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ORIGINAL RESEARCH

Substituting Book Reading for Screen Time Benefits Preschoolers' Sleep Health: Results from the Ulm SPATZ Health Study

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Purpose: Healthy sleep is essential for the physical, cognitive, and social development of children. Several studies have reported the increase in digital media use in preschool children and its association with impaired sleep. However, there is relatively little evidence on the effects of book reading as a potentially safe alternative. The objective of this study, therefore, was to investigate whether sleep in children could benefit from book reading, and whether the negative effects of media use on sleep can be mitigated by substituting book reading for screen time.

Participants and Methods: We used longitudinal data from three consecutive waves of the SPATZ Health study, including children at the ages of 4 (n=581), 5 (n=508), and 6 (n=426) years. All data were collected by self-administered questionnaires. Parent-reported child sleep was assessed by the Children's Sleep Habits Questionnaire.

Results: Across the three waves, screen-based media use increased and was associated with lower sleep quality. In contrast, the time spent with book reading decreased; however, book reading appeared to be beneficial for children's sleep. Substitution models revealed that the theoretical substitution of an equal amount of book reading for 50% of the time spent with screen-based media benefits several domains of preschoolers' sleep health, including parasomnias, sleep anxiety, daytime sleepiness, and sleep onset delay.

Conclusion: Besides implications for population-wide and individual prevention, book reading may also be incorporated as a useful intervention to improve sleep quality in children who are already affected by sleep problems. Given that book reading is perceived as a safe alternative, the presented evidence may suffice to support recommendations in this direction.

Keywords: digital media, paper book, sleep health, sleep quality, children, preschoolers

Introduction

Healthy sleep is crucial for mental and physical health and well-being at all ages, including childhood.[1,2] Unfortunately, sleep problems are well documented in children, affecting 15–50% of children.[3–5] In European children, the prevalence of sleep problems seems comparable to that observed in the USA and China.[6–8] This has resulted in several calls to act now and early in life, eg by promoting sleep health, including regular sleep assessment, in primary care, similarly to other vital signs, and by encouraging the use of wearable devices and mobile applications to evaluate and monitor sleep behavior.[5]

Children's sleep health is influenced by many factors, including bedtime being determined by parents, early school starting times,[9,10] feeding practices,[11] and family socioeconomic status.[12,13] Among the modifiable factors, media use continues to spike interest,[14,15] probably owing to its inevitable presence in our modern societies or its wide-ranging potential benefits and negative consequences.[16] Here, screen-based media (eg TV, tablet, smartphone, e-book) need to be distinguished from paper book reading, since there seem to be antagonistic effects regarding sleep behavior in children.[17–19] For instance, whereas sleep (eg sleep onset, subjective sleepiness, sleep duration) has shown to be impaired in children watching TV or reading an e-book before bedtime, reading a paper book appeared to be beneficial. In general, there is relatively little evidence about the effects of

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book reading on sleep health;[20] on the other hand, associations between screen-based media and sleep problems in children are widely reported.[21]

Suggested explanations for these associations include 1) displacement of sleep with media use,[22,23] although some work shows a mere shift of sleep phase rather than shorter sleep duration,[24] and displacement of daytime sleep in preschoolers may induce more consolidated night-time sleep;[25] 2) melatonin suppression by blue light emission from screens;[26] and 3) arousal linked to content,[27] to lack of parental involvement in the activity,[28] or to dysfunctional bedtime routines.[20]

From a public health perspective, these consistently shown negative associations of screen-based media consumption with sleep are alarming, especially given that such consumption is becoming more and more common among preschoolers.[29,30] In fact, screen time competes with other activities, such as book reading, for available time. Consistent with this, a recent longitudinal study[31] reported a reciprocal relationship between early screen use and book reading. More specifically, higher screen use at 24 months was associated with lower print book reading at 36 months, which itself was positively associated with higher screen use at 60 months. Findings from randomized trials regarding healthy media use suggest potential causal relations between screen-based media and sleep problems, and between book reading and improved sleep,[27,32] raising the question of whether substituting one with the other might change sleep behavior. In this explorative observational study, we therefore aimed to investigate whether theoretically substituting book reading for screen-based media use could benefit sleep health in preschool children. This was done for the entire week and separately for weekdays and the weekend owing to previously documented differential exposure during these periods.[17] Given the small number of studies on book reading and its association with sleep in children, we further aimed to describe trajectories of book reading and screen-based media use over age, followed by an investigation into their association with sleep quality.

Materials and Methods

Data Collection

The Ulm SPATZ Health Study is a prospective birth cohort study based on 1006 children consecutively recruited from the general population following their birth in Ulm University Medical Center, southern Germany, from April 2012 to May 2013.[33]

All data used in this analysis were collected via self-administered questionnaires shortly after delivery and consecutively at every birthday of the child. The present comparisons were defined post hoc and based on data from study waves when the children were aged 4 (n=581), 5 (n=508), and 6 (n=426) years, when data on screen-based media use and sleep were ascertained. Participation was voluntary, all families gave written informed consent in accordance with the Declaration of Helsinki, and the ethics board of Ulm University approved the study (no. 311/11).

Parents reported the time that their children spent with screen-based media use separately for weekdays and weekends (categorically in hours/day: never, up to 1, 1 to <2, 2 to <3, 3 to <4, ≥4; separately for watching TV (also on a computer or smartphone) or DVD, for video gaming (also on a smartphone), and for internet use via a computer or smartphone). Screen-based media use was computed by summing up these different activities in a single variable. Self or parent-assisted book reading was assessed on the same time spacing scale. All analyses for the whole week were performed using a weighted time averaged variable (weekdays with a weight of 5, weekends with a weight of 2). Supplementary analyses were performed for screen-based media use and book reading during the weekdays and at the weekends, separately.

The German, validated version of the Children's Sleep Habits Questionnaire (CSHQ) was used to assess parent-reported child sleep quality during a typical week.[34,35] The CSHQ is a multidimensional questionnaire scored on a three-level Likert scale assigned 1–3 points, with 3 being the most adverse characteristic. It investigates eight sleep quality domains with summation of single item scores into a subscale score: "bedtime resistance" (6–18 points), "sleep onset delay" (1–3 points), "sleep duration" (3–9 points), "sleep anxiety" (4–12 points), "night waking" (3–9 points), "parasomnias" (6–18 points), "sleep-disordered breathing" (3–9 points), and "daytime sleepiness" (8–24 points). The total CSHQ score was computed as the sum of all 34 CSHQ items, resulting in a score ranging between 34 and 102 points, with higher values representing lower sleep quality. A total CSHQ score of ≥41 indicates a pediatric sleep problem, as this cut-off correctly identified 80% of children with a previously diagnosed sleep disorder.[34] The German CSHQ[35], comparable with the English version,[34] shows an internal consistency of α=0.68 and a retest reliability of r=0.76. Subscales of the English version have been confirmed to have internal

consistencies of α=0.70 (bedtime resistance), α=0.70 (sleep duration), α=0.55 (sleep anxiety), α=0.49 (night waking), α=0.36 (parasomnias), α=0.23 (sleep-disordered breathing), and α=0.63 (daytime sleepiness).[35]

Statistical Analysis

Screen-based media use, book reading, and sleep quality total and subscale scores were described using the median and 5th and 95th percentiles for each time point. The trend over observational time was analyzed for all children as well as stratified by sex, using a non-parametric kernel regression approach, with the non-parametric R^2 coefficient of determination and a non-parametric test on the slope;[36] this can be interpreted in the same way as the R^2 from an ordinary least square regression. Sex-specific analyses were performed based on recent findings, which showed that sleep-related difficulties seem to differ between male and female children.[8]

We investigated the relationships between screen-based media use and book reading and the total CSHQ score and subscale scores using iso-time partition and substitution models, a methodology adapted from behavioral epidemiology.[37–39] In brief, iso-time partition analysis is based on a linear regression model in which the total time spent on entertainment by the child is partitioned into the different components contributing to it; in this case, screen-based media use and book reading coded in units of one hour. In this approach, the regression slope parameter corresponds to a theoretical hour increase in time spent in one activity (eg book reading) when the time spent in the other (eg screen-based media use) remains constant.

In the iso-time substitution model, the ratio between the time spent in a single activity (eg book reading) and the total time spent on entertainment is an explanatory variable in linear models with the CSHQ total or subscale scores as outcomes. The sum of the activities will result in a fixed numerical value (100%, given as a percentage). For an iso-time substitution model, the slope parameter for a given component will correspond to its theoretical substitution by one unit (50% in our analyses), with the excluded component as the reference category. The results of the partition and substitution model analyses are mutually adjusted for the activities included.

For the outcomes, first, we applied sex-specific Blom's transformation to the CSHQ total and subscale scores to obtain normalized *Z*-scores.[8] Here, the model has a continuous outcome with a standardized normal distribution, so that estimates are in the metric of Cohen's standardized effect sizes. Thus, the value of "1" corresponds to an effect size of one standard deviation, and the ranges of 0–0.2, 0.2–0.5, and above 0.8 are typically interpreted as small, medium, and large effect sizes, respectively. Second, we applied logistic regression models to dichotomized single CSHQ items (scores ≥2 vs 1, meaning the two most adverse scores vs the least adverse). This was done to investigate whether particular aspects, in addition to the more general total and subscale scores, are affected by substituting book reading for screen-based media use. Moreover, we wanted to provide the results in a different metric (odds ratios), which can be easily translated by clinicians into their patients' individual risk reduction. All analyses were based on random intercept mixed models with an unstructured covariance matrix for repeated measures, adjusted for observational time, sex, maternal age, and maternal education.

Analyses were performed using the lme4 package of the R software version 3.6. The lmer and glmer functions, based on a Gaussian distribution with identity link and a binomial distribution with logit link, were used for the analyses. Our aim was to explore the beneficial effect size of substituting book reading for screen-based media use, rather than testing their known associations with sleep health; thus, we do not present *p*-values and we did not correct for multiple testing.

Results

Full information on screen-based media use, book reading, CSHQ total and subscale scores, and covariates resulted in 1515 records collected over the three included SPATZ waves. The sex of the children was balanced at each study wave. Maternal age ranged between 24.8 and 58.3 years, with a median of 36.9 years, when the children were 4 years old. Among all mothers, 70% were highly educated, holding at least a high school degree, and almost all held German nationality. As such, the sample is representative of the geographical area (Southern Germany) in which SPATZ was conducted.

We found limited variability of screen-based media use, book reading, and sleep quality across the three waves, with observational time explaining only up to 2% of the variance in the non-parametric regression models (Table 1). Overall, we observed only slight changes in the median use of screen-based devices per day (4 years=30 min, 5 years=39 min, 6 years=39 min) and book reading (4 years=60 min, 5 years=60 min, 6 years=51 min). When looking at both sexes separately, boys

increased their screen-based media use from 30 min to 39 min per day during the three waves of the SPATZ study. In girls, a similar result was observed, with screen-based media use increasing from 34 min to 39 min per day. In contrast, book reading decreased over the observational time: in boys from 60 min to 51 min per day and in girls from 60 min to 54 min per day. Descriptive statistics for screen-based media use, book reading, and total CSHQ score and its subscales, at 4, 5, and 6 years of age are reported in Table 1.

In the partition analyses (Figure 1), an exposure to one hour of screen-based media use was associated with impaired child sleep (ie higher score), while book reading appeared to be neutral to slightly beneficial. For instance, small standardized effect sizes for an exposure of one hour to screen-based media use were observed for the CSHQ total score

Table 1 Media Use, Book Reading, Total CSHQ Score, and CSHQ Subscales for the Total SPATZ Sample and by Sex at Different Ages

Total Sample	**Age 4 (n=581)**	**Age 5 (n=508)**	**Age 6 (n=426)**	**R^2 (%)**
Media use (min per day)	30 (0, 120)	39 (3, 129)	39 (0, 150)	0.3
Book reading (min per day)	60 (12, 145)	51 (12, 129)	51 (12, 144)	0.4
Total CSHQ score	43 (36, 56)	43 (35, 55)	42 (35, 54)	<0.1
Daytime sleepiness	11 (8, 17)	11 (8, 17)	11.5 (8, 17)	0.2
Sleep-disordered breathing	3 (3, 4)	3 (3, 4)	3 (3, 4)	<0.1
Parasomnias	7 (6, 10)	7 (6, 10)	7 (6, 10)	0.2
Night waking	4 (3, 7)	4 (3, 7)	3 (3, 7)	1.6
Sleep anxiety	6 (4, 9.2)	5 (4, 9)	5 (4, 9)	0.5
Sleep duration	3 (3, 6)	3 (3, 6)	3 (3, 6)	0.3
Sleep onset delay	1 (1, 2)	1 (1, 2)	1 (1, 3)	<0.1
Bedtime resistance	8 (6, 13)	7 (6, 13)	7 (6, 14)	0.7
Girls	**Age 4 (n=290)**	**Age 5 (n=249)**	**Age 6 (n=215)**	**R^2 (%)**
Media use (min per day)	34 (0, 111)	34 (3, 120)	39 (9, 166)	0.5
Book reading (min per day)	60 (12, 150)	54 (12, 129)	54 (12, 131)	0.5
Total CSHQ score	44 (36, 55)	42 (35, 54)	42 (35, 54)	0.8
Daytime sleepiness	12 (8, 17)	11 (8, 16)	12 (8, 17)	0.5
Sleep-disordered breathing	3 (3, 4)	3 (3, 4)	3 (3, 4)	0.9
Parasomnias	7 (6, 10)	7 (6, 9.9)	7 (6, 9.8)	0.6
Night waking	4 (3, 7)	3 (3, 7)	3 (3, 7)	2.1
Sleep anxiety	6 (4, 10)	5 (4, 9)	5 (4, 9)	1.7
Sleep duration	3 (3, 6)	3 (3, 6)	3 (3, 6)	0.4
Sleep onset delay	1 (1, 2)	1 (1, 2)	1 (1, 3)	<0.1
Bedtime resistance	8 (86 13)	7 (6, 13)	6 (6, 14)	1.1
Boys	**Age 4 (n=291)**	**Age 5 (n=259)**	**Age 6 (n=211)**	**R^2 (%)**
Media use (min per day)	30 (0, 133)	39 (0.7, 133)	39 (0, 146)	0.3
Book reading (min per day)	60 (12, 132)	47 (12, 128)	51 (9, 158)	0.3
Total CSHQ score	43 (36, 57)	43 (36, 56)	42 (35, 56)	0.2
Daytime sleepiness	11 (8, 16)	11 (8, 17)	11 (8, 17)	0.4
Sleep-disordered breathing	3 (3, 4.1)	3 (3, 5)	3 (3, 4)	<0.1
Parasomnias	7 (6, 10)	7 (6, 10)	7 (6, 10)	<0.1
Night waking	4 (3, 7)	4 (3, 7)	4 (3, 7)	1.2
Sleep anxiety	6 (4, 9)	6 (4, 9)	5 (4, 9.9)	<0.1
Sleep duration	3 (3, 5)	3 (3, 6)	3 (3, 6)	0.2
Sleep onset delay	1 (1, 2)	1 (1, 2)	1 (1, 2)	<0.1
Bedtime resistance	8 (6, 13.2)	7 (6, 13)	7 (6, 14)	0.4

Notes: A total CSHQ score of ≥41 indicates a pediatric sleep problem. R^2 represents the variance explained by observational time according to the non-parametric analogue of the ordinary coefficient of determination. Data are reported as the median with 5th to 95th percentile range.

Abbreviation: CSHQ, Children's Sleep Habits Questionnaire.

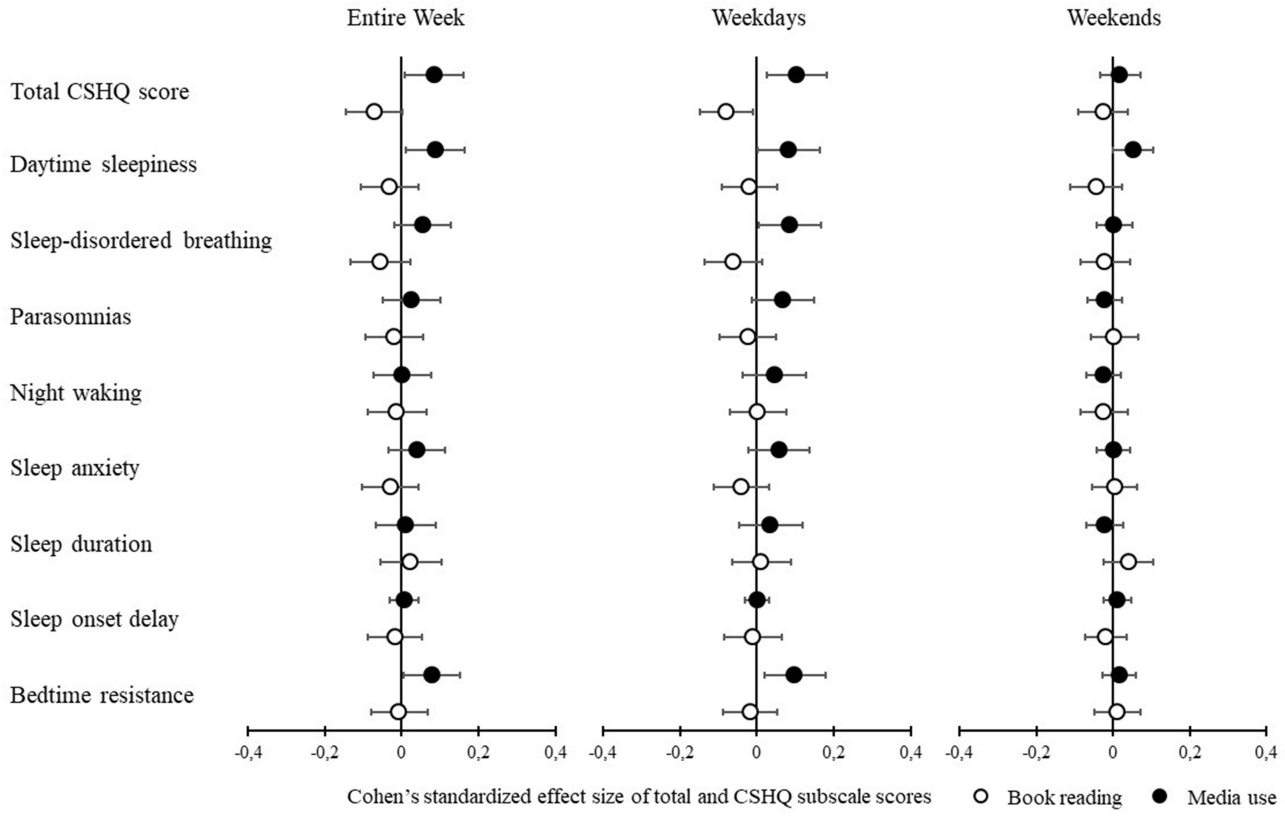

Figure 1 Partition model analyses of the association between one-hour exposure to media use and book reading during the week, on weekdays, and at weekends, and total CSHQ score and subscales. Results are provided as a metric of Cohen's standardized effect size (horizontal axis) by CSHQ overall score and subscales.
Abbreviation: CSHQ, Children's Sleep Habits Questionnaire.

[effect size (95% CI): 0.09 (0.01, 0.16)], for daytime sleepiness [0.09 (0.01, 0.17)], and for bedtime resistance [0.08 (0.01, 0.15)]. When analyzing data from weekdays only, similar results for both screen-based media use and book reading were observed. However, the associations between screen-based media use and sleep-disordered breathing [0.09 (0.01, 0.17)], as well as book reading and the total CSHQ score [−0.08 (−0.15, −0.01)], were more pronounced. Associations considering weekend exposures were, overall, much weaker.

The results of the substitution analyses (Figure 2) indicated a beneficial effect on sleep quality through substituting book reading for screen time. Specifically, the substitution of 50% of the time spent with screen-based media by the same amount of time spent reading books during a typical week would result in improved sleep quality, with a medium standardized effect size for the total CSHQ score [effect size (95% CI): −0.21 [−0.33, −0.10)]. Furthermore, the same substitution would also result in benefits in the CSHQ subscales daytime sleepiness [−0.15 (−0.27, −0.025)], parasomnias [−0.13 (−0.26, −0.002)], sleep anxiety [−0.13 (−0.25, −0.01)], and bedtime resistance [−0.13 (−0.25, −0.02)]. These results were again confirmed in subanalyses for weekdays only, but not for weekends (data not shown).

The aforementioned results are reinforced when considering partition and substitution models applied to single dichotomized CSHQ items. For each one-hour increase in screen-based media use during a typical week, we found increased odds of the need to be woken up by someone [odds ratio (95% CI): 1.45 (1.11, 1.90)] and of fear of the dark [1.31 (1.00, 1.72)] in the partition analyses. In contrast, each one-hour increase in book reading resulted in reduced odds of loudly snoring [0.70 (0.49, 1.00)]. Finally, we observed that the substitution of 50% of the time spent using screen-based media with an equal time spent on book reading would result in reduced odds of the fear of sleeping alone [0.53 (0.33, 0.86)], of fear of the dark [0.58 (0.38, 0.89)], of being restless in bed [0.72 (0.52, 1.00)], and of falling asleep in the car [0.66 (0.46, 0.94)]. This was again confirmed for weekdays, but not during weekends (data not shown).

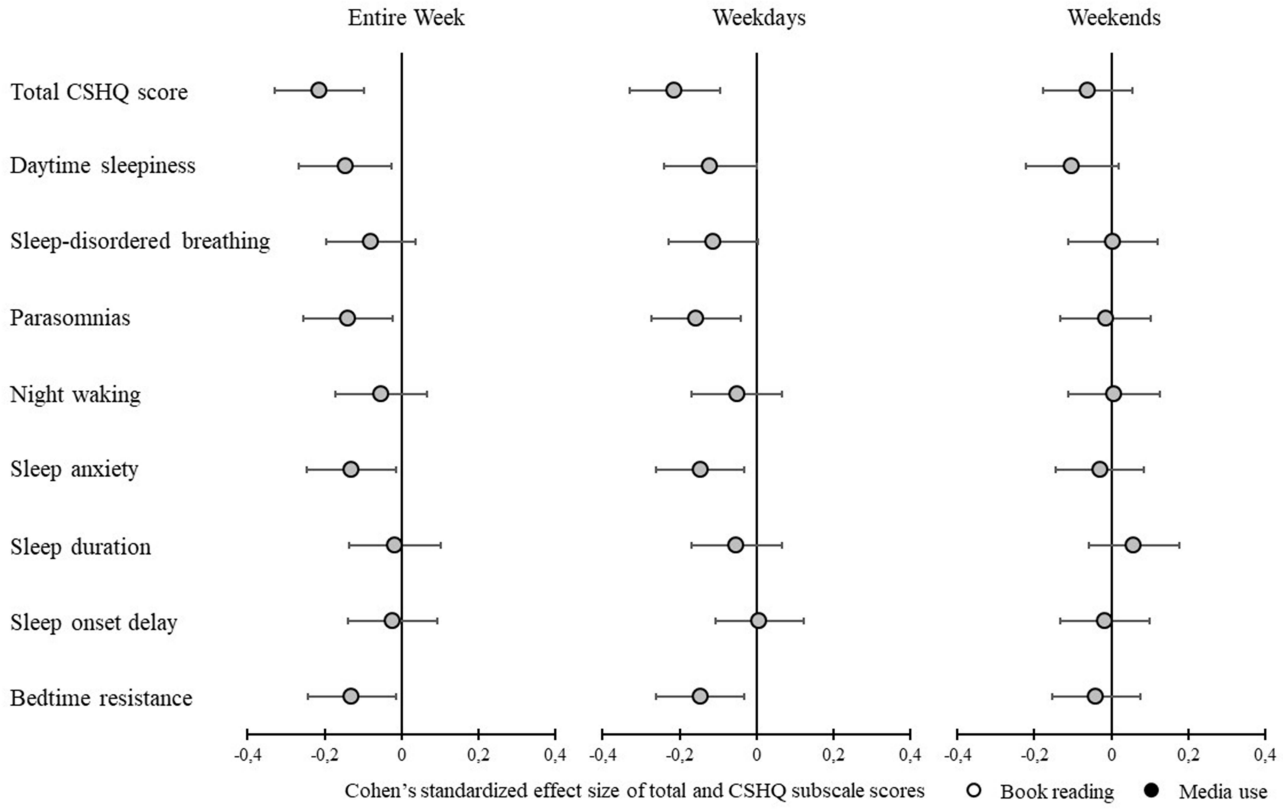

Figure 2 Substitution model analyses of the association between the substitution of 50% of the time spent on media use with an equal amount of time spent with book reading during the week, on weekdays, and at weekends, and total CSHQ score and subscales. Results are provided as a metric of Cohen's standardized effect size (horizontal axis) by CSHQ overall score and subscales.
Abbreviation: CSHQ, Children's Sleep Habits Questionnaire.

Discussion

We report that the use of screen-based media increased between the ages of 4 and 6 years, with a simultaneous decrease in book reading. Screen-based media use was associated with lower sleep quality, as indicated on the total CSHQ and its subscales, whereas book reading appeared to be beneficial with regard to sleep quality. Theoretically, substitution models revealed that substituting book reading for 50% of the time spent with screen-based media would benefit several domains of preschoolers' sleep health.

Our results are consistent with numerous other studies supporting the view that screen-based media use reduces sleep health in children including preschoolers.[21,40] For instance, in preschoolers, the use of electronic screen-based media was shown to be associated with more time spent in bed, longer time to wake up, or sleep duration, all of which are aspects of primary insomnia. Further evidence showed that the use of electronic devices is associated with parasomnias of different types. For example, parasomnias, and especially night walking, were prospectively associated with TV watching in children from kindergarten to fourth grade in the USA.[41] More recently, it was also observed that the use of a computer could be related to parasomnias in Chinese elementary school children.[42] The present study provides further evidence that book reading may be beneficial for children's sleep, a topic with rather limited evidence so far.[43]

While most studies assessed screen time coarsely, as we did, some studies documented specific associations between a given type of electronic device and sleep disturbance. For example, a study showed strong negative associations between TV watching and the use of tablets and several measures of children's sleep quantity, while iPod use coincided with earlier bedtimes.[24] Other studies reported that the use of mobile electronic devices (eg laptop, iPod) could be related to compromised sleep duration in preschoolers, especially when such devices are used to play videogames.[44] Future studies employing novel measures of screen time within the evolving digital landscape[45,46] may bring further insight on device- or task-specific effects. While our crude assessment may be viewed as a limitation in light of this, its importance may lie in the documentation that

book reading is beneficial compared to a comprehensive but aggregated measure of screen-based media time. Related to this, it is worth mentioning that, besides the negative effect of media use on sleep in children, digital reading via e-books may be as beneficial as paper books in other areas, such as the development of literacy skills.[47]

The associations in our study were observed considering the entire week, but were driven by the data for weekdays and not by the data for weekends. This is not completely unexpected and could be due to a dose–response mechanism given by an overall smaller exposure during the weekends, which obviously represent a smaller portion of the total week.[42] One could also speculate that the content of screen-based media differs between weekdays and weekends or that timing of exposure during the day was different. Especially during the evening hours, exposure to blue light can affect sleep.[48] In fact, paper book reading before bedtime also requires artificial light. However, in a comparative study, evening exposure to a digital but not to a paper book was shown to impair sleep physiology and sleep health.[18] Furthermore, certain content of screen-based media, particularly violent scenes, may feed anxiety and fears,[49] as opposed to book reading.[17] As such, substituting book reading for screen-based media use may be beneficial for sleep health, at least by leaving no time for negative influences, if not promoting sleep health.[49]

In our analysis, we present the theoretical substitution of 50% of the time spent with screen-based media by an equal time spent reading books. The average daily duration of screen-based media use was approximately 40 min. Thus, to improve sleep for an average child, approximately 20 min of media use would have to be substituted with book reading. However, our point estimates were derived from the whole distribution, which includes children with much longer, but also with shorter times spent with screen-based media. Neither our raw data nor our data analysis strategy is suited to finding or communicating the appropriate dose of substitution. In our preschool sample, with moderate screen-based media use, our pick of 50% seemed appropriate on a relative but also on an absolute scale. For example, the effect sizes that we document upon substitution are a downward shift (ie improved sleep) in the CSHQ total score distribution by 0.2 standard deviations (see Figure 2) and a halving of the odds of reporting 2 or more days per week with fear of sleeping alone (ie an odds ratio of 0.5). While the latter indicates a strong risk reduction that may translate easily to individual benefit, the former is a sizeable effect in terms of population-wide prevention. Smaller percentages of substitution below the 50% level that we chose, or even recommendations in small amounts of absolute minutes, eg 10 min per day, may be meaningful but are likely to result in smaller effects.

The present work has many strengths. Our results are based on a prospective birth cohort study with assessment tools validated for the German population. The partition and substitution analyses represent a novel, meaningful approach applied to our knowledge for the first time in this field of sleep medicine/health. Another strength is the study of preschoolers, a child population of great epidemiological interest because early intervention on media habits seems key to preventing subsequent harms. Finally, we revealed novel, original, and public health-relevant results confirming that book reading is preferable to screen-based media use for preschoolers. However, we acknowledge certain limitations. First, we cannot exclude that despite our sizable sample we may have had limited statistical power to detect smaller effect sizes, leading to a number of results without statistical significance. Thus, even more benefits of book reading may be uncovered by larger studies. Of note, we were able to report results with relatively small standardized effect sizes, indicating that the type II error rate is unlikely to limit our results. Second, our analyses were adjusted for maternal age and education, while paternal characteristics were not taken into account to avoid further restriction due to missing values, which could have led to residual confounding. However, sensitivity analyses considering paternal characteristics did not hint towards that possibility (data not shown). Third, our work was based on self-reported media use, book reading, and sleeping quality, which could have introduced certain biases, eg due to perceived social desirability, and measurement error. Moreover, a wide observational time between the SPATZ waves could have limited our study. On one hand, this could have limited the study owing to a lack of information on within-subject trajectories. On the other hand, it is convenient to have yearly data collection to improve participation compliance, thus reducing the loss to follow-up. Moreover, we did not observe a large association between the CSHQ score and subscales and time, suggesting that narrower time intervals would have not added substantial variability to the data. Recently, sensing and tracking of exposure to electronic media have been employed in studies;[45,46] however, this leaves aside older technology such as TVs, the use of non-registered electronic media, and, of course, paper book reading,[50] all of which we captured in this study. Furthermore, our study was of an observational nature, rendering causal interpretations difficult. Finally, our results are theoretical and are not related to an experimental intervention. Studies with a large sample size, adopting a randomized experimental approach, and based on objectively assessed outcomes would be necessary to confirm and corroborate our results.

Conclusion

In conclusion, using a substitution model paradigm, we showed that substituting equal amounts of book reading for 50% of the time spent with screen-based media benefits preschoolers' sleep quality substantially. Specifically, such a substitution may mitigate the harmful effects of screen-based media use regarding parasomnias, sleep anxiety, daytime sleepiness, and sleep onset delay. Besides implications for population-wide and individual prevention, book reading may therefore be incorporated as a useful intervention to improve sleep quality in children who are already affected by these sleep problems. As such, book reading could be considered as a potential low-threshold treatment, and the presented evidence may suffice to support recommendations in this direction.

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Disclosure

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