

Television Viewing, Bedroom Television, and Sleep Duration From Infancy to Mid-Childhood

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KEY WORDS

television, sleep duration, sleep hygiene, childhood

ABBREVIATIONS

CI—confidence interval

LRT—likelihood ratio test

TV—television

Ms Cespedes conceptualized and designed the present analysis, conducted all data analysis, drafted the initial manuscript, and completed all subsequent revisions until submission; Dr Gillman, Dr Kleinman, and Ms Rifas-Shiman were involved in the design and implementation of the parent study, Project Viva, advised in the design and presentation of the present analysis, and revised drafts critically for important intellectual content; Dr Redline advised in the design of the present analysis, and revised drafts critically for important intellectual content; Dr Taveras conceptualized the present analysis, was involved in the design and implementation of the Project Viva study, advised in presentation of analysis results, and revised drafts critically for important intellectual content; and all authors approved the final manuscript as submitted.

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WHAT'S KNOWN ON THIS SUBJECT: Inadequate sleep in childhood is associated with poor mental and physical health. Numerous cross-sectional studies reveal associations between television viewing and the presence of a bedroom TV and inadequate sleep in older children and adolescents, but longitudinal research is limited.



WHAT THIS STUDY ADDS: More TV viewing, and, among racial/ethnic minority children, bedroom TV, were associated with shorter sleep from infancy to midchildhood. These results raise the possibility that interventions to reduce TV could improve children's sleep.

abstract



BACKGROUND: Television and insufficient sleep are associated with poor mental and physical health. This study assessed associations of TV viewing and bedroom TV with sleep duration from infancy to mid-childhood.

METHOD: We studied 1864 children in Project Viva. Parents reported children's average daily TV viewing and sleep (at 6 months and annually from 1–7 years) and the presence of a bedroom TV (annually 4–7 years). We used mixed effects models to assess associations of TV exposures with contemporaneous sleep, adjusting for child age, gender, race/ethnicity, maternal education, and income.

RESULTS: Six hundred forty-three children (35%) were racial/ethnic minorities; 37% of households had incomes \leq \$70 000. From 6 months to 7 years, mean (SD) sleep duration decreased from 12.2 (2.0) hours to 9.8 (0.9) hours per day; TV viewing increased from 0.9 (1.2) hours to 1.6 (1.0) hours per day. At 4 years, 17% had a bedroom TV, rising to 23% at 7 years. Each 1 hour per day increase in lifetime TV viewing was associated with 7 minutes per day (95% confidence interval [CI]: 4 to 10) shorter sleep. The association of bedroom TV varied by race/ethnicity; bedroom TV was associated with 31 minutes per day shorter sleep (95% CI: 16 to 45) among racial/ethnic minority children, but not among white, non-Hispanic children (8 fewer minutes per day [95% CI: –19 to 2]).

CONCLUSIONS: More TV viewing, and, among racial/ethnic minority children, the presence of a bedroom TV, were associated with shorter sleep from infancy to midchildhood. *Pediatrics* 2014;133:e1163–e1171

Inadequate sleep in childhood is associated with poor mental and physical health, including impaired academic performance, depression, injury, and increased obesity risk.^{1–8} Among many factors that influence children's sleep, television 1RCMB_201300630C_wc_f4.tif (TV) viewing and the presence of a TV in the bedroom (bedroom TV) are increasingly prevalent in young children's lives.^{9,10} TV behaviors may directly displace sleep time or increase mental/emotional arousal and light exposure, which can be detrimental to sleep onset, duration, and quality.^{11–15} Numerous cross-sectional studies identify associations of TV behavior with inadequate sleep or sleep disturbance in older children and adolescents,^{11,16–19} but longitudinal research is limited.²⁰ For example, evening media use has been associated with increased sleep problems in preschool-aged children,¹⁴ and National Sleep Foundation data reveal associations of bedroom TV with shorter sleep duration in 6- to 10-year-olds.²¹ A recent study in Finnish schoolchildren, the first to examine TV and sleep duration longitudinally, revealed that TV viewing predicted shorter weekday sleep 18 months later.²⁰

Our study examines longitudinal associations of TV viewing and bedroom TV with sleep duration from infancy to midchildhood and explores differences by gender and race/ethnicity. Sleep in early childhood is particularly important to child health.^{8,22} We hypothesized that greater TV viewing and bedroom TV would predict shorter sleep duration.

METHODS

Population and Study Design

We studied participants in Project Viva, a longitudinal cohort of 2128 children (born 1999–2003) and their mothers founded to examine effects of diet and other factors during pregnancy and after birth. This analysis included 1864

mothers and children (86%) who reported average sleep and TV viewing at ≥ 1 assessment from infancy (6 months) to midchildhood (7 years); Table 1. We recruited women at prenatal visits to 8 Harvard Vanguard Medical Associates practices in Massachusetts. Details of recruitment/retention procedures are available elsewhere.²³ After obtaining written informed consent, we performed in-person study visits with mothers and children in infancy (mean age, 6 months) and early (mean age, 3.2 years) and midchildhood (mean age, 7.9 years). Mothers completed questionnaires at 1, 2, 4, 5, and 6 years postpartum. Institutional review boards of participating institutions approved the study.

Main Exposures: TV Viewing and Bedroom TV

At 6 months and 1 year, mothers reported average hours and minutes in the past week children were in a place

where a TV that was on could be seen. At each assessment from 2 to 7 years, mothers selected children's average hours per day of TV and video viewing in the past month from response categories (None, <1, 1–3, 4–6, 7–9, and ≥ 10 hours per day), separating weekdays and weekends. We assigned numeric values to categories (0, 0.5, 2, 5, 8, and 10, respectively) and computed weighted averages to construct an approximately continuous measure of TV in hours per day. This TV viewing measure, adapted from the National Longitudinal Survey of Youth,²⁴ is linked in a dose-response manner with childhood overweight.²⁵ At each assessment from 4 to 7 years, parents reported the presence of a TV in the room where children slept (bedroom TV [yes or no]).

Main Outcome: Sleep Duration

At 6 months, mothers reported children's average 24-hour sleep duration over the past month in hours and minutes in response to 3 separate

TABLE 1 Selected Characteristics of 1864 Project Viva Participants

	Overall	Lifetime Average TV Viewing <2 h per Day ^a (N = 1507; 81%)	Lifetime Average TV Viewing ≥ 2 h per Day (N = 357; 19%)
Maternal characteristics			
Age at enrollment, mean (SD), y	32.1 (5.1)	32.4 (4.9)	30.7 (5.8)
Prepregnancy BMI, mean (SD)	24.9 (5.5)	24.6 (5.2)	26.0 (6.2)
Educational attainment, N (%)			
College graduate or higher	1254 (68)	1083 (71)	171 (51)
Nulliparous, N (%)			
Yes	896 (48)	734 (48)	162 (49)
Household income, N (%)			
>\$70 000	1064 (63)	931 (67)	133 (47)
Married or cohabitating, N (%)			
Yes	1710 (92)	1434 (94)	276 (83)
Child characteristics, N (%)			
Gender			
Boy	958 (51)	786 (51)	172 (52)
Race/ethnicity			
White	1215 (65)	1041 (68)	174 (52)
Black	288 (16)	199 (13)	89 (27)
Latino	102 (5)	76 (5)	26 (8)
Asian	76 (4)	66 (4)	10 (3)
Other	177 (10)	142 (9)	35 (10)
Bedroom TV any time between 4- and 7-y assessments	397 (28)	245 (21)	152 (54)

^a Lifetime average TV viewing is calculated as the subject-specific mean TV viewing averaged over all measurement occasions from infancy to midchildhood.

questions about morning naps, afternoon naps, and nighttime sleep. At 1 year, respondents reported average total 24-hour sleep duration over the past month in hours and minutes including morning naps, afternoon naps, and nighttime sleep in response to a single question. From 2 to 4 and at 7 years, mothers selected children's average 24-hour sleep duration over the past month (separating weekdays and weekends) from categories (<9, 9, 10, 11, 12, 13, and ≥ 14 hours per day), which we combined in a weighted average sleep by assigning each a value in hours per day (8, 9, 10, 11, 12, 13, and 14, respectively). At 5 and 6 years, mothers reported average nightly sleep in hours per day without separating weekdays from weekends. We combined all sleep questions to form an approximately continuous measure of sleep duration in hours per day.

Study Covariates

Using self-administered questionnaires and interviews, we collected information about prespecified potential confounders including maternal age, education, prepregnancy BMI, parity, household income, the child's race/ethnicity, and active play.

Statistical Analysis

We examined longitudinal and cross-sectional associations of TV exposures with sleep duration. Cross-sectional analyses of sleep as predicted by TV viewing used separate linear regression models for each visit or questionnaire adjusted, first, for age in days; a second model additionally adjusted for race/ethnicity, gender, maternal education, and household income. For 4 years or later, we additionally adjusted for bedroom TV. We fit separate models for sleep predicted by bedroom TV, adjusting for the covariates above and for TV viewing. Other potential confounders did not meet inclusion criteria.

Longitudinal analyses used linear mixed effects models with random intercepts and random linear and quadratic slopes for age (including a quadratic term improved model fit) to account for correlations between repeated measures within subjects and allow participants with partial missing data to contribute information. We adjusted for age and age² (the square of age), then additionally for race/ethnicity, gender, education, and income.

For all longitudinal analyses, we separated time-varying exposure effects into 2 distinct sources of variation. One source is the within-subject variation in sleep, TV viewing, and bedroom TV, which reflects that these factors may change over time within subjects. The within-subject effect addresses the question: if a given child increased/decreased TV viewing, was his/her sleep duration over that period affected? The other source is the between-subject variation, which reflects that, at any given measurement occasion, different individuals have different values for sleep duration and for TV viewing and/or bedroom TV. The between-subject effect addresses the question: do children who watch more/less TV on average from infancy to mid-childhood sleep more/less than other children?

To separate within- and between-subject sources of variation, we included

mean-centered (subtracting the subject-specific average across time) and subject-specific mean (averaged within-subject over time) variables for both TV viewing and bedroom TV as covariates in models.²⁶ For bedroom TV, we subtracted the average presence of a TV (a proportion) from the presence or not (1 or 0) at each assessment point. The standard linear mixed effects model estimates effects of time-varying covariates on the basis of optimal combinations of within-subject and between-subject variation; if within-subject and between-subject effects are conflicting, they should not be combined in a standard model. For this reason, we separated within-subject effects (centered on the subject-specific mean) from between-subject (averaged from infancy to midchildhood) effects.

To assess potential effect modification, we included interaction terms of gender, race/ethnicity, and age with mean-centered and subject-specific mean TV exposures. We used likelihood ratio tests (LRTs) to determine if full models including interaction terms fit better than simpler models with fewer interactions. Where appropriate (LRT $P < .05$), we report stratified results and interaction P values.

All analyses used SAS version 9.3 (SAS Institute, Cary, NC).

TABLE 2 Average Daily Sleep Duration, TV Viewing, and Bedroom TV by Assessment Year

Assessment	Average Daily Sleep, Hours per Day		Average Daily TV Viewing, Hours per Day		Bedroom TV N (%)
	N	Mean (SD)	N	Mean (SD)	
6 mo	1673	12.2 (2.0)	1673	0.9 (1.2)	—
1 y	1227	12.8 (1.6)	1224	1.2 (1.5)	—
2 y	1360	12.0 (1.3)	1266	1.4 (1.2)	—
3 y	1242	11.2 (1.1)	1263	1.7 (1.1)	—
4 y	1202	10.8 (1.1)	1235	1.7 (1.0)	207 (17)
5 y	863	10.6 (1.0)	859	1.6 (1.0)	128 (15)
6 y	955	10.3 (0.9)	941	1.5 (0.9)	143 (15)
7 y	1170	9.8 (0.9)	1162	1.6 (1.0)	269 (23)

Data from 1864 participants in the Project Viva cohort.

RESULTS

The sample consisted of equal proportions of girls and boys and was multiethnic (35% racial/ethnic minority). At enrollment, most mothers (68%) had college education and household incomes > \$70 000 (63%). Mean (SD) sleep duration increased from 6 months to 1 year from 12.2 (2.0) to 12.8 (1.6) hours per day, remaining relatively constant from 2 to 5 years, then decreasing to 9.8 (0.9) hours per day by 7 years. TV viewing increased 6 months to 4 years from 0.9 (1.2) to 1.7 (1.0) hours per day, then declined slightly to 1.6 (1.0) hours per day at 7 years. At 4, 5, and 6 years, ~15% of children had a bedroom TV, rising to 23% at 7 years (Table 2). Ever having a bedroom TV was more common among racial/ethnic minority children (53%) than non-Hispanic white children (14%).

Cross-Sectional and Longitudinal Associations

In cross-sectional models, greater TV viewing was associated with shorter sleep duration. After multivariate adjustment, each additional hour of TV viewing was associated with 3 fewer minutes per day (95% confidence interval [CI]: -2 to 8) of sleep at 6 months; 2 fewer minutes per day (95% CI: -2 to 6) at 3 years; and 6 fewer

minutes/day (95% CI: 3 to 9) at 7 years (Table 3). Bedroom TV was also associated with less sleep after multivariate adjustment, independent of TV viewing, at 5, 6, and 7 years.

In longitudinal models, between-subject analyses revealed that each additional hour per day of lifetime average TV viewing was associated with 7 fewer minutes per day of sleep (95% CI: 4 to 10; Table 4). The effect of lifetime TV viewing did not vary by age, gender, or race/ethnicity, but between-subject associations of bedroom TV with sleep did vary by race/ethnicity

(*P* interaction .002). For racial/ethnic minority children, bedroom TV from 4 to 7 years was associated with 32 fewer minutes per day of sleep (95% CI: 18 to 46; Table 5) over the same period. Additional adjustment for TV viewing did not substantially change this between-subject effect. For non-Hispanic white children, bedroom TV was associated with 12 fewer minutes per day of sleep (95% CI: 1 to 22), which attenuated after adjustment for TV viewing (Table 5). Between-subject effects of bedroom TV did not vary by age or gender.

TABLE 3 Cross-Sectional Associations of TV Viewing (Hours per Day) and Bedroom TV With Sleep Duration (Minutes per Day)

	Mean Difference in Sleep Duration, Minutes per Day (95% CI)					
	<i>n</i>	Age-Adjusted ^a	<i>n</i>	Multivariate-Adjusted ^b	<i>n</i>	Bedroom TV-Adjusted ^c
TV Viewing						
6 mo	1666	-3 (-8 to 1)	1512	-3 (-8 to 2)	—	—
1 y	1200	-7 (-11 to -4)	1119	-6 (-9 to -2)	—	—
2 y	1224	-8 (-11 to -5)	1145	-6 (-10 to -2)	—	—
3 y	1233	-5 (-9 to -2)	1153	-2 (-6 to 2)	—	—
4 y	1197	-5 (-8 to -1)	1109	-4 (-8 to 0)	1108	-4 (-8 to 0)
5 y	850	-7 (-12 to -3)	807	-7 (-11 to -2)	802	-6 (-10 to -1)
6 y	935	-12 (-16 to -8)	879	-12 (-16 to -7)	876	-11 (-15 to -6)
7 y	1158	-13 (-16 to -10)	1058	-6 (-9 to -3)	1054	-5 (-9 to -2)
Bedroom TV						
4 y	1201	-16 (-25 to -6)	1113	-7 (-19 to 5)	1108	-16 (-18 to 6)
5 y	858	-23 (-35 to -11)	815	-19 (-32 to -6)	802	-18 (-31 to -5)
6 y	952	-31 (-41 to -21)	896	-21 (-32 to -10)	876	-14 (-26 to -3)
7 y	1162	-36 (-44 to -29)	1062	-15 (-24 to -7)	1054	-14 (-23 to -5)

^a Linear regression models fit in PROC GLM adjusted for child age in years at time of assessment.

^b Additional adjustments for race/ethnicity, gender, maternal education, and household income.

^c Additional adjustment for TV viewing or bedroom TV.

TABLE 4 Longitudinal Associations of TV Viewing (Hours per Day) With Mean Difference in Sleep Duration (Minutes per Day) by Gender

TV Viewing	Mean Difference in Sleep Duration, Minutes per Day (95% CI) ^a						<i>P</i> for Interaction
	All Children		Male Children		Female Children		
	Age-Adjusted 1864 Subjects; 9463 Observations	Multivariate-Adjusted 1672 Subjects; 8782 Observations	Age-Adjusted 958 Subjects; 4821 Observations	Multivariate-Adjusted 847 Subjects; 4406 Observations	Age-Adjusted 906 Subjects; 4642 Observations	Multivariate- Adjusted 825 Subjects; 4376 Observations	Multivariate- Adjusted 1672 Subjects; 8782 Observations
Between-subject (averaged over lifetime)	-11 (-14 to -8)	-7 (-10 to -4)	-12 (-16 to -8)	-8 (-12 to -4)	-11 (-15 to -7)	-6 (-10 to -2)	.72
Within-subject (centered on subject- specific mean)	-2 (-4 to 0)	-2 (-3 to 0)	-5 (-7 to -2)	-4 (-7 to -2)	1 (-2 to 3)	1 (-2 to 3)	.005

^a Models fit combined with no interactions, as well as separately for boys and girls. Age-adjusted estimates are from linear mixed effects models with random intercepts and slopes for age and age² fit in PROC MIXED adjusted for age and age². To decompose within-subject and between-subject effects, we include between-subject (averaged over time) and within-subject (centered on the subject-specific mean) covariates for TV viewing. Multivariate models include additional adjustments for race/ethnicity, maternal education, and household income.

TABLE 5 Longitudinal Associations of Bedroom TV With Mean Difference in Sleep Duration (Minutes per Day) by Race/Ethnicity

Bedroom TV	Mean Difference in Sleep Duration, Minutes per Day (95% CI) ^a												P for Interaction
	All Children				Non-Hispanic White Children				Racial/Ethnic Minority Children				
	Age-Adjusted 1438 Subjects; 4173 Observations	Multivariate- Adjusted 1312 Subjects; 3886 Observations	TV Viewing Adjusted 1310 Subjects; 3840 Observations	Age-Adjusted 947 Subjects; 2925 Observations	Multivariate- Adjusted 911 Subjects; 2827 Observations	TV Viewing Adjusted 909 Subjects; 2790 Observations	Age-Adjusted 489 Subjects; 1244 Observations	Multivariate- Adjusted 401 Subjects; 1059 Observations	TV Viewing Adjusted 401 Subjects; 1050 Observations	Multivariate- Adjusted 1312 Subjects; 3886 Observations			
Between- subject (averaged 4–7 y)	–38 (–44 to –31)	–22 (–31 to –14)	–20 (–28 to –11)	–22 (–32 to –12)	–12 (–22 to –1)	–8 (–19 to 2)	–37 (–48 to –25)	–32 (–46 to –18)	–31 (–45 to –16)			.002	
Within- subject (centered on subject- specific average)	0 (–8 to 9)	1 (–7 to 10)	1 (–7 to 10)	–3 (–13 to 8)	0 (–11 to 11)	0 (–11 to 11)	1 (–13 to 16)	0 (–15 to 15)	–1 (–16 to 14)			.87	

^a Models fit combined with no interactions, as well as separately for non-Hispanic white and racial/ethnic minority children. Age-adjusted estimates are from linear mixed effects models with random intercepts and slopes for age and age² fit in PROC MIXED adjusted for age and age². To decompose within-subject and between-subject effects, we include between-subject (averaged over time) and within-subject (centered on the subject-specific mean) covariates for bedroom TV. Bedroom TV was first asked about at the 4-year assessment; models including bedroom TV were re-centered for this time period. Multivariate models include additional adjustments for gender, maternal education, and household income, and TV-viewing adjusted models include additional adjustment for within and between-subject effects of TV viewing.

Within-subject analyses revealed that associations of individual-level changes in TV viewing with sleep duration varied by gender (*P* interaction .005). If an individual boy increased TV viewing by 1 hour per day over any period, this change was accompanied by a 4-minute per day decrease in his average sleep duration (95% CI: 2 to 7) over the same period (Table 4). By contrast, individual-level changes in TV viewing among girls did not influence sleep (1 minute per day, 95% CI: –2 to 3; Table 4). In within-subject analyses of bedroom TV, sleep was not associated with individual-level changes in the presence of a bedroom TV (1 minute per day, 95% CI: –7 to 10; Table 5).

Racial/ethnic minority (versus non-Hispanic white) children had lower predicted sleep duration regardless of lifetime TV viewing or bedroom TV (Figs 1 and 2). Overall, between-subject differences (Figs 1 and 2) had stronger associations with sleep duration than within-subject changes in TV viewing (Fig 3). For example, comparing hypothetical white boys with college-educated mothers from households earning > \$70 000 year with different durations of TV viewing, our model predicted that a boy who never watched TV and never had a bedroom TV would sleep 19 minutes per day longer in midchildhood than a boy who increased average daily TV viewing from 0 hours per day in infancy to 3 hours per day by midchildhood; 26 minutes per day longer than a boy who watched 3 hours per day of TV every year; and 34 minutes per day longer than a boy who watched 3 hours per day of TV every year and ever had a bedroom TV.

DISCUSSION

In this prospective study of 1864 children, greater TV viewing and bedroom TV were associated with decreased sleep duration. Overall, each additional

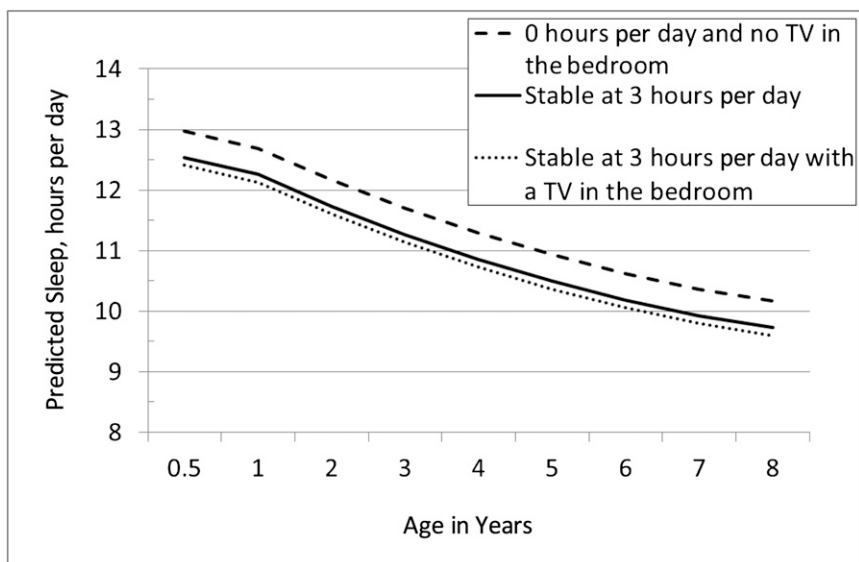


FIGURE 1

Non-Hispanic white boys: predicted sleep by TV and bedroom TV. Predicted sleep: longitudinal mixed effects model (random intercepts, random slopes for age and age²) adjusted for age, age², race/ethnicity, gender, education, income, and gender-interactions with mean-centered and subject-specific mean TV. Fixed values: boys (white or racial/ethnic minority), household income >\$70 000, maternal education ≥ college. Bedroom TV (never/ever).

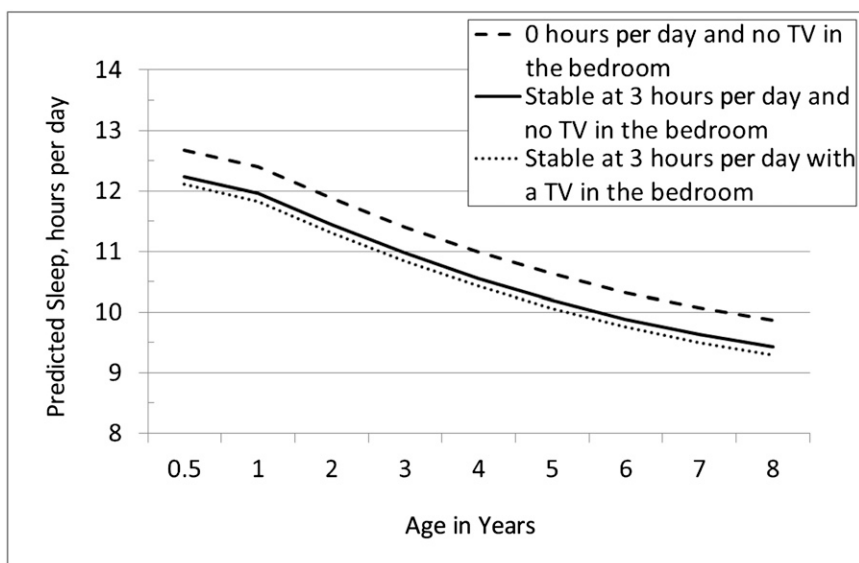


FIGURE 2

Racial/ethnic minority boys: predicted sleep by TV and bedroom TV. Predicted sleep: longitudinal mixed effects model (random intercepts, random slopes for age and age²) adjusted for age, age², race/ethnicity, gender, education, income, and gender-interactions with mean-centered and subject-specific mean TV. Fixed values: boys (white or racial/ethnic minority), household income >\$70 000, maternal education ≥ college. Bedroom TV (never/ever).

hour per day of average lifetime TV viewing from infancy through mid-childhood was associated with 7 fewer minutes per day of sleep over the same period. By contrast, individual-level

changes in TV viewing decreased sleep only among boys. For racial/ethnic minority children, bedroom TV was associated with 31 fewer minutes per day of sleep from 4 to 7 years in-

dependent of TV viewing, whereas for non-Hispanic white children associations disappeared after adjustment for TV viewing.

Between-subject (average lifetime TV) and within-subject (individual-level fluctuations) analyses yielded different effect estimates for TV viewing. For all groups, between-subject associations were of greater magnitude than within-subject associations. Within-subject effects are not susceptible to confounding by factors that do not vary within a subject (eg, race/ethnicity and, arguably, home environment or systematic reporting biases). However, between-subject effects could arise from differences in unmeasured factors (eg, parenting skills). Our data suggest that research on the basis of cross-sectional analyses alone may overestimate TV's influence on children's sleep. It is also possible that within-subject effects could be underestimated due to random error in reporting.

Of interest, we observed stronger within-subject effects of TV viewing in boys versus girls, and stronger between-subject effects of bedroom TV for racial/ethnic minority versus white children. Differences in effects may be due to differences in underlying susceptibility to external stimuli across population groups: other studies also indicate boys are particularly vulnerable to electronic media's influence on sleep,²⁰ as well as to the obesogenic effects of inadequate or disturbed sleep.²⁷ Subgroup differences may also relate to differences in patterns of TV viewing or content. For example, TV close to bedtime may be alerting, resulting in a phase delay in sleep onset. Exposure to violent content may lead to later sleep onset or interrupted sleep.¹⁴ It is also possible that parents differentially report behaviors such as sleep and TV for boys versus

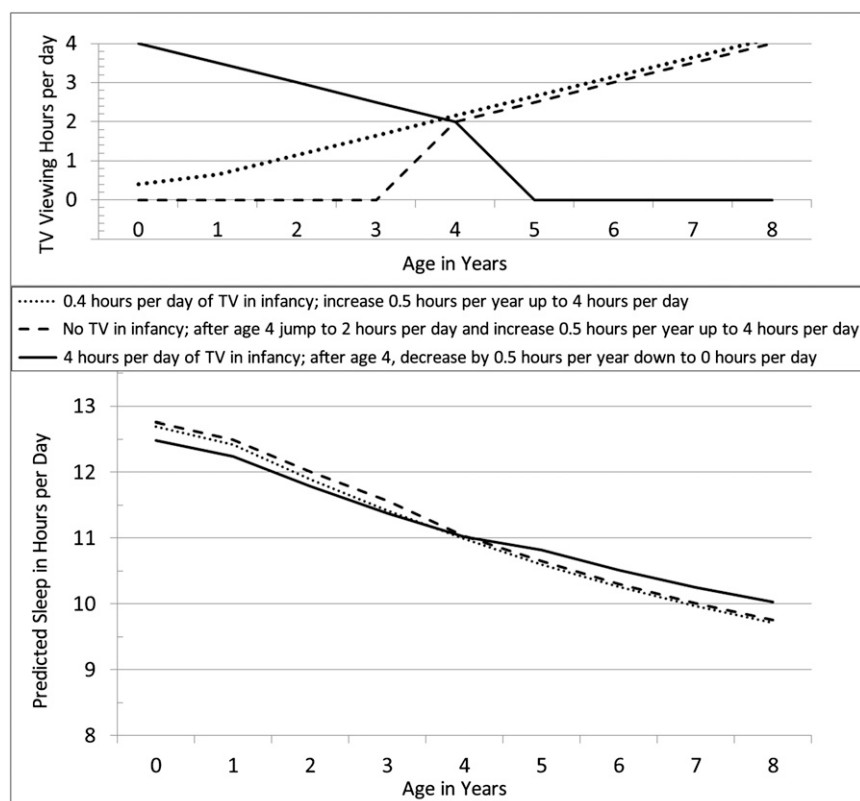


FIGURE 3

Predicted sleep by within-subject change in TV viewing among non-Hispanic white boys. Predicted sleep results from longitudinal mixed effects model with random intercepts and random slopes for age and age², adjusted for age, age², race/ethnicity, gender, education, household income, and interactions of gender with both mean-centered and subject-specific mean TV viewing. Bedroom TV is not included in the model.

girls, or that parents' race/ethnicity influences reporting biases.

Previous studies have been mostly cross-sectional or measured sleep problems rather than duration.^{18,19,28–33} The magnitude of association in our study is similar to that observed in the only other longitudinal study of TV viewing and child sleep duration: among 353 Finnish schoolchildren 10 to 11 years old, TV viewing predicted shorter weekday sleep duration 18 months later (5 fewer minutes per day, 95% CI: 1 to 10; adjusted for gender, grade level, and family structure). However, in the Finnish study, the presence of a bedroom TV was not associated with shorter sleep though it predicted later bedtimes in boys.²⁰ Our study extends a sparse literature by describing longitudinal associations of

TV viewing and bedroom TV with sleep duration over a longer follow-up period in a larger and more diverse sample. Further, ours is the first study to examine this important period from infancy to midchildhood when habits are being formed that are likely to persist into later childhood.³⁴

Consistent with our finding that bedroom TV is associated with shorter sleep duration, cross-sectional National Sleep Foundation data reveal that children with a bedroom TV (versus without) slept 9 fewer minutes per day (95% CI: 1 to 19).²¹ In our study, between-subject associations with bedroom TV were particularly strong among racial/ethnic minorities. This between-subject difference may partially reflect unmeasured confounders, differential reporting by race/ethnicity

or unmeasured TV viewing (the presence of a bedroom TV may make it more difficult for parents to accurately report children's viewing and/or sleep, particularly if children fall asleep watching). However, the strength of the observed association (31 minutes less sleep for bedroom TV) may indicate an adverse influence of bedroom TV on children's sleep independent of increased TV viewing; bedroom TV may increase screen illumination and mental/emotional arousal near bedtime, negatively influencing sleep duration.^{13,35} Racial/ethnic minority children in our study watched more TV and slept less than white non-Hispanic children; others have noted similar disparities by race/ethnicity in TV viewing, bedroom TV,^{10,36} and sleep duration.^{37,38}

Our study makes a unique contribution to the literature: to our knowledge, no previous study of TV and sleep duration includes a cohort of children followed from infancy to midchildhood. Further, no previous study has separated time-varying TV exposures into within- and between-subject sources of variation to address the different impacts on sleep duration of lifetime average TV and individual-level changes in TV. This study also had several limitations. Measures of TV and sleep were from parent-report, which may result in misclassification. Because children sleep less as they age,³⁹ reverse causation (less sleep leading to greater TV) is a possibility. However, we controlled for age-related declines in sleep by adjusting for age and including random slopes for age and age² in longitudinal models. Finally, although there are many forms of screen media (eg, mobile phones), TV is still the largest single contributor to children's total screen time.¹⁰ In this study, we first measured total screen exposure at 7 years and found that cross-sectional associations were similar to

those observed with TV viewing alone, suggesting that longitudinal associations with total screen time would also be similar.

Finally, bias due to nonrandom dropout is possible: mothers whose children's sleep and TV relationship was different might be less likely to return questionnaires. This bias would attenuate our estimates over time: racial/ethnic minority (vs white) participants had a higher probability of missing data at later assessment points, and racial/ethnic minority children watched more TV and slept less.

CONCLUSIONS

Our study supports a negative influence of TV viewing and bedroom TV on children's sleep. Although a comparison of within- and between-subject analyses suggests that associations previously reported by using cross-sectional data alone may have been inflated, we demonstrated that subgroups of young children, in particular, boys and racial/ethnic minorities, may be more vulnerable to TV's effects on sleep. TV viewing and the presence of a bedroom TV track over time^{40,41}; thus,

modest decreases in sleep duration could form lasting habits leading to substantial sleep deficits as children age. Given the associations between greater TV viewing and shorter sleep suggested by this study and the strong evidence that greater TV viewing and shorter sleep are associated with poor outcomes, screen time interventions have the potential to improve sleep.

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