JAMA Pediatrics | Original Investigation

Association Between Portable Screen-Based Media Device Access or Use and Sleep Outcomes
A Systematic Review and Meta-analysis

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IMPORTANCE Sleep is vital to children's biopsychosocial development. Inadequate sleep quantity and quality is a public health concern with an array of detrimental health outcomes. Portable mobile and media devices have become a ubiquitous part of children's lives and may affect their sleep duration and quality.

OBJECTIVE To conduct a systematic review and meta-analysis to examine whether there is an association between portable screen-based media device (eg, cell phones and tablet devices) access or use in the sleep environment and sleep outcomes.

DATA SOURCES A search strategy consisting of gray literature and 24 Medical Subject Headings was developed in Ovid MEDLINE and adapted for other databases between January 1, 2011, and June 15, 2015. Searches of the published literature were conducted across 12 databases. No language restriction was applied.

STUDY SELECTION The analysis included randomized clinical trials, cohort studies, and cross-sectional study designs. Inclusion criteria were studies of school-age children between 6 and 19 years. Exclusion criteria were studies of stationary exposures, such as televisions or desktop or personal computers, or studies investigating electromagnetic radiation.

DATA EXTRACTION AND SYNTHESIS Of 467 studies identified, 20 cross-sectional studies were assessed for methodological quality. Two reviewers independently extracted data.

MAIN OUTCOMES AND MEASURES The primary outcomes were inadequate sleep quantity, poor sleep quality, and excessive daytime sleepiness, studied according to an a priori protocol.

RESULTS Twenty studies were included, and their quality was assessed. The studies involved 125 198 children (mean [SD] age, 14.5 [2.2] years; 50.1% male). There was a strong and consistent association between bedtime media device use and inadequate sleep quantity (odds ratio [OR], 2.17; 95% CI, 1.42-3.32) ($P < .001$, $I^2 = 90\%$), poor sleep quality (OR, 1.46; 95% CI, 1.14-1.88) ($P = .003$, $I^2 = 76\%$), and excessive daytime sleepiness (OR, 2.72; 95% CI, 1.32-5.61) ($P = .007$, $I^2 = 50\%$). In addition, children who had access to (but did not use) media devices at night were more likely to have inadequate sleep quantity (OR, 1.79; 95% CI, 1.39-2.31) ($P < .001$, $I^2 = 64\%$), poor sleep quality (OR, 1.53; 95% CI, 1.11-2.10) ($P = .009$, $I^2 = 74\%$), and excessive daytime sleepiness (OR, 2.27; 95% CI, 1.54-3.35) ($P < .001$, $I^2 = 24\%$).

CONCLUSIONS AND RELEVANCE To date, this study is the first systematic review and meta-analysis of the association of access to and the use of media devices with sleep outcomes. Bedtime access to and use of a media device were significantly associated with the following: inadequate sleep quantity, poor sleep quality, and excessive daytime sleepiness. An integrated approach among teachers, health care professionals, and parents is required to minimize device access at bedtime, and future research is needed to evaluate the influence of the devices on sleep hygiene and outcomes.

JAMA Pediatr. 2016;170(12):1202-1208. doi:10.1001/jamapediatrics.2016.2341
Published online October 31, 2016.

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Sleep is crucial to the development of physically and psychologically healthy children. Sleep disturbance in childhood is known to lead to adverse physical and mental health consequences. Short- and long-term detrimental health outcomes include poor diet, sedentary behavior, obesity, reduced immunity, stunted growth, mental health issues (eg, depression and suicidal tendencies), and substance abuse.[1-3]

Despite its importance to health, insufficient sleep and resultant daytime sleepiness are prevalent among the pediatric population and increase throughout adolescence.[4,5] In the United States, 75% of those 17 to 18 years old report insufficient sleep, which is consistent with the findings in other developed countries.[6] The American Academy of Pediatrics has highlighted factors, including electronic media device use, early school start times, and increase in caffeine consumption, that contribute substantially to this trend of insufficient and deteriorating sleep in the pediatric population.[4,5]

Studies[7,8] during the past decade have demonstrated that the use of conventional electronic devices, such as televisions, gaming consoles, and computers, negatively affects sleep. Newer portable mobile and media devices, including smartphones and tablet devices with broader capabilities (eg, internet and social networking), provide a different type of exposure because they allow real-time interaction and therefore continuous stimulation for children, unlike older stationary devices.[8] Herein, these newer portable screen-based mobile and media devices are termed *media devices*.

The presence of media devices is almost ubiquitous among children: 72% of all children and 89% of adolescents have at least 1 device in their sleep environment, with most used near bedtime.[3,6] Such devices are hypothesized to adversely affect sleep through various pathways.[7,8] First, they may negatively influence sleep by directly displacing, delaying, or interrupting sleep time. Second, the content can be psychologically stimulating, and, third, the light emitted from devices affects circadian timing, physiological sleep, and alertness.[9] However, the association between media device use and poor sleep outcomes has been underexplored because the speed at which these devices have been developed has outpaced research capabilities.[8,9] A previous literature review[8] reported a suspected association between screen time and poor sleep outcomes and stimulated debate to assess the quality of evidence and quantify the magnitude of the potential relationship.[7] To our knowledge, we present the first systematic review to quantify the influence of media device use on sleep outcomes in a meta-analysis.

Key Points

Question Is there an association between screen-based media device access or use in the sleep environment, and sleep quantity and quality?

Findings A systematic review and meta-analysis showed strong and consistent evidence of an association between access to or the use of devices and reduced sleep quantity and quality, as well as increased daytime sleepiness.

Meaning An integrated approach among teachers, health care professionals, and parents is needed to improve sleep hygiene.

Methods

Study Selection

This study was conducted following Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines[10] and was performed according to an a priori protocol. All experimental and observational study designs, in any language, published between January 1, 2011, and June 15, 2015, were included. The time frame was selected to reflect the interactive nature of media devices now used. The inclusion criteria were studies of children and adolescents of school age between 6 and 19 years. The exclusion criteria were studies of stationary exposures, such as televisions or desktop or personal computers, or studies investigating electromagnetic radiation.

Data Sources and Search Strategy

A search strategy consisting of 24 Medical Subject Headings was developed in Ovid MEDLINE and adapted for other databases (eTable 1 in the Supplement). On June 15, 2015, searches of the published literature were conducted across 12 databases, including the British Education Index, Cumulative Index to Nursing and Allied Health database, Cochrane Library, Educational Resources Information Center, International Biography of Social Sciences, Ovid MEDLINE (EMBASE, MEDLINE, and PsycINFO), PubMed, Science Direct, Scopus, and Web of Science. The gray literature was searched using the OpenGrey online database. Bibliographies of included studies and conference abstracts were hand searched, and authors of included studies were contacted to identify any ongoing or unpublished studies.

Device Exposure Categories and Sleep Outcomes

Cohorts of children with access to media devices less than 3 times a week were combined with children who had no media device access and were categorized as having no access to a media device. Children with bedtime access to a media device at least 3 times a week were categorized as having access to a media device. Children who used media devices around bedtime were categorized as those who used a media device. Outcomes were the proportion of children who experienced inadequate sleep quantity (defined as <10 hours of daily sleep for children and <9 hours of daily sleep for adolescents[5,11,12]), poor sleep quality (defined as frequent difficulty in sleep initiation or sleep maintenance or nonrefreshing sleep[13]), and excessive daytime sleepiness (defined as poor daytime functioning as a result of both sleep quantity and quality[14]).

Study Screening and Quality Assessment

Titles and abstracts identified from searches were screened for relevance, and duplicates were excluded. The full texts of all relevant articles were retrieved, and their eligibility for inclusion was assessed. Two reviewers (D.B. and M.S.P.) independently assessed the methodological quality of all full-text articles, and discrepancies were resolved by a third reviewer (B.C.). The quality assessment tool consisted of 13 domains that

appraised the overall evidence of a study.[15] Each domain was determined as having a low risk of bias (RoB), an unclear RoB, or a high RoB. If a study had all domains with a low RoB, it was assessed as being of good quality. If a study had at least 1 domain with a high RoB, it was assessed as being of low quality. Alternatively, if a study was assessed as having a combination of low and unclear RoB domains, it was determined to be of unclear quality. Methodologically flawed studies were excluded, and the reasons for exclusion were stated. A Grading of Recommendations, Assessment, Development and Evaluation (GRADE) was performed on all findings.[16]

Data Extraction

Two reviewers (P.R. and M.S.P.) independently extracted data, and a third reviewer (B.C.) resolved discrepancies. Study authors were contacted if incomplete data had been reported and to provide aggregate or individual participant data (IPD).

Measures of Association Between Media Device Use and Sleep

Included studies measured the association between exposure to a media device and the influence on sleep using either linear regression slopes (β), correlation coefficients (*r*), or odds ratios (ORs). To ensure consistency in interpretation, only studies that reported dichotomous data or logistic regression analyses were pooled in a meta-analysis.

Data Synthesis

If study designs, populations, interventions, and outcomes were deemed to be clinically homogeneous, the data were pooled in a random-effects meta-analysis using the Mantel-Haenszel method.[17,18] If dichotomous data were not available but study analyses were reported, the analysis data were pooled with the dichotomous data using a generalized inverse variance approach.[19] If IPD were available and considered to have external validity, a logistic regression model was fitted, accounting for the study as the random effect, and adjusted for participant age.[20]

Assessment of Subgroups and Statistical Heterogeneity

Statistical heterogeneity was assessed using the I^2 statistic. Heterogeneity exceeding 85% was explored using subgroup analyses.[19] All meta-analysis data were presented as OR with the associated 95% CIs, *P* values, and I^2 summary data. Prespecified subgroups to explore heterogeneity included quality assessment (high-quality vs unclear and low-quality studies), age of children (6-11, 12-15, and 16-18 years), and type of media device (cell phone vs tablet).

Results

Identified Studies and Quality Assessment

A total of 467 studies were identified, and 69 full texts were reviewed, leading to 49 being excluded (**Figure 1**). Of 20 studies involving 125 198 children (mean [SD] age, 14.5 [2.2] years; range, 6-18 years; 50.1% male) that were assessed for methodological quality, 17 were included, with 3 excluded because of poor methods conduct or reporting[21-23] (eTable 2 in the Supplement). Two studies[13,24] were of good quality, 6 studies[3,25-29] were of low quality, and 9 studies[30-38] were of unclear quality (eTable 2 in the Supplement).

Characteristics of Included Studies

Included studies were conducted in Europe (n = 7),[13,27,28,30,33,35,38] North America (n = 4),[3,25,26,31] Asia (n = 3),[24,36,37] and Australasia (n = 3),[29,32,34] (eTable 3 in the Supplement). Six studies[13,24,26,27,30,33] assessed the association between media device use and sleep during weekday periods only. Five studies[3,25,28,32,34] assessed sleep separately on weekdays and weekends, and 6 studies[29,31,35-38] aggregated weekly data.

Media Device Exposure Categories

Media device investigations were categorized into 2 exposure groups, namely, studies[3,13,24,27,28,30-33,35,37,38] that reported bedtime media device use and studies[3,25-27,31,32,35] that described children who had access to (but did not use) media devices at night. One study[36] presented data on the use of media devices throughout the entire day, which is not reported herein. Individual study results grouped by device exposure category are listed in eTable 4 in the Supplement.

Bedtime Media Device Use Compared With Not Having Access to a Device

We identified 12 studies that investigated the use of media devices near bedtime (eTable 4 in the Supplement). Eight studies reported that bedtime media device use was significantly associated with inadequate sleep quantity ($P < .05$). Seven of the studies reported an association between bedtime media device use and poor sleep quality ($P < .05$), and 1 study[35] reported that bedtime media device use was associated with improved sleep quality. Four studies that presented data on excess daytime sleepiness demonstrated statistically significant results ($P < .05$).

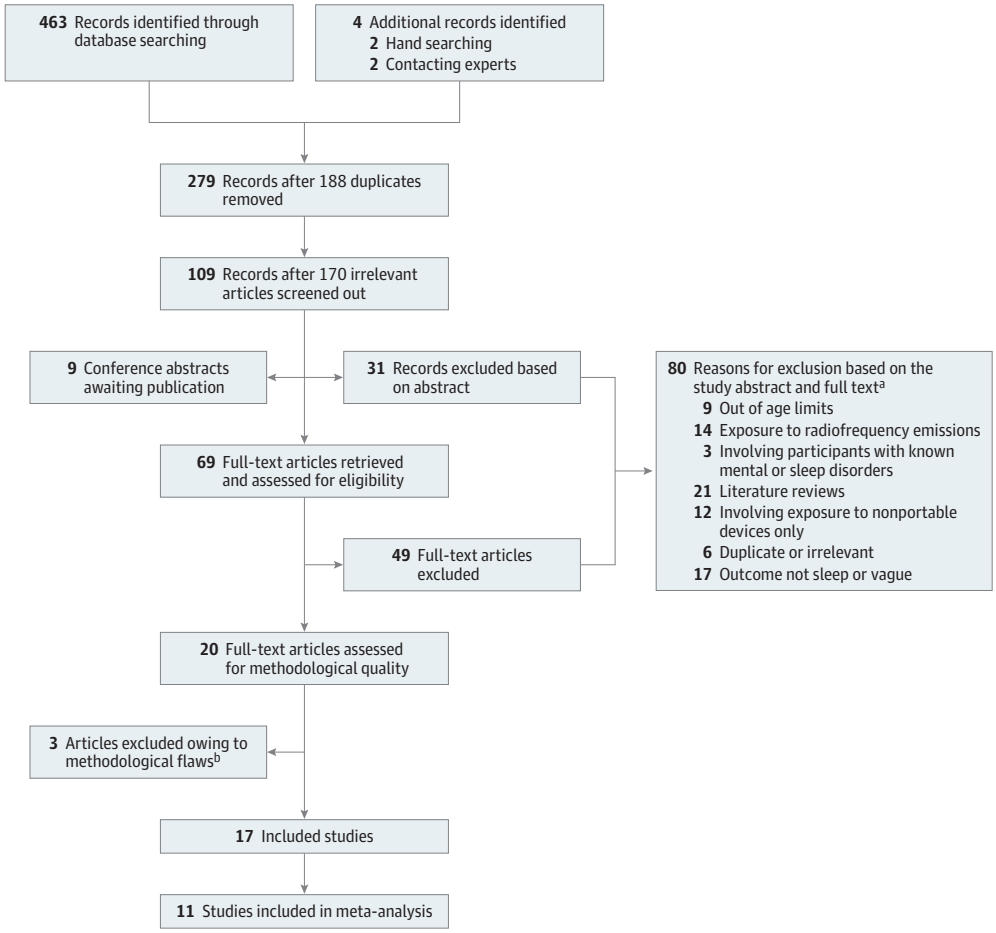
Inadequate Sleep Quantity

In 7 studies,[3,13,27,30-32,35] the prevalences of inadequate sleep quantity among the 2 groups were 45.4% (children having bedtime media device use) and 31.5% (children not having access to a device). The pooled OR was 2.17 (95% CI, 1.42-3.32) ($P < .001$, $I^2 = 90\%$) (**Figure 2**). The large heterogeneity was due to the study by Chahal et al,[31] which recruited only 10-year-old and 11-year-old children. After that study was excluded, the OR was 2.52 (95% CI, 1.79-3.55) ($P < .001$, $I^2 = 72\%$). Two studies[3,27] were included in an IPD meta-analysis, and the age-adjusted OR (aOR) was 3.06 (95% CI, 2.01-4.70) ($P < .001$).

Poor Sleep Quality

Five studies[3,13,27,32,35] reported dichotomous data on poor sleep quality, and the prevalences of poor sleep quality among the 2 groups were 52.1% (children having bedtime media device use) and 34.4% (children not having access to a device). Two additional studies[27,35] reported the OR from a logistic regression. The pooled OR was 1.46 (95% CI, 1.14-1.88) ($P = .003$, $I^2 = 76\%$) (**Figure 3**). There was an increased odds of poor sleep quality in those who used a media device near bedtime. The IPD meta-analysis aOR was 1.92 (95% CI, 1.27-2.90) ($P = .002$) from 2 studies.[3,27]

Figure 1. PRISMA Flowchart of the Searched, Identified, and Included Studies

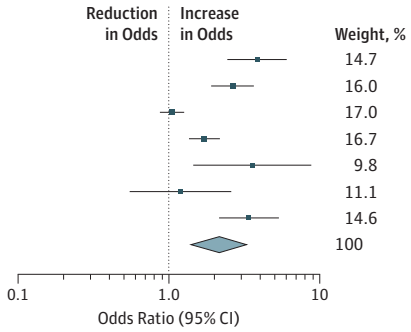


PRISMA indicates Preferred Reporting Items for Systematic Reviews and Meta-analyses.
[a]Some studies satisfied more than 1 criteria.
[b]Further details are listed in eTable 1 in the Supplement.

Figure 2. Children With Inadequate Sleep Quantity

Source	Device Users Near Bedtime: No. of Events	Device Users Near Bedtime: Total No.	No Access to a Device: No. of Events	No Access to a Device: Total No.	Odds Ratio (95% CI)
Arora et al,[30] 2013	185	289	38	120	3.84 (2.44-6.04)
Arora et al,[13] 2014	199	440	71	298	2.64 (1.91-3.66)
Chahal et al,[31] 2013	207	611	914	2785	1.05 (0.87-1.26)
Gamble et al,[32] 2014	252	555	205	629	1.72 (1.36-2.18)
Gradisar et al,[3] 2013	116	181	8	24	3.57 (1.45-8.79)
Kubiszewski et al,[35] 2013	41	141	11	43	1.19 (0.55-2.59)
Lemola et al,[27] 2015	88	180	40	182	3.40 (2.15-5.36)
Total events	1088	2397	1287	4081	2.17 (1.42-3.32)

Heterogeneity: $\tau^2 = 0.27$; $\chi^2_6 = 57.48$; $P<.001$; $I^2 = 90\%$
Test for overall effect: $z = 3.57$; $P<.001$



We compared children having bedtime media device use with children not having access to a device.

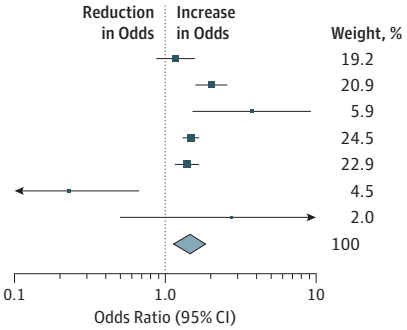
Excessive Daytime Sleepiness

Two studies[3,32] reported dichotomous data on excess daytime sleepiness, and the prevalences were 21.3% (children having bedtime media device use) and 6.7% (children not having access to a device). The pooled OR was 2.72 (95% CI, 1.32-5.61) (P = .007, I^2 = 50%) (eFigure 1 in the Supplement). There

Figure 3. Children With Poor Sleep Quality

Source	Log Odds Ratio	SE	Device Users Near Bedtime, Total No.	No Access to a Device, Total No.	Odds Ratio (95% CI)
Arora et al,[13] 2014	0.157	0.150	440	298	1.17 (0.87-1.57)
Gamble et al,[32] 2014	0.703	0.125	555	629	2.02 (1.58-2.58)
Gradisar et al,[3] 2013	1.319	0.462	181	24	3.74 (1.51-9.24)
Hysing et al,[33] 2015	0.392	0.065	0	0	1.48 (1.30-1.68)
Jiang et al,[24] 2015	0.329	0.094	0	0	1.39 (1.16-1.67)
Kubiszewski et al,[35] 2013	-1.470	0.546	141	43	0.23 (0.08-0.67)
Lemola et al,[27] 2015	1.008	0.867	180	182	2.74 (0.50-15.00)
Total events			1497	1176	1.46 (1.14-1.88)

Heterogeneity: $\tau^2 = 0.06$; $\chi^2_6 = 25.30$; $P<.001$; $I^2 = 76\%$
Test for overall effect: $z = 2.98$; $P = .003$

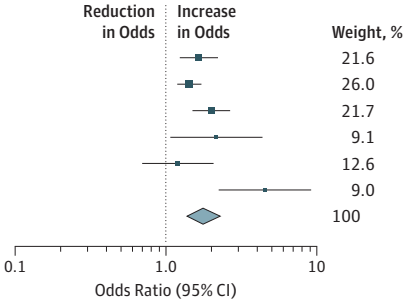


We compared children having bedtime media device use with children not having access to a device. The number of participants was not provided by Hysing et al[33] or Jiang et al[24]; only the results from the statistical analysis were reported.

Figure 4. Alternate Comparison of Children With Inadequate Sleep Quantity

Source	Access to a Device: No. of Events	Access to a Device: Total No.	No Access to a Device: No. of Events	No Access to a Device: Total No.	Odds Ratio (95% CI)
Buxton et al,[25] 2015	108	238	289	865	1.66 (1.24-2.22)
Chahal et al,[31] 2013	229	577	888	2819	1.43 (1.19-1.72)
Gamble et al,[32] 2014	376	884	81	300	2.00 (1.50-2.67)
Gradisar et al,[3] 2013	45	61	52	92	2.16 (1.07-4.37)
Kubiszewski et al,[35] 2013	55	221	24	111	1.20 (0.70-2.07)
Lemola et al,[27] 2015	118	287	10	75	4.54 (2.24-9.19)
Total events	931	2268	1344	4262	1.79 (1.39-2.31)

Heterogeneity: $\tau^2 = 0.06$; $\chi^2_5 = 13.77$; $P = .02$; $I^2 = 64\%$
Test for overall effect: $z = 4.51$; $P<.001$



We compared children having access to a bedtime media device with children not having access to a device.

was an increased odds of excessive daytime sleepiness among children who used a media device near bedtime.

Having Access to a Media Device Compared With Not Having Access to a Device

Most studies reported statistically significant evidence of an association between the presence of a media device in the sleep environment near bedtime and inadequate sleep quantity (6 of 7 studies), poor sleep quality (4 of 6 studies), and excessive daytime sleepiness (3 of 4 studies). These results are summarized in eTable 4 in the Supplement.

Inadequate Sleep Quantity

There were data from 6 studies[3,25,27,31,32,35] that investigated inadequate sleep quantity, and the prevalences were 41.0% (children having access to a bedtime media device) and 31.5% (children not having access to a device). The OR was 1.79 (95% CI, 1.39-2.31) ($P < .001$, $I^2 = 64\%$) (**Figure 4**). There was an increased odds of inadequate sleep quantity among children who had access to a media device near bedtime. The IPD meta-analysis aOR was 1.88 (95% CI, 1.46-2.42) ($P < .001$) from 2 studies.[3,27]

Poor Sleep Quality

Dichotomous data were available from 4 studies[3,25,27,32] that investigated poor sleep quality, and the prevalences were 44% (children having access to a bedtime media device) and 32.4% (children not having access to a device). The OR was extracted from 2 studies.[26,35] The pooled OR for poor sleep quality was 1.53 (95% CI, 1.11-2.10) ($P = .009$, $I^2 = 74\%$) (eFigure 2 in the Supplement). There was an increased odds of poor sleep quality in children who had access to a media device in the sleep environment near bedtime.

Excessive Daytime Sleepiness

Dichotomous data were available from 3 studies[3,25,32] that investigated excessive daytime sleepiness, and the prevalences were 13.2% (children having access to a bedtime media device) and 4.9% (children not having access to a device). The OR was extracted from an additional study.[35] The pooled OR for excessive daytime sleepiness was 2.27 (95% CI, 1.54-3.35) ($P < .001$, $I^2 = 24\%$) (eFigure 3 in the Supplement). There was an increased odds of excessive daytime sleepiness in children who had access to a media device in the sleep environment near bedtime.

Subgroup Analyses

There were no subgroup associations found owing to the quality of included studies or type of media device. Similarly, there was no subgroup association for the age of the children, although most were between 10 and 18 years old.

GRADE Assessment

The GRADE assessment of included studies was low because of their nonrandomized nature. The assessment of the findings was upgraded owing to the large effect sizes found but was downgraded because of the substantial heterogeneity. Therefore, the level of evidence is low, meaning that the results may change on publication of further evidence.

Discussion

Summary of the Findings

To our knowledge, this study is the first systematic review and meta-analysis to quantify the association of media device access and use with children's sleep. We found that bedtime device use was associated with an increase in the odds of inadequate sleep quantity, poor sleep quality, and excessive daytime sleepiness. Media device presence in the bedroom (even without use) was also associated with an increased odds of detrimental sleep outcomes.

This study is the first systematic review and meta-analysis to date to include a robust quality assessment that quantified the association of media device access and use with poor sleep outcomes.[8] Our study provides supporting evidence for an interaction between media device use and psychophysiological arousal as a key mechanism of effect.[33] Our findings support recommendations that interventions should be developed and evaluated to reduce media device access and use at bedtime. Specifically, we support age-specific guidance for media device access and use[33] and parent-led initiatives to reduce device access and use in collaboration with teachers and health care professionals.[39]

These findings herein support current clinical opinion that media device access and use result in poor sleep outcomes. The limitations of research in this area include measurement error of self-reported data, difficulty in ascertaining causality, isolation of the influences of specific exposures, technological devices outpacing research, and weaknesses inherent to observational study designs. Substantial heterogeneity was found in many of the meta-analyses and is likely a reflection of the included nonrandomized studies. Therefore, a degree of caution is needed when interpreting these findings.

Implications for Policy and Practice

The deleterious association between screen-based media use and sleep in children and adolescents is a major public health concern. Given the evolving technological landscape and the replacement of textbooks with media devices in schools, screen-based media device access and use are likely to rise. It is imperative that teachers, health care professionals, parents, and children are educated about the damaging influence of device use on sleep. Policy-led population-level health promotion to not stigmatize individual children but guide communities to promote the importance of sleep hygiene is needed. In addition, we encourage screening of children during routine clinical visits (by health visitors, school nurses, or family physicians) to identify those with inadequate sleep to explore device use as a potential cause and target sleep hygiene promotion.

Implications for Research

Multidisciplinary interventions to improve sleep hygiene have been investigated[40,41]; however, pragmatic studies are needed to understand the mechanism of action and causal pathway between device use and sleep using objective data collection methods. Interventions could be delivered by family physicians as a part of routine care for those seen with health concerns and by teachers who introduce devices into education.[41] Device technologists should investigate software and parent-led interventions, such as automatic time switches to restrict access to media devices near bedtime. Interventions and policies must be developed, evaluated, and implemented at the population level to raise awareness of the potential health hazard to improve sleep hygiene through an integrated approach involving teachers, health care professionals, and parents.

Conclusions

Media device access and use at bedtime are significantly associated with detrimental sleep outcomes and lead to poor health outcomes. We recommend that interventions to minimize device access and use need to be developed and evaluated. Interventions should include a multidisciplinary approach from teachers and health care professionals to empower parents to minimize the deleterious influence on child health.

ARTICLE INFORMATION

Accepted for Publication: June 20, 2016.

Published Online: October 31, 2016. doi:10.1001/jamapediatrics.2016.2341

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Author Contributions: Dr Carter had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Carter, Paradkar.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Carter, Rees.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Carter, Paradkar.
Obtained funding: Hale.

Administrative, technical, or material support: Carter, Rees, Bhattacharjee, Paradkar.
Study supervision: Carter, Paradkar.

Conflict of Interest Disclosures: None reported.

Funding/Support: This research is funded in part by grant R01HD073352 from the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (Dr Hale).

Role of the Funder/Sponsor: The funding source had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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