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Evidence synthesis

Timing of sedentary behaviour and access to sedentary activities in the bedroom and their association with sleep quality and duration in children and youth: a systematic review

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Abstract

Background: The purpose of this study was to systematically review the relationship between the timing of sedentary behaviours and access to sedentary activities in the bedroom with sleep duration and quality in children and youth. A secondary purpose was to examine whether these relationships differ when comparing screen-based and non-screen-based sedentary activities.

Methods: We searched four databases for peer-reviewed studies published between 1 January 2010 and 19 January 2021. Risk of bias assessment for each study and certainty of evidence were assessed using the GRADE framework.

Results: We identified 44 eligible papers reporting data from 42 separate datasets and including 239 267 participants. Evening participation in screen-based sedentary behaviours and access to screen-based devices in the bedroom were associated with reduced sleep duration and quality. Daytime screen use was also associated with reduced sleep duration, although this was examined in relatively few studies. Whether performed during the day or night, non-screen-based sedentary behaviours were not consistently associated with sleep duration or quality. The quality of evidence was rated as low to very low for all outcomes.

Conclusion: In order to maximize sleep duration and quality, children and youth should be encouraged to minimize screen time in the evening and remove screens from bedrooms. (PROSPERO registration no.: CRD42020189082)

Keywords: *sedentary behaviour, screen time, sleep duration, sleep quality, timing, systematic review, youth, public health*

Highlights

- Using screen-based devices in the evening and access to screen-based devices in the bedroom were associated with reduced sleep duration and quality.
- Findings were based primarily on observational studies, using self-report methodologies.
- Children and youth should be encouraged to minimize the use of screen-based devices before bed and remove screens from bedrooms.

Introduction

Sedentary behaviours (waking behaviours characterized by an energy expenditure of 1.5 or less metabolic equivalents while in a sitting, reclining or lying posture)[1] are linked with numerous important health outcomes among school-aged children and youth.[2] While screen-based sedentary behaviours are often associated with detrimental health outcomes, non-screen-based sedentary behaviours such as reading typically show null or even beneficial associations with health.[3,4]

In a 2016 systematic review of 235 studies, Carson et al.[4] reported that higher durations and frequencies of screen time were associated with unfavourable body composition, behavioural conduct, fitness, self-esteem and clustered cardiometabolic risk. In contrast, reading and homework were positively associated with academic achievement.[4] Other recent systematic reviews and meta-analyses report that higher levels of screen-based sedentary behaviours are also associated with increased risk of depression,[5,6] although questions remain regarding the magnitude of this relationship.[7]

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Inadequate sleep duration and quality likely mediate the relationship between screen-based sedentary behaviour and health outcomes.[8] Longer sleep duration is associated with favourable body composition, emotional regulation, academic achievement and quality of life.[9] A systematic review reported that 90% of studies examined found that screen time is associated with poor sleep outcomes (primarily shorter and delayed sleep) among children and youth.[10] Reductions in total daily screen time are also associated with small increases in sleep duration among children and youth.[11]

A number of mechanisms have been suggested to explain these associations, the most obvious being time displacement; more time using screens means less time for other behaviours, including sleep.[10,12] Other mechanisms include increased arousal and negative effects on circadian rhythms.[10,13] Limited evidence has also suggested that interactive screen time (e.g. using a computer, smartphone or video game console) is more consistently associated with poor sleep than more passive forms of screen time (e.g. television viewing).[10]

Based on these suggested mechanisms, it is plausible that the timing of screen-based sedentary behaviours may have a greater impact on sleep than total daily volume. A meta-analysis by Carter et al.[14] reported a strong and consistent association between bedtime use of smartphones and tablets with deleterious sleep quantity (odds ratio [OR] = 2.17; 95% confidence interval [CI]: 1.42–3.32) and quality (OR = 1.46; 95% CI: 1.14–1.88). Not surprisingly, it is common to recommend that children and youth avoid screens in the hour(s) before bed and limit using screen-based devices in the bedroom.[10,13,15,16]

While this evidence suggests that the timing of sedentary behaviour may be associated with sleep quality and duration, several key questions remain. Although previous reviews have examined the impact of screen use in the bedroom, or immediately preceding sleep, to date none have compared this with the impact of screen use during other periods of the day or with the impact of non-screen-based sedentary behaviours during these same periods. It is therefore unclear whether the relationship between evening screen use and sleep differs markedly from that of daytime screen use. It is also unclear whether non-screen-based sedentary behaviour such as reading a book or doing paper-based homework show similar or different associations with sleep. These are important research gaps, as they preclude specific public health recommendations related to sedentary behaviour and sleep.

The purpose of this study was to systematically review the relationship between the timing of sedentary behaviours and access to sedentary activities in the bedroom with sleep duration and quality in children and youth. A secondary purpose was to examine whether these relationships differ based on the mode of sedentary behaviour (i.e. screen based and non-screen based).

Methods

Protocol and registration

This systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO; Registration no. CRD42020189082) and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[17] Methods are presented below using the Population, Intervention/Exposure, Comparison/Control and Outcome (PICO) framework.

Eligibility criteria

Population

The population of interest was apparently healthy children and youth aged 5 to 17.99 years. Studies with participants outside of this age range were included if participants aged 5 to 17.99 were reported separately or if the mean age fell within this range. Studies exclusively targeting disease-specific populations (e.g. children with diabetes, children with congenital heart defects) or patients with sleep disorders were excluded.

Intervention/exposure

The intervention or exposure was the timing of sedentary behaviour as well as access to both screen-based and non-screen-based sedentary activities in the bedroom. Sedentary behaviours were defined as any waking behaviour characterized by low energy expenditure and a sitting, reclining or lying posture.[1] This included measures of time spent sitting as well as screen-based sedentary behaviours (e.g. watching TV, playing video games, accessing social media, reading an ebook) and non-screen-based sedentary behaviours (e.g. reading a print book, listening to music, playing board games).

Sedentary behaviour timing refers to the time of day that sedentary behaviours occur. The timing may be reported as time of day or time relative to bedtime. Studies were eligible if they included device-measured (e.g. using an inclinometer, actigraph unit/accelerometer) or self-reported (e.g. questionnaire) measures of sedentary behaviour timing or both. Studies were also included if they reported the presence of objects used to engage in screen-based or non-screen-based sedentary activities in the bedroom. For experimental studies, the interventions must have targeted sedentary behaviour timing or presence of sedentary activities exclusively and not multiple health behaviours (e.g. both sedentary behaviour and diet or sedentary behaviour and physical activity).

Comparison/control

Various levels of sedentary behaviour timing/access to sedentary activities in the bedroom were used for comparison. However, a comparator or control group was not required for inclusion.

Outcomes

This systematic review had two outcomes: sleep duration (e.g. hours per night, hours per 24-hour period), and sleep quality, which included the following measures: sleep onset latency, sleep efficiency (% of time in bed spent sleeping), waking after sleep onset, waking up too early, sleeping restlessly, difficulty falling asleep, insomnia symptoms and overall sleep quality.

Study designs

All study designs, except case studies, were eligible for inclusion, but only published or in-press English or French language peer-reviewed studies were eligible; all grey literature (e.g. book chapters, dissertations, conference abstracts) were excluded. For longitudinal studies, any length of follow-up was allowed, but there must have been at least one measure of sleep timing at 5 to 17 years of age. Because we initially identified a large number of small cross-sectional studies, we set the minimum sample size for cross-sectional studies to 1000 midway through the review. This threshold is consistent

with previous systematic reviews in this field.[9] There were no sample size limitations for longitudinal or experimental studies.

Information sources and search strategy

A comprehensive search strategy was developed by a research librarian (AR-W). Four bibliographic databases were searched: Ovid MEDLINE, Ovid Embase, Ovid PsycINFO and EBSCO Cumulative Index to Nursing & Allied Health Literature (CINAHL). Searches were conducted on 19 January 2021. All studies had to have been published on or since 1 January 2010; these dates were chosen to manage scope and to focus on the most recent body of evidence.

The search strategy is shown in Supplementary Table 1 (https://osf.io/q7wes/?view_only=420496c898b740f988e9077c3a9010e1).

We also searched the reference lists of all review studies identified during level 2 screening for additional relevant studies.

Data extraction

To remove duplicates, bibliographic records were extracted and imported into EndNote software (Clarivate, Philadelphia, PA, US). During level 1 screening, two reviewers (any combination of JC, TM, SP or TJS), working independently, screened titles and abstracts of potentially relevant articles using Covidence (Veritas Health Innovation, Melbourne, AU). We obtained full-text copies of the articles that met initial screening criteria. During level 2 screening, two reviewers (any combination of JC, TM, SP, KD or TJS), working independently, examined all the full-text articles. Any discrepancies were resolved via discussion until consensus was reached.

A reviewer (TM) extracted the relevant data using a customized Google Form, and another (TJS) verified the data. Authors' and journal names were not blinded when the reviewers were extracting data. The extracted information included descriptive study characteristics (e.g. author, publication year, study design, country, sample size, age, sex), intervention/exposure, outcome(s), results and confounders. Where studies reported multiple models, the reviewers extracted results from the most fully adjusted model, including both the direction and statistical significance of any associations.

Risk of bias and study quality assessment

Using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework,[18] we systematically examined the quality of primary research contributing to each health indicator and assessed the overall quality and risk of bias of the evidence across health indicators. We completed the risk of bias assessment for individual intervention studies according to methods described in the Cochrane Handbook.[19] GRADE does not have a tool for assessing risk of bias in observational studies, but does recommend the types of characteristics to examine.[18] For individual observational studies, we assessed selection bias, performance bias, selective reporting bias, detection bias, attrition bias and other biases (e.g. inadequate control for key confounders). Risk of bias for individual studies was assessed by one reviewer (TM) and verified by another (TJS). According to the GRADE framework, randomized controlled trials start with a quality of evidence rating of "high"; all other designs start at a rating of "low."[18] The quality of evidence can be downgraded if there are limitations across studies as a result of risk of bias (operationalized as ≥50% of studies showing high risk of bias for a given outcome), inconsistency, indirectness, imprecision or other factors.[18] The quality can be upgraded if there are no serious limitations, as well as a large magnitude of effect or evidence of a dose–response relationship.[18]

Results

Description of studies

A total of 3548 studies were identified through database searches, leaving 2999 after duplicates were removed. After title and abstract screening, 803 papers underwent full-text review. Of these, 42 met all inclusion criteria. Searching the reference lists of all reviews identified at level 2 screening identified 132 potentially relevant papers, of which 2 met the inclusion criteria. This left a total of 44 papers, reporting on 42 individual datasets. (See Figure 1 for the PRISMA flow diagram[17].)

The most common reasons for excluding an article at level 1 full-text screening was that the study failed to measure or report sedentary behaviour timing (n = 290), it was a conference abstract (n = 154) or that it examined ineligible populations (n = 110). Forty-three cross-sectional studies that met other inclusion criteria were excluded because the sample size was less than 1000. A list of reasons for excluding individual papers is in Supplementary Table 2 (https://osf.io/q7wes/?view_only=420496c898b740f988e9077c3a9010e1). Quality of evidence for each outcome are presented in Table 1, and a high-level summary of findings is presented in Table 2.

Characteristics of the individual studies included in this review are in Supplementary Tables 3–6 and risk of bias assessments of individual studies are in Supplementary Tables 7–10 (https://osf.io/q7wes/?view_only=420496c898b740f988e9077c3a9010e1). We identified 28 cross-sectional studies, 6 longitudinal studies lasting between 1 and 3 years, and 8 nonrandomized intervention studies lasting 1 to 14 days.

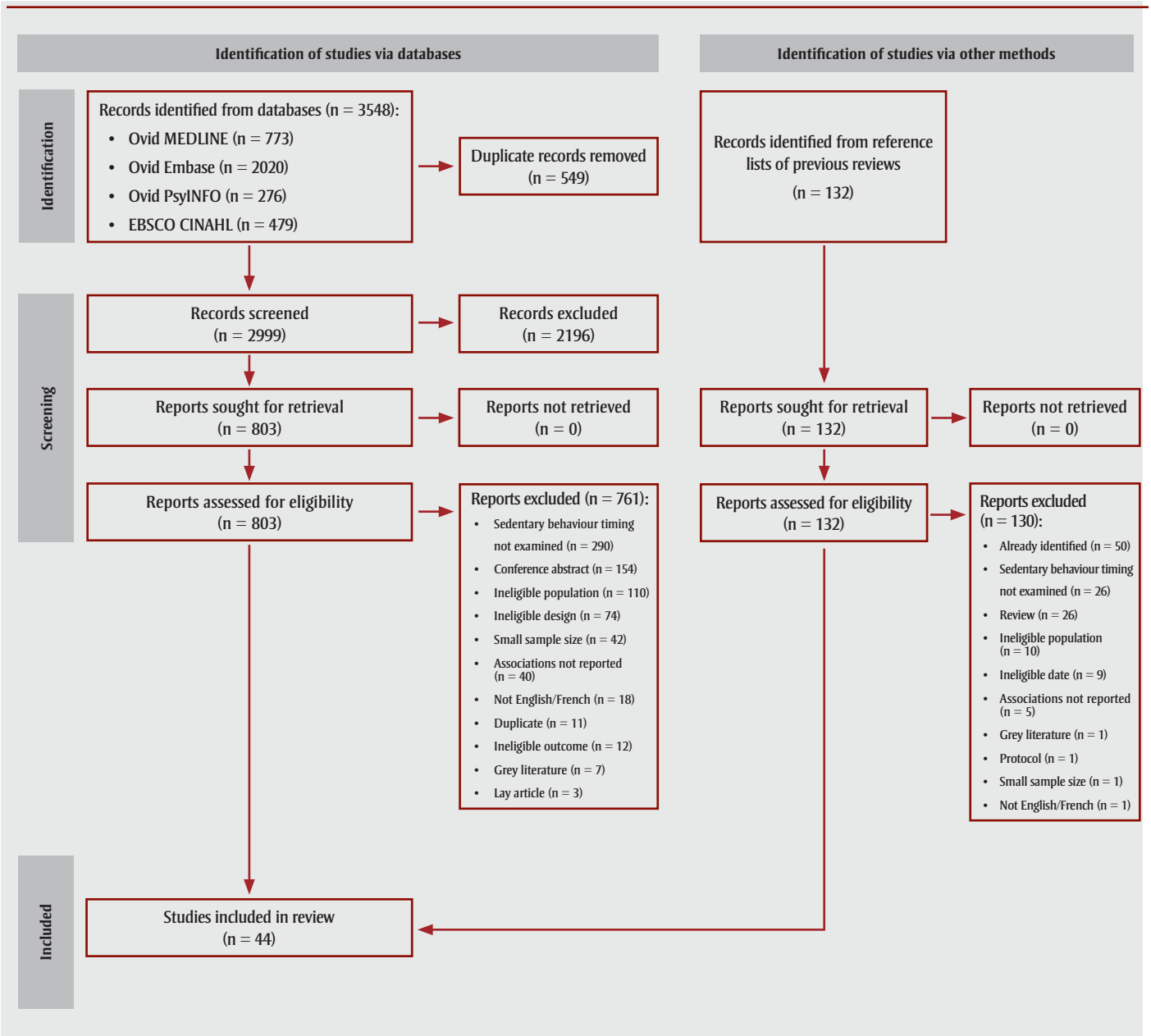
Sedentary behaviour was self- or parent-reported in 36 studies, device-measured in 1 study, and intervened upon by the research team in 5 nonrandomized intervention studies. Sleep duration and quality were device-measured in 7 of the 8 intervention studies and 1 of the 34 observational studies. Sedentary behaviour timing was categorized in a variety of ways across studies, including "morning," "after school," "dinner time," "after dinner," "before bedtime/sleep," "at night," "before and/or after lights out," "last hour before bed" and "in bed," as well as the specific time of use/last use. For this review, "morning," "after school" and "dinner time" were considered daytime, and all other time points, evening.

Thirty-one studies examined the impact of sedentary behaviour timing, while 16 studies examined the impact of sedentary behaviours in the bedroom (5 studies included both). Sleep duration was assessed in 34 studies, and sleep quality in 23, with 16 studies examining both eligible outcomes. Across all studies, there were 239267 participants from 23 countries. Mean ages ranged from 5.3 to 17.4 years.

Data synthesis

Because the heterogeneity in study design, measurement of sedentary behaviour and

FIGURE 1
PRISMA 2020 flow diagram[17] of search and inclusion of studies in this systematic review



Abbreviation: PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

sleep, and statistical analyses precluding the use of meta-analyses, we present our results as a narrative synthesis.

Sedentary behaviour timing and sleep duration

Four nonrandomized intervention studies[20-23] examined the relationship between sedentary behaviour timing and sleep duration. One 2-week-long intervention reported that reducing total screen time after 9 p.m. increased sleep duration by 17 ± 2 minutes.[20] Another 1-week-long intervention found that reducing mobile phone use in the hour before bed led to sleep lasting 21 minutes longer each night.[21] An intervention lasting a single night reported a negative correlation between video game time and sleep duration ($r = -0.92$; $p < 0.05$),[22] while another single-night intervention reported that playing video games for 150 minutes reduced sleep duration by 27 ± 12 minutes, compared to effects of playing the same game for 50 minutes.[23]

Quality of evidence was rated as very low for these experimental studies because of the lack of randomized trials, concerns related to bias and lack of evidence of large effects or dose–response relationships.

One longitudinal study lasting 3 years reported that, in comparison to those who did not use screens at any time after dinner, those who used screens after dinner had significant reductions in sleep duration ($\beta = -0.10$; 95% CI: -0.18, -0.02; $p = 0.01$).[24] However, there was no significant association between changes in screen use after dinner and changes in sleep duration ($\beta = -0.08$; 95% CI:

TABLE 1
Quality assessment and quality of evidence rating of studies included in this systematic review

Health outcome	Study design	No. of studies	No. of participants	Quality assessment indicator						Quality
				Risk of bias	Inconsistency	Indirectness	Imprecision	Large magnitude of effect	Dose response	
Sleep duration										
Sedentary timing	Nonrandomized trials	4	71	High risk of selection bias	Low	Low	Low	No	No	Very low
	Observational studies	21	208 801	Low risk of bias	Low	Low	Low	No	No	Low
Presence of sedentary behaviours in bedroom	Nonrandomized trials	0	0	NA	NA	NA	NA	NA	NA	NA
	Observational studies	15	36 711	Low risk of bias	Low	Low	Low	No	No	Low
Sleep quality										
Sedentary timing	Nonrandomized trials	8	361	High risk of selection bias	High	Low	Low	No	No	Very low
	Observational studies	12	154 836	Low risk of bias	Low	Low	Low	No	No	Low
Presence of sedentary behaviours in bedroom	Nonrandomized trials	0	0	NA	NA	NA	NA	NA	NA	NA
	Observational studies	5	11 154	Low risk of bias	Low	Low	Low	No	No	Low

Abbreviations: NA, not applicable; no., number.

−0.16, 0.01; $p = 0.07$). A longitudinal study that lasted 2 years reported that watching TV/using video games before bedtime was associated with reduced sleep duration (β = −0.04; 95% CI: −0.05, −0.12; $p < 0.05$).[25]

Nineteen cross-sectional studies examined the relationship between sedentary behaviour timing and sleep duration[26-44], 2 of which looked only at daytime sedentary behaviour[39,44]. Evening screen use was negatively associated with sleep in 15/17 studies[26-35,37,40-43], positively associated with sleep in 1/17 study[38], and showed one or more null associations in 5/17 studies[28,36,40-42]. Several studies reported associations for multiple modalities of screen use.

All 3 of the studies that examined daytime screen use reported negative associations with sleep duration.[33,39,44] One study reported that daytime homework/reading was negatively associated with sleep duration[39], while another reported no association[30].

Apart from video game use, the associations between evening screen use and deleterious sleep duration were consistent across devices. The majority of studies reported that sleep duration was negatively associated with evening use of smartphones (8/10 studies)[26-29,33-35,40], total screen time (6/8 studies)[30,33,34,40,42,43], watching TV (5/6 studies)[29,32-34,42], texting/instant messaging (6/6 studies)[27,28,31,35,37,42], using a computer (3/3 studies)[32,33,41] and accessing the Internet (3/3 studies)[28,29,42], but not video games (1/4 studies)[33].

In terms of non-screen-based sedentary behaviours, 1 study reported a positive association between evening homework/

TABLE 2
High-level summary of findings by health outcome

Sleep outcome	No. of studies	No. of participants	Quality of evidence	Summary of findings
Sleep duration	34	233 067	Very low	Evening screen use is negatively associated with sleep duration Reducing evening screen use may increase sleep duration Presence of screen-based devices in the bedroom may be associated with reduced sleep duration
Sleep quality	22	160 686	Low	Evening screen use and presence of screens in the bedroom are negatively associated with sleep quality Reducing evening screen use may increase sleep quality

Abbreviation: No., number.

reading and sleep duration[30], while 2 studies reported no association[29,43]. Listening to music on a phone or MP3 player in the evening was negatively associated with sleep duration in 2/2 studies[28,33], while listening to the radio was not associated with sleep duration in 1/1 studies[41]. Two cross-sectional studies examined the relationship between evening screen use in bed and sleep duration[30,41]. Of these, one reported that adolescents with the lowest self-reported sleep were more likely to report screen use in bed[30]; the other reported that self-reported sleep duration was lower among adolescents who used computers, but not other screen-based devices, in bed "almost every night" or more often[41].

Quality of evidence was rated as low for all observational studies because of the lack of large effects or dose–response relationships.

Access to sedentary activities in the bedroom and sleep duration

Three longitudinal[25,46,47] and 12 cross-sectional[41-45,48-54] studies examined the relationship between access to sedentary activities in the bedroom and sleep duration. The longitudinal studies provided mixed results: Cespedes et al.[45] found that the presence of a TV in the bedroom was associated with reduced sleep duration; King et al.[23] reported no association between bedroom screens and sleep duration; and Nuutinen et al.[46] reported that having a TV in the bedroom was negatively associated with weekend sleep duration among boys, and positively associated with weekend sleep duration among girls, with no significant associations observed between having a TV or computer in the bedroom and weekday sleep in either gender.

In the cross-sectional studies, associations between the use of screens in the bedroom and deleterious sleep duration were observed for computers (3/4 studies)[41,42,44] and all screen-based devices (3/3 studies)[40,42,52], with inconsistent results observed for TV watching (negative association observed for at least one analysis in 5/11 studies)[42,47,50,52,53], playing video games (negative association in 1/2 studies)[42] and using cell phones (negative association in 1/2 studies)[42].

The quality of evidence was rated as low; although bias was not a concern, there was no evidence of large magnitude of effect or dose–response relationships.

Sedentary behaviour timing and sleep quality

Eight nonrandomized intervention studies and 12 observational studies examined the relationship between sedentary behaviour timing and sleep quality. One intervention asked participants to avoid using screens after 9 p.m. on school nights for 2 weeks[20]. Compared to baseline, this intervention resulted in earlier sleep onset on school nights, by 20 minutes, with no change in sleep efficiency[20]. The other interventions lasted one night; they reported significant associations between evening screen use and sleep onset latency (negative in 2/6 studies)[23,54], sleep efficiency (negative in 2/3 studies)[23,55], number of arousals per hour (negative in 1/1 studies)[55] but not waking after sleep onset (0/1 studies)[55].

One intervention study also reported that exposure to violent video games before bed reduced overall sleep quality for those with low exposure to games in daily life (≤1 hour/day), but not for those with high exposure (≥3 hours/day)[56].

Of the 6 interventions investigating device-measured sleep quality[20,22,23,54,55,57], 4 reported negative associations between evening screen use and at least one outcome [20,23,54,55]. The quality of evidence for intervention studies was rated as very low because of the lack of randomized trials, high risk of selection bias and inconsistency of results, with no evidence of large effects or dose–response relationship.

Two longitudinal studies examined the relationship between timing of sedentary behaviour and sleep quality over 1 year[58] and 3 years[59]. Foerster et al.[58] reported that adolescents woken by their phone were more likely to develop restless sleep and problems falling asleep than those who were not woken up by their phone. Similarly, Vernon et al.[59] reported that nighttime phone use was also associated with poor sleep quality.

The relationship between timing and sleep quality was also assessed in 10 cross-sectional studies[32-35,37,39,40,43,60,61]. The use of screen-based devices in the evening was negatively associated with measures of sleep quality in 7/9 studies[33-35,37,40,60,61], positively associated with sleep quality in 1/9 studies[34] and demonstrated null associations in 3/9 studies[32,34,43]. (Several studies reported associations for multiple measures of sleep quality.)

Daytime screen use was negatively associated with measures of sleep quality in 2/2 studies[33,39] or had null associations in 1/2 studies[39].

Overall sleep quality was negatively associated with evening screen use in 3/4 studies[35,40,61], but was not associated with reading in 1/1 studies[43]. Sleep onset latency was positively associated with evening screen use in 2/3 studies[33,60], negatively associated with evening screen use in 1/3 studies[34] and positively associated with daytime screen use in 1/1 studies[33]. Sleep efficiency was negatively associated with evening screen access/use in 1/1 studies[40]. Insomnia symptoms were positively associated with evening screen use in 2/2 studies[35,37]. Waking up too early, difficulty falling asleep and sleeping restlessly were all positively associated with evening screen use in 1/1 studies[34]. Waking after sleep onset[34] and frequency of sleep disturbances[32] were not associated with evening screen use in 1/1 studies.

After-school homework and mobile phone use were positively associated with difficulty maintaining sleep in Grades 6 to 8 (but not Grades 4 to 5) and were not associated with difficulty falling asleep in either age group in 1/1 studies[39].

The quality of evidence for these observational studies was rated as low, as there was a low risk of bias with no evidence of large effects or dose–response relationships.

Access to sedentary activities in the bedroom and sleep quality

Of the 5 cross-sectional studies[40,43,52,53,61] that examined the relationship between access to screen-based devices in the bedroom and sleep quality, 4/5 reported negative associations between the presence of electronic screens in the bedroom and at least one measure of sleep quality[40,43,52,61], and 1/5 reported only null associations[53]. Overall sleep quality was negatively associated with the presence of screen-based devices in the bedroom in 3/3 studies[40,43,61], while both sleep efficiency[40] and perceived insufficient sleep[52] were negatively

associated with screen-based sedentary behaviours in 1/1 studies. Sleep onset insomnia was not associated with the presence of screens in the bedroom in 1/1 studies[53].

The quality of evidence for these cross-sectional studies was rated as low; although risk of bias was low, there was no evidence of large effects or dose–response relationship.

Discussion

The purpose of this study was to systematically review the relationship between the timing of sedentary behaviours and access to sedentary activities in the bedroom with sleep duration and quality in children and youth. Our findings suggest that evening screen use and access to screen-based devices in the bedroom are associated with reduced sleep duration and quality in this age group. Intervention-based studies suggest that reducing evening screen use may lead to improved sleep duration and quality, although most interventions only examined a single night's sleep. In the 2 studies lasting 1 week or longer, restricting evening screen use resulted in a roughly 20-minute increase in each night's sleep[20,21], suggesting that the impacts may be clinically meaningful.

A secondary purpose of this review was to examine whether these relationships differ based on the mode of sedentary behaviour. In contrast to screen-based sedentary behaviours, our results suggest that reading and doing homework are not consistently associated with sleep duration or quality in this age group. Although only 3 studies reported on listening to music, 2 studies reported that listening to music on a cell phone or MP3 player was negatively associated with sleep duration[30,33], whereas listening to the radio was not associated with sleep duration[41].

Taken together, these findings suggest that screen-based sedentary behaviours are more likely to negatively impact sleep duration and quality, although relatively few studies examined the impact of non-screen-based sedentary behaviours. In contrast to previous research[10], we found that, with the exception of video games, both interactive (e.g. computers, phones) and passive (e.g. TV viewing) forms of screen use were consistently associated with reduced sleep duration.

Compared to evening screen use, far fewer studies examined the impact of daytime use on sleep duration[33,39,44] or quality[33,39]; only one study examined associations between both daytime and evening sedentary behaviours and sleep duration or quality[33]. However, all these studies reported deleterious relationships between daytime screen use and at least one measure of sleep duration or quality. This is in line with previous research that found that total screen time is consistently associated with poorer sleep outcomes among children and youth[10]. Unfortunately, the timing of sedentary behaviour was measured in various ways across studies, using broad descriptions such as "morning," "after school" or "before bedtime." This evidence gap makes it impossible to identify the optimal "cooling off" period prior to sleep. Further research is needed to directly compare the impact of sedentary behaviour during different periods of the day and night, as well as to examine the optimal interval between screen use and bedtime.

Our findings do suggest that children and youth are likely to benefit from following the recommendations of the American Academy of Pediatrics[15] and Canadian Pediatric Society[16], both of which include removing screens from bedrooms and avoiding screens for at least 1 hour before bed. Although the current findings are based on very low quality evidence, meeting these recommendations will likely still benefit sleep, with very low risk of harm. Removing screens from bedrooms is particularly important because bedroom screen use is most likely to directly displace or delay sleep. This may also be easier than reducing screen time during other periods of the day, when parents have less control over screen use. It is important that schools and teachers help to support students in limiting their evening screen time, by limiting the volume and frequency of screen-based homework that must be completed each day.

Although we cannot rule out the possibility of a bidirectional relationship, the evidence included in this review does not suggest that changes in sleep duration or quality lead to increases in evening screen use. Of the longitudinal studies we identify in the review, none reported that reductions in sleep quality or duration predicted subsequent increases in evening screen time. Further, the intervention studies included suggest that increases in evening screen use are associated with subsequent reductions in sleep duration and quality. Future studies should specifically investigate the directionality of the relationship between sedentary behaviour timing and sleep outcomes.

Strengths and limitations

This review has a number of strengths and limitations. We used a comprehensive search strategy, included all study designs, assessed risk of bias within studies and used the GRADE approach to determine the certainty of evidence across studies. However, GRADE takes a conservative approach, with all study designs other than randomized trials starting as "low quality" by default.[18]

All the cross-sectional studies (but not longitudinal or intervention studies) had to have a minimum of 1000 participants, which may have limited the number of included studies for some outcomes. Restricting inclusion to larger cross-sectional studies increases the likelihood of detecting a true effect[62], and the large number of included studies (n = 44) and participants (n = 239 267) increased the confidence in our findings. The studies excluded because of small sample size had altogether 17 603 eligible participants, which represents just 7% of participants in the papers in this review.

Our search strategy did not include grey literature and we did not contact content experts, although we believe this would be unlikely to impact our overall findings. Our review also identified relatively few intervention studies.

The studies did not differentiate between recreational and school-related screen time; nor did they indicate whether homework was screen or paper based. Future studies should employ randomized intervention studies to better understand the chronic impact of reductions in evening screen use, and to examine the associations between sleep and both recreational and school-related screen time.

All the observational studies in our review measured self- or parent-reported sedentary behaviour; using objective measures of sedentary behaviour timing would improve the quality of future research. Because of the heterogeneity in the included studies, we were unable to

perform meta-analyses, which also precluded a formal assessment of publication bias or investigation of whether relationships varied by age or gender. However, only including studies published in the last 10 years could have partly mitigated the risk of publication bias, as many more journals publish null findings in recent years.

Finally, our review was limited to English and French language peer-reviewed papers, although available evidence suggests these restrictions are unlikely to impact our findings[63,64].

Conclusion

Our results suggest that engaging in screen-based sedentary behaviours in the evening and access to screen-based devices in the bedroom are associated with reduced sleep duration and quality among school-aged children and youth. In contrast, there were no consistent associations between non-screen-based sedentary behaviours and sleep duration or quality in this age group. In order to maximize sleep duration and quality, children and youth should minimize screen time prior to bedtime and remove screens from their bedrooms.

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Registration of the protocol

PROSPERO registration no. CRD42020189082, available from www.crd.york.ac.uk/PROSPERO/.

Conflicts of interests

TJS has received honorariums for public presentations on the health impact of sedentary behaviour. The other authors have no conflicts to declare.

Authors' contributions and statement

TJS, TM, JC, SAP and KD screened the papers.

TM and TJS extracted the data and performed the risk of bias and GRADE assessments.

TJS drafted the final version of the manuscript.

All authors were involved in the conception of the study, and all authors reviewed and approved the final version for publication.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

References

1. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act. 2017;14:75. https://doi.org/10.1186/s12966-017-0525-8

2. Tremblay MS, Carson V, Chaput J-P, et al. Canadian 24-Hour Movement Guidelines for Children and Youth: an integration of physical activity, sedentary behaviour, and sleep. Appl Physiol Nutr Metab. 2016;41(6 (Suppl. 3)):S311-27. https://doi.org/10.1139/apnm-2016-0151

3. Prince SA, LeBlanc AG, Colley RC, Saunders TJ. Measurement of sedentary behaviour in population health surveys: a review and recommendations. Peer J. 2017;5:e4130. https://doi.org/10.7717/peerj.4130

4. Carson V, Hunter S, Kuzik N, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. Appl Physiol Nutr Metab. 2016;41(6 Suppl 3):S240-65. https://doi.org/10.1139/apnm-2015-0630

5. Wang X, Li Y, Fan H. The associations between screen time-based sedentary behavior and depression: a systematic review and meta-analysis. BMC Public Health. 2019;19(1):1524. https://doi.org/10.1186/s12889-019-7904-9

6. Liu M, Wu L, Yao S. Dose-response association of screen time-based sedentary behaviour in children and adolescents and depression: a meta-analysis of observational studies. Br J Sports Med. 2016;50(20):1252-8. https://doi.org/10.1136/bjsports-2015-095084

7. Tang S, Werner-Seidler A, Torok M, Mackinnon AJ, Christensen H. The relationship between screen time and mental health in young people: a systematic review of longitudinal studies. Clin Psychol Rev. 2021;86:102021. https://doi.org/10.1016/j.cpr.2021.102021

8. Saunders TJ, McIsaac T, Douillette K, et al. Sedentary behaviour and health in adults: an overview of systematic reviews. Appl Physiol Nutr Metab. 2020;45(10 (Suppl. 2)):S197-217. https://doi.org/apnm-2020-0272

9. Chaput JP, Gray C, Poitras V, et al. Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. Appl Physiol Nutr Metab. 2016;41(6 Suppl 3):S266–82. https://doi.org/10.1139/apnm-2015-0627

10. Hale L, Guan S. Screen time and sleep among school-aged children and adolescents: a systematic literature review. Sleep Med Rev. 2015;21:50-8. https://doi.org/10.1016/j.smrv.2014.07.007

11. Martin KB, Bednarz JM, Aromataris EC. Interventions to control children's screen use and their effect on sleep: a systematic review and meta-analysis. J Sleep Res. 2021;30(3):e13130. https://doi.org/10.1111/jsr.13130

12. Chaput J-P, Carson V, Gray CE, Tremblay MS. Importance of all movement behaviors in a 24 hour period for overall health. Int J Environ Res Public Health. 2014;11(12):12575-81. https://doi.org/10.3390/ijerph111212575

13. Hale L, Kirschen GW, LeBourgeois MK, et al. Youth screen media habits and sleep: sleep-friendly screen behavior recommendations for clinicians, educators, and parents. Child Adolesc Psychiatr Clin N Am. 2018;27(2):229-45. https://doi.org/10.1016/j.chc.2017.11.014

14. Carter B, Rees P, Hale L, Bhattacharjee D, Paradkar M. Association between portable screen-based media device access or use and sleep outcomes: a systematic review and meta-analysis. JAMA Pediatr. 2016;170(12):1202-8. https://doi.org/10.1001/jamapediatrics.2016.2341

15. Council on Communications and Media. Media use in school-aged children and adolescents. Pediatrics. 2016;138(5):e20162592. https://doi.org/10.1542/peds.2016-2592

16. Canadian Paediatric Society. Screen time and young children: promoting health and development in a digital world. Paediatr Child Health. 2017;22(8):461-68. https://doi.org/10.1093/pch/pxx197

17. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71

18. Guyatt GH, Oxman AD, Vist G, et al. GRADE guidelines: 4. Rating the quality of evidence—study limitations (risk of bias). J Clin Epidemiol. 2011;64(4):407-15. https://doi.org/10.1016/j.jclinepi.2010.07.017

19. Higgins JP, Green S, editors. Cochrane handbook for systematic reviews of interventions. Version 5.1.0 [Internet]. London (UK): The Cochrane Collaboration; [updated March 2011]. Available from: www.handbook.cochrane.org

20. Perrault AA, Bayer L, Peuvrier M, et al. Reducing the use of screen electronic devices in the evening is associated with improved sleep and daytime vigilance in adolescents. Sleep. 2019;42(9):zsz125. https://doi.org/10.1093/sleep/zsz125

21. Bartel K, Scheeren R, Gradisar M. Altering adolescents' pre-bedtime phone use to achieve better sleep health. Health Commun. 2019;34(4):456–62. https://doi.org/10.1080/10410236.2017.1422099

22. Wolfe J, Kar K, Perry A, Reynolds C, Gradisar M, Short MA. Single night video-game use leads to sleep loss and attention deficits in older adolescents. J Adolesc. 2014;37(7):1003-9. https://doi.org/10.1016/j.adolescence.2014.07.013

23. King DL, Gradisar M, Drummond A, et al. The impact of prolonged violent video-gaming on adolescent sleep: an experimental study. J Sleep Res. 2013;22(2):137-43. https://doi.org/10.1111/j.1365-2869.2012.01060.x

24. Komrij NL, van Stralen MM, Busch V, et al. Predictors of changes in sleep duration in Dutch primary schoolchildren: the CheckKid Study. Int J Behav Med. 2021;28(2):189-99. https://doi.org/10.1007/s12529-020-09876-7

25. Alqaderi H, Goodson JM, Subramanian SV, Tavares M. Short sleep duration and screen-based activities: a longitudinal multilevel analysis. Am J Lifestyle Med. 2018;12(4):340-8. https://doi.org/10.1177/1559827616667048

26. Alves FR, de Souza EA, de França Ferreira LG, de Oliveira Vilar Neto J, de Bruin VM, de Bruin PF. Sleep duration and daytime sleepiness in a large sample of Brazilian high school adolescents. Sleep Med. 2020;66:207-15. https://doi.org/10.1016/j.sleep.2019.08.019

27. Garmy P, Idecrans T, Hertz M, Sollerhed A-C, Hagell P. Is sleep duration associated with self-reported overall health, screen time, and nighttime texting among adolescents? J Int Med Res. 2020;48(3):300060519892399. https://doi.org/10.1177/0300060519892399

28. Mei X, Hu Z, Zhou D, et al. Sleep patterns, mobile phone use and psychological symptoms among adolescents in coastal developed city of China: an exploratory cross-sectional study. Sleep Biol Rhythms. 2019;17(2):233-41. https://doi.org/10.1007/s41105-019-00208-1

29. Li X-D, Tai J, Xu Z-F, Wang G-X, et al. Sleep duration and factors related to sleep loss in 3-14-year-old children in Beijing: a cross-sectional survey. Chin Med J (Engl). 2018;131(15):1799-807. https://doi.org/10.4103/0366-6999.237403

30. Widome R, Berger AT, Lenk KM, et al. Correlates of short sleep duration among adolescents. J Adolesc. 2019;77:163-7. https://doi.org/10.1016/j.adolescence.2019.10.011

31. Grover K, Pecor K, Malkowski M, et al. Effects of instant messaging on school performance in adolescents. J Child Neurol. 2016;31(7):850-7. https://doi.org/10.1177/0883073815624758

32. Seo WS, Sung H-M, Lee JH, et al. Sleep patterns and their age-related changes in elementary-school children. Sleep Med. 2010;11(6):569-75. https://doi.org/10.1016/j.sleep.2010.03.011

33. Hysing M, Pallesen S, Stormark KM, Jakobsen R, Lundervold AJ, Sivertsen B. Sleep and use of electronic devices in adolescence: results from a large population-based study. BMJ Open. 2015;5(1):e006748. https://doi.org/10.1136/bmjopen-2014-006748

34. Mireku MO, Barker MM, Mutz J, et al. Night-time screen-based media device use and adolescents' sleep and health-related quality of life. Environ Int. 2019;124:66-78. https://doi.org/10.1016/j.envint.2018.11.069

35. Munezawa T, Kaneita Y, Osaki Y, et al. The association between use of mobile phones after lights out and sleep disturbances among Japanese adolescents: a nationwide cross-sectional survey. Sleep. 2011;34(8):1013-20. https://doi.org/10.5665/SLEEP.1152

36. Orben A, Przybylski AK. Teenage sleep and technology engagement across the week. PeerJ. 2020;8:e8427. https://doi.org/10.7717/peerj.8427

37. Polos PG, Bhat S, Gupta D, et al. The impact of Sleep Time-Related Information and Communication Technology (STRICT) on sleep patterns and daytime functioning in American adolescents. J Adolesc. 2015;44:232-44. https://doi.org/10.1016/j.adolescence.2015.08.002

38. Seo J-H, Kim JH, Yang KI, Hong SB. Late use of electronic media and its association with sleep, depression, and suicidality among Korean adolescents. Sleep Med. 2017;29:76-80. https://doi.org/10.1016/j.sleep.2016.06.022

39. Jiang X, Hardy LL, Baur LA, Ding D, Wang L, Shi H. Sleep duration, schedule and quality among urban Chinese children and adolescents: associations with routine after-school activities. PLoS One. 2015;10(1):e0115326. https://doi.org/10.1371/journal.pone.0115326

40. Dube N, Khan K, Loehr S, Chu Y, Veugelers P. The use of entertainment and communication technologies before sleep could affect sleep and weight status: a population-based study among children. Int J Behav Nutr Phys Act. 2017;14(1):97. https://doi.org/10.1186/s12966-017-0547-2

41. Gamble AL, D'Rozario AL, Bartlett DJ, et al. Adolescent sleep patterns and night-time technology use: results of the Australian Broadcasting Corporation's Big Sleep Survey. PLoS One. 2014;9(11):e111700. https://doi.org/10.1371/journal.pone.0111700

42. Chahal H, Fung C, Kuhle S, Veugelers PJ. Availability and night-time use of electronic entertainment and communication devices are associated with short sleep duration and obesity among Canadian children. Pediatr Obes. 2013;8(1):42-51. https://doi.org/10.1111/j.2047-6310.2012.00085.x

43. Brambilla P, Giussani M, Pasinato A, et al.; "Ci piace sognare" Study Group. Sleep habits and pattern in 1–14 years old children and relationship with video devices use and evening and night child activities. Ital J Pediatr. 2017;43(1):7. https://doi.org/10.1186/s13052-016-0324-x

44. Continente X, Pérez A, Espelt A, López MJ. Media devices, family relationships and sleep patterns among adolescents in an urban area. Sleep Med. 2017;32:28-35. https://doi.org/10.1016/j.sleep.2016.04.006

45. Cespedes EM, Gillman MW, Kleinman K, Rifas-Shiman SL, Redline S, Taveras EM. Television viewing, bedroom television, and sleep duration from infancy to mid-childhood. Pediatrics. 2014;133(5):e1163-71. https://doi.org/10.1542/peds.2013-3998

46. Nuutinen T, Ray C, Roos E. Do computer use, TV viewing, and the presence of the media in the bedroom predict school-aged children's sleep habits in a longitudinal study? BMC Public Health. 2013;13(1):684. https://doi.org/10.1186/1471-2458-13-684

47. Garmy P, Nyberg P, Jakobsson U. Sleep and television and computer habits of Swedish school-age children. J Sch Nurs. 2012;28(6):469-76. https://doi.org/10.1177/1059840512444133

48. Cameron AJ, van Stralen MM, Brug J, et al. Television in the bedroom and increased body weight: potential explanations for their relationship among European schoolchildren. Pediatr Obes. 2013;8(2):130-41. https://doi.org/10.1111/j.2047-6310.2012.00094.x

49. Borghese MM, Tremblay MS, Katzmarzyk PT, et al. Mediating role of television time, diet patterns, physical activity and sleep duration in the association between television in the bedroom and adiposity in 10 year-old children. Int J Behav Nutr Phys Act. 2015;12(1):60. https://doi.org/10.1186/s12966-015-0221-5

50. de Jong E, Stocks T, Visscher TLS, HiraSing RA, Seidell JC, Renders CM. Association between sleep duration and overweight: the importance of parenting. Int J Obes. 2012;36(10):1278-84. https://doi.org/10.1038/ijo.2012.119

51. Garmy P, Clausson EK, Nyberg P, Jakobsson U. Insufficient sleep is associated with obesity and excessive screen time amongst ten-year-old children in Sweden. J Pediatr Nurs. 2018;39:e1-5. https://doi.org/10.1016/j.pedn.2017.11.009

52. Falbe J, Davison KK, Franckle RL, et al. Sleep duration, restfulness, and screens in the sleep environment. Pediatrics. 2015;135(2):e367-75. https://doi.org/10.1542/peds.2014-2306

53. Yilmaz K, Kilinçaslan A, Aydin N, Kul S. Understanding sleep habits and associated factors can help to improve sleep in high school adolescents. Turk J Pediatr. 2011;53(4):430-6.

54. Weaver E, Gradisar M, Dohnt H, Lovato N, Douglas P. The effect of presleep video-game playing on adolescent sleep. J Clin Sleep Med. 2010;6(2):184-9. https://doi.org/10.5664/jcsm.27769

55. Hartmann M, Pelzl MA, Kann PH, et al. The effects of prolonged single night session of videogaming on sleep and declarative memory. PLoS One. 2019;14(11):e0224893. https://doi.org/10.1371/journal.pone.0224893

56. Ivarsson M, Anderson M, Åkerstedt T, Lindblad F. The effect of violent and nonviolent video games on heart rate variability, sleep, and emotions in adolescents with different violent gaming habits. Psychosom Med. 2013;75(4):390-6. https://doi.org/10.1097/PSY.0b013e3182906a4c

57. Heath M, Sutherland C, Bartel K, et al. Does one hour of bright or short-wavelength filtered tablet screenlight have a meaningful effect on adolescents' pre-bedtime alertness, sleep, and daytime functioning? Chronobiol Int. 2014;31(4):496-505. https://doi.org/10.3109/07420528.2013.872121

58. Foerster M, Henneke A, Chetty-Mhlanga S, Röösli M. Impact of adolescents' screen time and nocturnal mobile phone-related awakenings on sleep and general health symptoms: a prospective cohort study. Int J Environ Res Public Health. 2019;16(3):E518. https://doi.org/10.3390/ijerph16030518

59. Vernon L, Modecki KL, Barber BL. Mobile phones in the bedroom: trajectories of sleep habits and subsequent adolescent psychosocial development. Child Dev. 2018;89(1):66-77. https://doi.org/10.1111/cdev.12836

60. Pieters D, De Valck E, Vandekerckhove M, et al. Effects of pre-sleep media use on sleep/wake patterns and daytime functioning among adolescents: the moderating role of parental control. Behav Sleep Med. 2014;12(6):427-43. https://doi.org/10.1080/15402002.2012.694381

61. Morrissey B, Allender S, Strugnell C. Dietary and activity factors influence poor sleep and the sleep-obesity nexus among children. Int J Environ Res Public Health. 2019;16(10):1778. https://doi.org/10.3390/ijerph16101778

62. Button KS, Ioannidis JP, Mokrysz C, et al. Power failure: why small sample size undermines the reliability of neuroscience. Nat Rev Neurosci. 2013;14(5):365-76. https://doi.org/10.1038/nrn3475

63. Sterne JA, Egger M, Smith GD. Systematic reviews in health care: investigating and dealing with publication and other biases in meta-analysis. BMJ. 2001;323(7304):101-5. https://doi.org/10.1136/bmj.323.7304.101

64. Nussbaumer-Streit B, Klerings I, Dobrescu AI, et al. Excluding non-English publications from evidence-syntheses did not change conclusions: a meta-epidemiological study. J Clin Epidemiol. 2020;118:42-54. https://doi.org/10.1016/j.jclinepi.2019.10.011