08 a.m. on weekdays and 3:53 a.m. on weekends); Abnormal catch-up sleep (difference of weekday & weekend sleep duration > 2 hr); Social jetlag (difference of weekday & weekend sleep midpoint > 1 hr).

a) Mobile phone use



b) Television watching

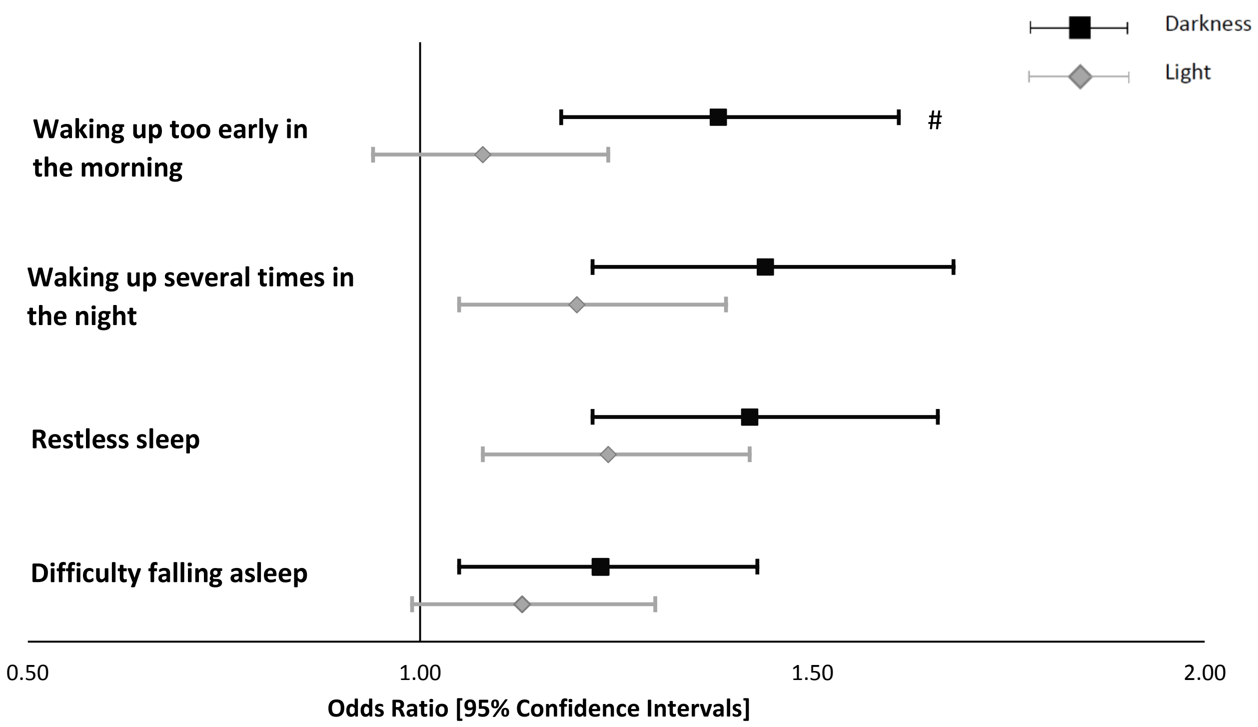


Figure 2. Associations between night-time (a) mobile phone use and (b) television use (in light/dark) and sleep quality dimensions (indicated on the left-hand side of the figure).

All models were adjusted for sex, age, ethnicity, school type, parental occupation and parental education. Points (square and diamonds) represents adjusted odds ratios. Error bars indicate 95% CIs.

Reference group for all models: no night-time use of mobile phones (Odds Ratio = 1)

[#]$p<0.01$, [‡]$p<0.001$ for the comparison of the observed measure of effect between device use in darkness and in a lit room. Models without symbols indicate no statistical significant difference ($p>0.05$) in the observed effect between device use in a dark room compared to a lit room.