Published in final edited form as:

J Youth Adolesc. 2019 January ; 48(1): 56–70. doi:10.1007/s10964-018-0917-3.

Early Life Socioeconomic Disparities in Children's Sleep: The Mediating Role of the Current Home Environment

Leah D. Doane^{*}, Reagan S. Breitenstein, Charles Beekman, Sierra Clifford, Trevor J. Smith, and Kathryn Lemery-Chalfant

Department of Psychology, Arizona State University

Abstract

Despite identified concurrent socioeconomic disparities in children's sleep, little research has examined pathways explaining such associations. This study examined the quality of the home environment as a direct predictor of sleep and potential mediator of associations between early life socioeconomic status and objective and subjective indicators of sleep in middle childhood. A socioeconomically and ethnically diverse sample of 381 twin children (50% female; 46.6% lower middle class or living at or below the poverty line; 26% Hispanic/Latino) were assessed at 12 months for SES and eight years using gold-standard home environment interviews and actigraphy-measured sleep. Multilevel mediation path models indicated that lower early SES and lower quality concurrent home environments were associated with shorter sleep durations, longer sleep latencies, and greater sleep timing variability. The home environment significantly mediated associations with sleep duration and sleep timing variability. The findings illustrate an important target in the prevention of poor childhood and adolescent sleep.

Keywords

Sleep; Socioeconomic status; Home environment; Middle childhood

^{*}Corresponding Author: Department of Psychology, Arizona State University, P.O. Box 871104, Arizona State University, Tempe, AZ 85287-1104, Phone: (480)965-5289, Fax: (480)965-8544, Leah.Doane@asu.edu.

Authors' Contributions

LDD and KLC conceived of the study, participated in its design, led data collection, and drafted the manuscript; LDD performed statistical analysis; RSB, CB, and SC participated in the design of the study, helped draft the manuscript and performed statistical analysis; TJS participated in the design and helped draft the manuscript. All authors read and approved the final manuscript.

Data Sharing Declaration

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors report no conflict of interests.

Compliance with Ethical Standards

Ethical Approval

All procedures performed in this study involving human participants were in accordance with the ethical standards of our institutional review board and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent

Informed consent was obtained from all individual participants included in the study and assent was obtained from all children under the age of 18 at the 8 year assessment.

Introduction

Obtaining sufficient and high-quality sleep in childhood and adolescence has been linked to key developmental outcomes including emotional control and cognitive function (Dewald et al., 2010; O'Brien, 2009), as well as important indicators of health (e.g., weight status; Magee and Hale, 2012). However, many youth do not obtain the recommended hours of nightly sleep and others report sleep problems beyond shortened durations (National Sleep Foundation, 2014), with low SES youth particularly likely to experience poor sleep quality and duration (Jarrin et al., 2014). Theoretical arguments and empirical evidence suggest that such differences in sleep duration and quality partially explain socioeconomic disparities in academic achievement, physical and mental health (Buckhalt, 2011; Moore et al., 2002), but little research has examined the proximal processes which may explain socioeconomic disparities in sleep itself. Theoretical models posit that future research must examine crucial mediators of early life socioeconomic status to be able to best target interventions aimed at promoting better health later in development and into adulthood (Chen et al., 2002).

Thus, this study examined the proximal home environment as a key mediator of associations among early socioeconomic status (SES) and subjective and objective indicators of sleep duration, quality, and problems in a community sample of twins in middle childhood. First, this study explored associations between early SES and several indicators of sleep in middle childhood. Next, the current study tested whether the quality of the home environment in middle childhood was associated with sleep and whether the home environment mediated the effects of early SES on sleep. An examination of such mechanisms may provide researchers, parents, and clinicians with potential targets of change in the prevention of shortened sleep, poor sleep quality and sleep problems that may onset in childhood and continue into adolescence. The identification of mechanisms in middle childhood is key to understanding whether the numerous changes in sleep that have been identified in adolescence (Carskadon, 2011; Crowley et al., 2014) are simply continuities of earlier problems or newly emerging patterns.

In this study sleep duration was defined as the number of hours and minutes spent sleeping (excluding wake periods) between sleep onset and waking, while sleep quality was measured via indicators of sleep efficiency (the percent of time spent sleeping while in bed) and sleep onset latency (number of minutes needed to fall asleep once in bed). Greater sleep durations and greater sleep efficiency have been linked indicators of higher quality physical health, mental well-being, and school performance in children and adolescents (Cappuccio et al., 2008; Chaput et al., 2016; Dewald et al., 2010), while greater sleep latency has been linked with greater daytime sleepiness and negative affect in children and adolescents (Calhoun et al., 2011, Kourou and El-Sheikh, 2014). Sleep variability was defined by variability in sleep schedule (variability in the midpoint time between bedtime and waketime) with studies suggesting that lower sleep timing variability has been associated fewer behavioral difficulties (e.g., Biggs et al., 2011). Finally, sleep problems were defined by parent-reported sleep difficulties including sleep duration problems, bedtime resistance, sleep latency, nighttime wakings, sleep anxiety, parasomnias, and daytime sleepiness (Owens et al., 2000b). Greater sleep problems have been associated with poorer attentional and emotional control, greater internalizing symptoms, worse academic achievement, increased conduct

problems, peer problems and hyperactivity in children and adolescent populations (e.g., Dewald et al., 2010; Gregory et al., 2006; Wang et al., 2013).

Socioeconomic Status and Sleep

A growing body of empirical research has documented links between concurrent SES and sleep in youth across racial and ethnic groups, finding that lower SES children had shorter sleep durations, more sleep difficulties and more daytime sleepiness in middle childhood and adolescence (El-Sheikh, et al., 2013; Jarrin et al., 2014; Marco et al., 2012). The evidence is not always consistent, with some studies showing that higher SES youth spent less time in bed at night and had shorter sleep durations (Arman et al., 2011; Zhang et al., 2010), but associations between lower SES and poor sleep have been documented using both objective (e.g., actigraphy) and subjective reports of sleep and sleep problems. Studies have yet to examine the influence of early life SES (e.g., in infancy) on sleep in middle childhood. However, poor early life socioeconomic circumstances have been linked with poor health and development later in childhood and into adulthood across numerous domains (e.g., cardiovascular health, executive functioning), independent of current socioeconomic circumstances (reviewed in Cohen et al., 2010; Hackman et al., 2015; Power et al., 2003), suggesting the possibility that early SES may have lasting effects on later sleep over and above the effects of the current environment. Indeed, Chen and colleagues (2002) argued that SES may have differing associations with health across development including associations that are persistent, those that are limited to childhood, or associations that emerge during adolescence. Further, little research has examined proximal mechanisms that explain socioeconomic differences in duration and quality of sleep. This study investigated the home environment as one such mechanism, likely to act as a proximal influence on children's sleep through both physical and interpersonal pathways. Socio-ecological theories (e.g., Brooks-Gunn and Duncan, 1997) suggest that home environment processes mediate associations between SES and child well-being, but few studies have tested mediating pathways with observational measures of the home environment (Bradley and Corwyn, 2002).

Home Environment and Sleep

The home environment has been defined as the qualities of a child's most proximal context, including the built physical environment, qualities of parenting (e.g., responsivity, encouragement of maturity), availability of learning and enrichment resources inside and outside of the home (e.g., musical instruments, access to libraries), and time spent with family (Bradley, 1994). The physical home environment, including noise, light, and temperature, may affect key predictors of sleep quality (Bagley et al., 2015). A large study of the home environment and children's diary-reported sleep found no associations between the physical environment and sleep when covarying for SES (Spilsbury et al., 2005), but the authors did not test longitudinal or mediating pathways. Interpersonal factors within the home may also be predictive of poor sleep. For instance, prior research suggests that chaotic home and family environments and stressors such as interparental conflict are all associated with poorer sleep in school-aged children (e.g., shorter duration, poor quality; El-Sheikh et al., 2006; El-Sheikh et al., 2007; Kelly and El-Sheikh, 2011), and other parental factors including perceived social support and perceived stress may also influence children's sleep

(Bernier et al., 2013). Qualities of parenting are also important predictors of sleep. Researchers examining indicators of dyadic attunement between parents and children have found that low parental emotional availability or sensitivity during interactions are related to sleep problems and less sleep in infants, toddlers and older children (Bell and Belsky, 2008; Keller and El-Sheikh, 2010; Teti et al., 2010). In addition, supportive and positive parenting are related to diary, parent-report, and objective measurement of healthy sleep, perhaps due to high-quality structured environments (Bell and Belsky, 2008; Spilsbury et al., 2005) or the development of emotional security (Davies et al., 2013). For example, in a national sample, parental warmth was related to longer sleep duration for children (Adam et al., 2007).

Finally, research in academic and socioemotional domains has illustrated the importance of autonomy-granting (e.g., age-appropriate decision-making) for well-being (e.g., Liew et al., 2014; Smetana et al., 2004). Children whose parents allow more autonomy at bedtime and during the night (i.e., less involvement) have shown higher quality sleep including longer durations and higher sleep quality (for review see Erath and Tu, 2011). Similarly, a large study of an urban community-based cohort of children and early adolescents (8–11 years) found that parents' encouragement of maturity was positively associated with child-reported sleep duration, lower odds of having a late bedtime (i.e., after 11 PM) and, for girls only, lower sleep variability (Spilsbury et al., 2005). Notably, other research finds no association between autonomy granting and adolescent sleep (e.g., Meijer et al., 2016), so there is more to be learned about the developmental importance of autonomy-granting for sleep.

SES and Home Environment

The family and home environments of low SES children are more likely to be characterized as chaotic, lacking in routine and greater exposure to multiple stressors relevant to children and adolescents' sleep (Evans, 2006). For instance, children and adolescents in low SES homes are more likely to have an unstable sleep location, a television in their room, and inconsistent bedtime routines (Hale et al., 2009; National Sleep Foundation, 2014; Tandon et al., 2012). Disruptive facets of the home environment (e.g., crowding, noise) are empirically and theoretically distinct from SES (Dumas et al., 2005; Petrill et al., 2004), but are more common in low SES homes, and these facets may mediate associations between SES and adjustment (Evans et al., 2005). Indeed, one study examining cross-sectional mediation by the physical home environment found that self-reported disruptive sleep conditions (e.g., noise) mediated links between SES and subjective sleep problems and daytime sleepiness (Bagley et al., 2015). Finally, the family stress model suggests that economic stressors influence child well-being through the quality, sensitivity, and responsivity of the caregivers in the home (Conger and Donnellan, 2007), and some studies show stronger associations between stressors such as marital conflict and children's sleep in low SES families (e.g., Kelly and El-Sheikh, 2011), suggesting that links between qualities of the home environment and sleep may differ by SES. However, little research has examined whether the home environment is a proximal *mechanism* by which SES affects children's sleep, particularly using objective measures of sleep and observational measures of the home environment.

The Current Study

This study was guided by Chen and colleagues' (2002) model positing the changing influence of SES across development and need for research examining potential mediators of early socioeconomic influences on health. Further, based on prior research illustrating relations between the home environment and sleep (e.g., Spilsbury et al., 2005), the current study examined whether the home environment was a key mediator in the association between early SES and sleep in a large socioeconomically diverse sample of twin children, with substantial Latino representation.

There were two primary aims of this study. The first aim was to examine associations between SES in infancy and indicators of sleep at eight years of age. Based on previous research supporting concurrent socioeconomic differences in children and adolescent's sleep (e.g., El-Sheikh et al., 2013; Spilsbury et al., 2005), it was predicted that early SES would be positively related to sleep duration and efficiency, but negatively related to sleep latency, variability and parent-reported sleep problems (*Hypothesis 1*). The second aim was to test relations between the quality of the home environment and indicators of sleep, and whether the quality of the home environment mediated associations between early SES and children's sleep in middle childhood. Prior empirical research (e.g., Spilsbury et al., 2005) and theoretical models (Chen et al., 2002) supported the prediction that the quality of the concurrent home environment would mediate the associations among early SES and sleep duration and sleep problems (*Hypothesis 2*). Prior research has not yet explored the potential mediating role of the home environment between SES and sleep quality (e.g., efficiency, latency) and variability, and therefore these were exploratory aims.

Methods

Participants

The study sample comprised a subsample of Arizona Twin Project participants (Lemery-Chalfant et al., 2013), which is an ongoing birth cohort of twins designed to examine the development of children's physical and mental health. The full panel included families of twins born in the state of Arizona to mothers over 18 years of age in 2007–2008. Families of twins were recruited from state birth records with the assistance of the Arizona State Department of Health Services. Because Arizona is a closed records state, the State Section of Vital Statistics mailed recruitment letters in English and Spanish to a random sample of mothers who had given birth to live twins within the previous year (2007–2008), including a postage-paid return letter where families were invited to indicate their interest in participating and provide their contact information. Of the 401 families who elected to contact us, 329 families (82.29%) participated at 12 months of age. Of the 329 families who had participated at 12 months, 229 families (69.60%) have participated in the ongoing 7–8 year Sleep assessment to date. Data will be collected from 300 families across three years to have the power to conduct genetic analyses, although the current subsample size is more than adequate to address the current research questions. 191 families (58.1%) were eligible for the current subsample (e.g., lived in the state of AZ, no diagnosed disability). The current subsample included 381 twins (191 families; monozygotic or MZ families = 50, same-sex dizygotic or DZ families = 66, opposite-sex dizygotic or DZ families = 63, unknown

zygosity = 12) who participated at the baseline assessment at 12 months of age ($M = 12.49$ months, $SD = 1.16$; data collected from 2009–2010) and again at approximately 8 years of age in the more intensive objective sleep assessment ($M = 8.47$ years, $SD = .45$; data collected from 2016–2017).

The sample was 50.5% male and ethnically diverse (approximately 56.5% European American, 25.1% Latino, 5.2% Asian American, 4.2% African American, 1.0% Native American, 1.6% Native Hawaiian families, and 6.3% multiethnic or unknown ethnicity). Annual household income ranged from under \$20,000 to over \$150,000 at the 12-month and eight-year assessments (Median = \$80,000–\$100,000). The majority of primary caregivers reported either a completed college degree (37.2%; 26.7% spouse/partner), two or more years of graduate school (3.7%; 2.1%), or a completed graduate or professional degree (20.9%; 15.7%), with the remaining reporting some college (22.0%; 19.9%), a high school degree or equivalent (6.8%; 13.6%), or less than a high school degree (1.0%; .5%) at the eight year assessment, and unknown education level for 8.4% of primary caregivers (8.9% spouse/partner). For 12.6% of the sample, twins had only a primary caregiver. Sample comparison analyses indicated no differences between the sub- and full sample in sex, $b = .025$, $t(376) = .59$, $p = .56$, or ethnicity, $t(381) = -1.31$, $p = .189$, but SES was significantly higher in the sample of families with eight year data ($M = .11$, $SD = .76$) than the sample of families without ($M = -.17$, $SD = .84$), $t(305) = 3.096$, $p = .002$.

Of the participants included in analyses, 31 twins were only missing data on demographics or socioeconomic status at the 12-month assessment, 10 twins were missing data only on objective sleep, 4 twins were missing data only on the home environment assessment, 20 twins were missing data only on the parent-report of sleep, 1 twin was missing data on only BMI, and 33 twins were missing data on two or more variables. There were 283 twins with complete data on all assessments.

Procedures

Parents of twins were recruited from state birth records, and primary caregivers (94.6% mothers) completed telephone interviews assessing twin zygosity, family demographics, and children's health and development at age 12 months. When twins were approximately eight years old, families were contacted via telephone, e-mail, or mail and offered the opportunity to participate in an intensive assessment of family environment, daily health practices, physical health, and academic achievement, including two home visits separated by approximately a week, during which they completed daily assessments of health. The majority of families with valid sleep data were assessed during the school year (71%).

Two trained interview staff conducted a home visit consisting of parent training for a week-long protocol (including sleep), biological assessments (e.g., height, weight), cognitive tasks, and parent-child interaction tasks. Interviewers assessed the home environment using the Middle-Childhood Home Observation for the Measurement of the Environment (MC-HOME; Caldwell and Bradley, 2003). Twins wore actigraphs 24 hours a day (excluding bathing or swimming) for seven consecutive days. Primary caregivers completed daily sleep diaries via electronic report (48.7%), paper diaries (44.5%), or both (2.1%) to cross-validate actigraphy data. Two families (1.0%) declined to complete diaries, and seven (3.7%) were

missing diary data. During the study week, staff contacted families daily to ensure protocols were followed accurately. At the second visit, actigraphs and paper diaries were collected, biological measurements taken, and families compensated. Primary caregivers also completed an online or telephone questionnaire, including measures of child sleep, related health (e.g., medication use, chronic health) and demographics. All phases of the study were approved by the Institutional Review Board. Written informed consent and verbal assent were obtained from primary caregivers and children, respectively.

Measures

Socioeconomic status.—SES was assessed at 12 months and eight years as a standardized composite of the family income-to-need ratio for 2009 and 2016, respectively, primary caregiver education level, and spouse/partner education level. Eleven families chose not to answer demographic questions at 12 months but responded retrospectively at 30 months. Primary caregivers reported their total household income in the past year (before taxes), and response categories included: (1) less than \$30,001; (2) \$30,001-\$40,000; (3) \$40,001-\$50,000; (4) \$50,001-\$60,000; (5) \$60,001-\$70,000; (6) \$70,001-\$80,000; (7) \$80,001-\$90,000; (8) \$90,001-\$100,000; (10) \$100,001-\$150,000; (11) More than \$150,001. Income to needs was calculated based on number of individuals in the household and federal poverty standards published for 2009 and 2016. The mean of the family income range was used, and income was divided by the federal poverty threshold for that household size (U.S. Census Bureau). Families were considered to be living in poverty if they received a score of <1 (10.4% of sample at 12 months), near the poverty line if scored 1–2 (20.9% of sample at 12 months), lower middle class if scored 2–3 (23.9% at 12 months), and middle to upper class if scored above a 3 (44.8% at 12 months).

Primary caregivers also reported on their and their spouse/partner's level of education with the following response categories: (1) less than high school; (2) high school or equivalent; (3) some college, not graduated; (4) college degree (e.g., BA, BS); (5) two or more years of graduate school; (6) graduate or professional degree. Family SES was highly correlated across 12 months and eight years ($r = .81, p < .001$). SES at 12 months was used as the primary predictor and SES at eight years was a covariate for primary analyses.

Home environment.—The MC-HOME was used to assess twins' home environments at eight years. The instrument was created to assess physical, emotional, and social facets of a child's home environment in middle childhood (Caldwell and Bradley, 2003). The HOME has been validated across diverse populations within the United States (Bradley, 1994; Caldwell and Bradley, 2003), is estimated to have an α coefficient of 0.80 for the total score (ranging from 0.30 to 0.80 across subscales), and has been validated across observers and over time (Bradley, 1994). The HOME inventory is correlated with numerous demographic indices (e.g., parent education, SES) and developmental outcomes across childhood (e.g., Bradley, 1994).

The MC-HOME was conducted by trained experimenters based on their observations during the two-hour home visit, including an approximately 30 minute in-home interview with the primary caregiver, and consists of 59 items. All questions require a response of *yes* (scored

as 1) or *no* (scored as 0) through primary caregiver response (e.g., “child has been praised at least twice during the last week for doing something”) or observer rating (“child’s room has a picture or wall decoration appealing to children”). The MC-HOME inventory is divided among eight subscales: 1) Parental Responsivity (e.g., child has been praised at least twice during the past week for doing something), 2) Physical Environment (e.g., house is not overly noisy), 3) Learning Materials (e.g., child has free access to at least ten appropriate books), 4) Active Stimulation (e.g., family encourages child to develop or sustain hobbies), 5) Encouraging Maturity (e.g., family requires child to carry out certain self-care routines), 6) Emotional Climate (e.g., child can express negative feelings toward parents without harsh reprisals), 7) Parental Involvement (e.g., father (or father substitute) regularly engages in outdoor recreation with child), and 8) Family Participation (e.g., family member has taken child to some type of live musical performance).

Subscale items are summed to create a score for each domain. All items are summed to create a total HOME score, with higher scores suggesting greater quality of the home environment (current sample α coefficient = .79). Items were asked for each twin, but due to low within-family variability, we the family-level mean was used in all analyses. Primary analyses used the total score, while the Physical Environment, Emotional Climate, and Encouragement of Maturity subscales were examined in sensitivity analyses given theoretical and empirical evidence supporting pathways with SES and sleep.

Actigraphy measured sleep.—Actigraphy was used to objectively assess children’s sleep over seven nights. Each child wore a Motion Logger Micro Watch, a wrist-based accelerometer (Ambulatory Monitoring, Inc, Ardsley, NY USA) on their non-dominant wrist. These devices measure motion in one-minute epochs using a zero-crossing mode. Researchers scored sleep data using the Sadeh algorithm (Sadeh et al., 1995; Sadeh et al., 1994) in Action W-2 software version 2.7.1 (Ambulatory Monitoring) program. Actigraphy has demonstrated good reliability when measured over 5 nights or more (Acebo et al., 1999) and has been validated against polysomnography (Sadeh et al., 1995). Following recent recommendations (Gregory and Sadeh, 2012), the current study included multiple sleep parameters: (1) sleep duration (total sleep minutes, excluding wake periods), (2) efficiency (percentage of time sleeping while in bed), (3) onset latency (minutes spent in bed before falling asleep), and (4) midpoint variability (variability indicator of the midpoint time between bed and wake time). Mean composites of duration, efficiency, and latency were used in analyses (ICC’s = .75, .81, .80, respectively).

There were full missing sleep data for 32 children (8.4%) due to loss of actigraph watch or water submersion ($N = 4$), mechanical problems ($N = 7$), or deciding not to wear the actigraph watch but participating in other study procedures ($N = 19$). There was excellent compliance with study procedures among children without full missing sleep data: 306 (80.1%) children completed seven or more nights of actigraphy (3% chose to wear the watches more than 7 nights), 31 (8.1%) children completed six, four (1.0%) children completed five, five (1.3%) children completed four, and four (1.0%) children completed three. Previous research suggests actigraphy assessments include at least five nights. Exploratory analyses were conducted excluding cases ($N = 9$) with less than five nights and results were similar. Therefore, all cases were included in analyses.

Sleep problems.—Primary caregivers reported on the twins' sleep problems at eight years using the Child Sleep Habits Questionnaire (CSHQ; Owens et al., 2000b), which has demonstrated reliability and validity in other samples (Owens et al., 2000a; Owens et al., 2000b). The CSHQ is a 35-item parent-report measure of sleep problems, including sleep duration, sleep duration problems, bedtime resistance, sleep latency, nighttime wakings, sleep anxiety, parasomnias, and daytime sleepiness. Items are rated on a five-point Likert scale, with higher scores indicating more sleep problems. A mean across all subscales was computed (α coefficient = .81). When summed, scores over 41 indicate a pediatric sleep disorder (6.60% of this sample; Owens et al., 2000b).

Covariates.—Several other variables were explored as covariates in preliminary analyses based on known associations with primary study variables. If covariates were significantly associated with primary study variables in exploratory and descriptive analyses, they were included in the final analytic models. Covariates included child age, sex (female = 1), SES at eight years, race/ethnicity (European American = 1), whether the child was in or “out” of school (e.g., summer break = 1), and body mass index (BMI).

Analysis

Preliminary analyses included zero order correlations among SES, HOME scales, and sleep indicators. Next, to broadly characterize genetic and environmental influences, twin intraclass correlations were conducted (ICCs). The current sample size was too small to obtain more precise estimates of genetic effects using multi-group structural equation model fitting (Neale and Maes, 2004). However, twin ICCs can be used descriptively to obtain general estimates of genetic and environmental effects. MZ ICCs higher than DZ ICCs indicate genetic influences on sleep indicators, because MZ twins share 100% of their segregating genes, whereas DZ twins share 50% on average. The extent to which DZ twins are more than half as similar as MZ twins indicates shared environmental influences, and the extent to which MZ twins are not perfectly correlated provides an estimate of nonshared environmental influences plus measurement error.

Multivariate analyses were conducted with MPlus 7.0 using full information maximum likelihood (FIML) estimation to handle missing data and adjusting for covariates identified in preliminary analyses. Covariates were allowed to correlate with each other as well as early SES. Nonsignificant covariances were omitted to increase degrees of freedom. Model fit was examined using recommended fit indices and cutoffs on χ^2 , CFI, RMSEA, and SRMR (Hu and Bentler, 1999). A 2 → 2 → 1 multilevel mediation path model was used to adjust for nesting of twins within family (Preacher et al., 2010; Preacher et al., 2011). Such a model was necessary as the primary predictors of interest (e.g., SES, HOME total) were measured and modeled at the family level (e.g., the same for both twins in a family), whereas all sleep parameters were twin-specific estimates. HOME total was examined as a mediator in the association between early SES and children's sleep. Specifically, we simultaneously estimated five indicators of children's sleep: duration, efficiency, latency, midpoint variability, and parent-reported sleep problems. Mediation of the effect of early SES on sleep by HOME total was tested by examining the statistical significance of the indirect effect using 95% confidence intervals (Preacher et al., 2010; Preacher et al., 2011).

If the 95% confidence interval does not include zero, the path is statistically significant. The total (e.g., associations between early SES and sleep without mediating variable), direct (e.g., relation between early SES and sleep adjusting for the HOME total), and indirect effects (e.g., effect of early SES on sleep through the HOME total) were estimated.

Sensitivity analyses examined whether SES at eight years was an important covariate or whether SES at eight years was a stronger predictors of children's concurrent sleep in full path model. Additional sensitivity analyses were conducted to examine the potential mediating pathways for specific subscales of the HOME – the HOME Physical Environment, HOME Emotional Climate, and HOME Encouragement of Maturity.

Results

Preliminary Analyses

Table 1 contains descriptive statistics and zero order phenotypic correlations for all study variables. On average, children slept approximately 8.11 hours ($SD = .71$) per night, which reflects the low end of current sleep recommendations (National Sleep Foundation, 2015). Two variables exceeded recommended cutoffs for positive or negative skew (2.00) or kurtosis (7.00; Muthén and Kaplan, 1985). Sleep latency was positively skewed so a log transformed value was used in all analyses. The Physical Environment subscale of the HOME was negatively skewed and was squared to approximate normality for all multivariate analyses. Sleep duration was significantly positively correlated with SES and all indicators of the HOME. Sleep onset latency and parent-reported sleep problems were negatively correlated with the HOME total, Physical Environment, and SES. Sleep latency was negatively correlated with the HOME total, Emotional Climate, Physical Environment, and SES. Midpoint variability was negatively correlated with all SES and all HOME indicators with the exception of Encouragement of Maturity. Covariates that were marginally or significantly correlated with primary study variables (Table 1) were included in final analytic models (e.g., sex, BMI, and race/ethnicity were included as within family factors in multivariate analyses predicting sleep duration).

Twin ICC's are presented in Table 2. For objective sleep parameters, twin ICCs suggested both genetic and shared environmental influences, with about half the variance in objective sleep explained by genetic factors for duration (46%) and efficiency (49%), only 14% of the variance in latency and 23% of the variance in midpoint variability explained by genetic factors, and estimates of shared environmental variance ranging from 24–67%. Parent-report of sleep problems was highly heritable (80%), with shared and nonshared environmental influences accounting for 12% and 8% of the variance, respectively.

Multilevel Path Model Predicting Sleep

Prior to testing mediation, total effects of SES on sleep were calculated in a panel model examining the direct associations between early SES and the five sleep indicators. There was good model fit, $X^2(57) = 358.257$, $p < .001$, CFI = 1.00, RMSEA = .000, and SRMR within = .026, SRMR between = .060. Higher early SES was associated with longer sleep duration ($B = .178$ {95% CI, .058, .298}, $SE = .061$, $p = .004$), shorter sleep latency ($B = -.159$ {95%

CI, $-.285, -.033$, $SE = .064$, $p = .013$), and lower midpoint variability ($B = -.056$ {95% CI, $-.108, -.003$ }, $SE = .027$, $p = .038$), but not sleep efficiency or parent-reported sleep problems.

The full mediational model was estimated with early SES and HOME total as predictors of the different facets of sleep (see Figure 1) and demonstrated good model fit, $X^2(76) = 588.303$, $p < .001$, CFI = 1.00, RMSEA = .000, and SRMR within = .026, SRMR between = .067. Covariates included sex, BMI, SES at 8 years, and race/ethnicity. Early SES was positively associated with HOME total ($B = .026$ {95% CI, $.017, .034$ }, $SE = .004$, $p < .001$). In this full model, there were no direct effects of early SES on any of the indicators of sleep, although associations with sleep duration and efficiency were at $p < .10$ (duration: $B = .131$ {95% CI, $-.005, .267$ }, $SE = .069$, $p = .059$; efficiency: $B = .934$ {95% CI, $-.137, 2.005$ }, $SE = .547$, $p = .088$).

The HOME total was positively associated with sleep duration ($B = 1.219$ {95% CI, $.166, 2.272$ }, $SE = .537$, $p = .023$) and the indirect path from early SES to sleep duration through HOME total was significant ($B = .031$ {95% CI, $.003, .059$ }, $SE = .014$, $p = .028$). The HOME total was negatively associated with sleep latency ($B = -1.220$ {95% CI, $-2.434, -.006$ }, $SE = .619$, $p = .049$) and the indirect path was not significant ($B = -.031$ {95% CI, $-.066, .003$ }, $SE = .018$, $p = .074$). In regard to the prediction of midpoint variability, greater HOME total was significantly associated with less variability ($B = -.522$ {95% CI, $-.944, -.099$ }, $SE = .216$, $p = .015$) and the indirect path from early SES to midpoint variability through HOME total was significant ($B = -.013$ {95% CI, $-.024, -.003$ }, $SE = .006$, $p = .016$). Finally, there were no significant direct or indirect paths predicting sleep efficiency or parent-reported sleep problems in the final model.

Sensitivity Analyses

Several sets of sensitivity analyses were conducted to test the robustness of these findings. Early SES and SES at eight years were highly correlated, therefore the full model was tested without including SES at eight years as a covariate. Model fit was strong $X^2(66) = 411.884$, $p < .001$, CFI = 1.00, RMSEA = .000, and SRMR within = .026, SRMR between = .065. All path estimates were similar to the model controlling for SES at eight years with a few exceptions. These include results suggesting that without controlling for concurrent SES, early SES was a significant predictor of sleep duration, and the HOME total was not significantly associated with sleep latency. The indirect effects from early SES to sleep duration and midpoint variability remained significant and similar in magnitude.

Next, a model was fit where SES at eight years was the primary independent variable and HOME total was the mediator in the prediction of all five sleep indicators. There was good model fit, $X^2(76) = 588.303$, $p < .001$, CFI = 1.00, RMSEA = .000, and SRMR within = .025, SRMR between = .066. However, there were several differences in path estimates when compared to the final model. SES at 8 years was positively associated with HOME total ($B = .056$ {95% CI, $.041, .070$ }, $SE = .008$, $p < .001$) and sleep efficiency ($B = 1.302$ {95% CI, $.213, 2.390$ }, $SE = .556$, $p = .019$), but was not directly associated with sleep duration, sleep latency, midpoint variability or sleep problems. The indirect path from SES at eight years to sleep duration through HOME total was significant ($B = .065$ {95% CI, $.000, .130$ },

SE = .033, $p = .048$), as was the indirect path from SES at eight years to midpoint variability through HOME total ($B = -.031$ {95% CI, $-.055, -.007$ }, SE = .012, $p = .012$). Finally, there were no significant direct or indirect paths predicting sleep latency, sleep efficiency or parent-reported sleep problems when using SES at eight years as compared to early SES. Such findings suggest that estimates when using the different indicators of SES are similar but there are some distinct differences in the prediction of sleep efficiency and sleep latency.

Finally, given strong associations with the HOME total and prior empirical work linking the HOME to qualities of sleep in children and adolescence (e.g., Spilsbury et al., 2005), Emotional Climate, Physical Environment, and Encouragement of Maturity subscales were examined as alternate mediators of early SES and the five indicators of sleep. Importantly, in preliminary path models early SES was not a significant predictor of Encouragement of Maturity so the full model was not tested. The full path model with HOME Emotional Climate as the mediator fit the data well, $X^2(76) = 536.679$, $p < .001$, CFI = 1.00, RMSEA = .000, and SRMR within = .026, SRMR between = .064. However, there were no significant direct paths between the HOME Emotional Climate and the five indicators of sleep (all $ps > .05$). Last, the full model path model with HOME Physical Environment as the mediator fit the data well, $X^2(76) = 554.633$, $p < .001$, CFI = 1.00, RMSEA = .000, and SRMR within = .025, SRMR between = .067. Early SES was positively associated with HOME Physical Environment ($B = .050$ {95% CI, $.023, .077$ }, SE = .014, $p < .001$), sleep duration ($B = .145$ {95% CI, $.014, .275$ }, SE = .067, $p = .030$), and midpoint variability ($B = -.055$ {95% CI, $-.101, -.008$ }, SE = .024, $p = .021$), but not sleep efficiency, sleep latency or sleep problems. The HOME Physical Environment was positively associated with sleep duration ($B = .457$ {95% CI, $.084, .831$ }, SE = .191, $p = .016$), and negatively associated with sleep latency ($B = -.421$ {95% CI, $-.840, -.002$ }, SE = .214, $p = .049$). However, there were only significant indirect effects of early SES through HOME Physical Environment on sleep duration ($B = .023$ {95% CI, $.002, .044$ }, SE = .022, $p = .032$). There were no significant direct or indirect paths predicting sleep efficiency, sleep midpoint variability or parent-reported sleep problems.

Discussion

While a growing body of empirical research has documented concurrent socioeconomic disparities in sleep in children and adolescents (e.g., El-Sheikh et al., 2013; Marco et al., 2012), researchers have yet to examine the influence of early life SES (e.g., in infancy) on sleep in middle childhood or the proximal mechanisms underlying such longitudinal associations. This study builds on the broader literature by showing that lower *early life* SES predicted shorter sleep duration and worse sleep quality seven years later in a socioeconomically and racially diverse sample of twins in middle childhood. Following theorized pathways regarding the changing influence of SES across development and calls for research examining potential mediators of early socioeconomic influences on health (Chen et al., 2002), the most novel contribution was the examination of the home environment as a potential mechanism through which early SES affects childhood sleep. SES and the quality of the home environment were associated with sleep duration, latency and midpoint variability, and this is the first study to uncover that quality of the home environment mediated the effects of early SES on sleep duration and variability. Given

studies showing that sleep during childhood and adolescence predicts cognitive, socioemotional, and physical well-being (e.g., Dewald et al., 2010; O'Brien, 2009), and that childhood SES predicts adult sleep outcomes (Tomfohn et al., 2010), the present findings provide new information about potential targetable pathways through which early SES may influence sleep. Notably, these novel associations were identified using gold standard measurements of the home environment and multiple indicators of sleep including objective actigraphy and parent-report.

As hypothesized, early life SES was positively associated with sleep duration and negatively associated with latency and variability (but not parent-reported sleep problems or efficiency). Associations between SES and sleep identified in previous literature primarily relying on parent-reports of children's sleep have often varied by measurement of SES and sleep (e.g., Adam et al., 2007; El-Sheikh et al., 2010; El-Sheikh et al., 2013; Spilsbury et al., 2006). Further, previous studies have focused on the importance of the current socioeconomic environment, as opposed to examining whether SES may have differential influences depending on the developmental period examined. The current study's findings suggest that early SES is an important predictor of children's sleep, over and above associations with concurrent SES. One hypothesis is that experiences and resources in early life may influence a child's ability to develop routines and regulatory control over their sleep (e.g., self-soothing), and subsequent development and sleep patterns (e.g., Williams et al., 2015).

Recent research and critical reviews examining sleep in conjunction with different domains of functioning have noted the importance of including multiple indicators or methods for assessing sleep (Dewald et al., 2010; Gregory and Sadeh, 2012), which is further supported by results in this study. While some studies using parent-reported sleep have found associations between SES and children's sleep (e.g., Adam et al., 2007) and have used the CSHQ (e.g., Jarrin et al., 2014), the current study did not identify links between SES and parent-reported sleep problems. This suggests that more normative deviations in sleep (as captured by actigraphy), rather than chronic sleep disturbances, may be more related to early SES given the age of our sample (i.e., middle childhood). Future research should examine pathways between SES and both typical sleep patterns and more serious sleep problems across multiple periods of development to understand the development of more serious sleep disturbances longitudinally.

The second aim of the current study was to examine whether quality of the home environment was associated with children's sleep and whether the home environment was a proximal *mechanism* between early SES and sleep. Results suggested links between the total quality of the home environment and children's sleep. Specifically, higher quality home environments were associated with longer sleep duration, shorter sleep latencies, and less sleep variability. Only one other study has connected measurement of the home environment using the HOME with sleep in middle childhood (e.g., Spilsbury et al., 2005). The current study's results are primarily consistent with Spilsbury and colleagues' finding that the HOME total score was associated with sleep duration, but only for African American children. While the majority of children in this study were European American or Latino, similar associations were identified for all children in terms of sleep duration. Further, the

current study illustrated that the quality of the home environment was linked not only with the length of sleep, but with sleep quality and variability in sleep timing. In addition, like Spilsbury and colleagues (2005), it was found that encouragement of maturity was positively related to sleep duration and, in this study, to less sleep variability. This suggests that across methods of assessment (daily diaries, actigraphy), parents' promotion of autonomy in middle childhood promotes more sleep and less variable sleep, likely reflecting encouragement of consistent routines and self-regulatory abilities.

The next aim was to understand whether the quality of the home environment mediated associations between early SES and sleep duration and quality, or whether each was an independent predictor of sleep. Consistent with theoretical models (Chen et al., 2002; Conger et al., 2010), past research (e.g., Schreier et al., 2014), and the current study's hypotheses, the total quality of the home environment significantly mediated associations between early SES and sleep duration and mediated associations between early SES and sleep midpoint variability. Recent evidence from low income community samples shows that short term interventions in infancy and early childhood can improve sleep by changing qualities of the physical sleep environment and bedtime routines (e.g., Labella et al., 2017). The current study's findings suggest that the home environment in middle childhood is also an important, targetable environment for promoting high quality sleep, particularly *before* children begin puberty and adolescence when both biologically and environmentally-driven shifts in sleep duration and timing occur (Carskadon, 2011; Crowley et al., 2014).

To understand whether there were particularly potent home environment predictors of sleep, sensitivity analyses of subscales with both theoretical and empirical support for their relations to sleep were conducted. For example, given research showing the importance of the interpersonal context of the home for sleep in children (Bell and Belsky, 2008; Keller and El-Sheikh, 2011), the emotional climate of the home was explored as a predictor of subjective and objective sleep. In contrast to past research, in multivariate analyses, no links were found between higher quality emotional climates in the home and more adaptive indicators of sleep. Past studies have identified that indicators such as parental warmth, responsivity, and emotional well-being are related to children's sleep in early and middle childhood (Adam et al., 2007; Bell and Belsky, 2008; Keller and El-Sheikh, 2011). It is possible that the current study's indicator of emotional climate did not capture the qualities of parenting that might be important for sleep. For example, parent-child relationships characterized by emotional attunement and closeness might promote feelings of security leading to longer sleep duration and shorter sleep latencies. However, the indicator of emotional climate used in this study was based primarily on observed interactions during a structured home visit so may not represent the full range of parenting. Further, findings did not support emotional climate as a mediator, suggesting that a more global indicator of home environment is the best proximal mechanism linking early SES with sleep.

This study also examined whether the physical home environment was associated with longer and better-quality sleep. El-Sheikh and colleagues (2013) proposed that using an investment model (Yeung et al., 2002) could help explain how SES is associated with sleep. Such a framework suggests that a family's ability to invest in high quality environments (e.g., those that promote good quality sleep) may explain SES disparities in sleep. Consistent

with this framework, high quality physical environments were related to longer sleep duration and shorter latencies in the present study. Further, quality of the physical environment significantly mediated associations between SES and sleep duration. These findings suggest that the home environments of youth in higher SES families may be more likely to promote sleep through quieter, more consistent (e.g., same sleeping location, temperature) contexts.

The current study's results should be compared with those of Bagley and colleagues (2015), who found that lower quality sleep environments were associated with greater sleep variability, subjective sleep problems, and daytime sleepiness, but not duration, in a predominantly low-income community sample of early adolescents. Further, poor environmental conditions served as intervening variables for associations between SES and sleep variability, and mediated associations between SES and sleep problems. Interestingly, the current study did not replicate associations with variability or sleep problems. However, direct pathways were found between lower quality home environments and another indicator of sleep quality, sleep latency, which Bagley and colleagues (2015) did not assess. There are several possibilities for the inconsistencies across studies. This study used different measures of the physical environment and SES (e.g., concurrent vs. early life), and the sample was more socioeconomically diverse and younger than those studied by Bagley and colleagues (2015). Even so, both studies identified qualities of the physical environment as important direct contributors to children's sleep quality and potential mechanisms that can be targeted to mitigate socioeconomic disparities in sleep.

While the current study identified the total home environment as an important contributor to individual differences in children's sleep and mediating mechanism between SES and sleep duration and quality, it should be emphasized that analyses using just the indicators of emotional climate and physical environment did not fully replicate the findings from the full scale. This suggests that these factors may contribute to children's sleep, but do not fully represent how early SES may be associated with children's sleep. This presents a challenge for prevention and intervention work, indicating that we must evaluate the broader home environment, rather than the piece-meal, variable-by-variable approach that is typically employed.

This study had several notable strengths. A first strength was the longitudinal design with multi-method assessments of sleep in a large socioeconomically diverse sample of twins in middle childhood with strong representation of Latino youth. Second, one potential mechanism underlying socioeconomic disparities in sleep was explored. Future analyses with larger samples will allow genetic and environmental decomposition of relations between sleep and twin-specific aspects of the environment, allowing for more targeted recommendations about pathways for intervention. Third, to minimize the influence of parent self-report, this study used a well-known standardized assessment of the home environment for middle childhood (Caldwell and Bradley, 2003). The HOME is considered a gold standard measure of the home environment because it is a developmentally appropriate, multi-rater (parent and observer) assessment that has been validated in diverse populations, across observers, and over time within the United States (Bradley, 1994; Caldwell and Bradley, 2003). Finally, the current research findings have important

developmental implications for youth in middle childhood as they prepare to enter adolescence. Specifically, given the numerous changes in sleep during adolescence due to both biological (e.g., phasic shifts; Crowley et al., 2014) and environmental influences (e.g., school start times, increasing responsibilities; Carskadon, 2011), which have been shown to influence subsequent health and well-being (for review see Owens et al., 2014), the current study illustrated important targetable environmental influences on sleep during a time of relative stability. For example, these findings may provide the basis for understanding whether environmental influences on sleep during adolescence are novel (e.g., new sources of influence) or whether they are simply continuations of existing patterns or trajectories.

Despite these strengths, some limitations should be noted. First, this sample of twin children may not be representative of single-born children. For example, twins may be more likely to share a room, leading to greater sleep problems, longer latencies or more night-time wakings. In general, twins are representative of singletons for measures of development including temperament and personality (Borkenau et al., 2002; Johnson et al., 2002), and family demographics, biological maturity, self-control, and psychopathology (Barnes and Boutwell, 2013). Results on sleep should be replicated in samples of single-born children to ensure generalizability.

A second limitation is that the measurement of the home environment and children's sleep occurred close together in time (i.e., the home environment was assessed at a home visit, and the children began wearing the watches to assess sleep beginning the following Sunday evening), precluding the ability to discuss direction of effects or bidirectional processes. For example, it is possible that early SES may directly influence children's sleep quality which, in turn, may influence the quality of the home environment including parent responsiveness, parental autonomy granting, or conflict in the home. Although no one has considered bidirectional influences of the home environment and sleep, some recent work has considered bidirectional associations between characteristics of the parent and children's sleep, showing that parental drinking was prospectively associated with shorter sleep duration and lower sleep efficiency in children, but that greater child awakenings were also prospectively associated with greater paternal problem drinking (Kelly and El-Sheikh, 2018). Future work should aim to include both concurrent and prospective prediction of sleep to understand potential bidirectional longitudinal associations.

A final limitation is that the measures of early life SES represent qualities of the parents (e.g., education, income) rather than more global indicators of the neighborhood, schools, or other community resources. Some research suggests that different facets of SES or adversity may be related differentially to sleep (e.g., El-Sheikh et al., 2013), so it may be that significant pathways between SES and sleep (e.g., subjective sleep problems) were not identified because the current study did not include measure of SES beyond parent's reported education and income to needs ratio.

Conclusion

Understanding pathways toward high quality sleep across socioeconomic groups is imperative given the importance of sleep for academic functioning, interpersonal and

socioemotional well-being, and physical health, particularly during adolescence. This study identified unique associations between lower socioeconomic status in infancy and shorter sleep duration and worse sleep quality seven years later. Importantly, quality of the home environment in middle childhood was a key mediator of such associations for sleep duration and variability of sleep schedules. Such findings add to growing evidence suggesting that the quality of home environment is a potential pathway between early life SES and sleep. Future studies should examine specific sleep-related cognitions and qualities of the physical environment in the home as potential malleable factors that researchers and clinicians can endorse as positive influences on children's sleep. Indeed, many aspects of the home environment are malleable (e.g., quality of sleep environment) and can be important targets of interventions aimed at supporting children's sleep within the family context. Interventions that occur prior to previously identified biological and environmental shifts toward poor sleep during adolescence may have the ability to promote positive academic and behavioral outcomes for adolescents through higher quality sleep.

Acknowledgment

Funding

This research was supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development of the National Institutes of Health under Award Number R01HD079520 and a William T. Grant Foundation Early Scholar Award to LDD.

Biographies

Leah D. Doane, Ph.D., is an Associate Professor of Psychology at Arizona State University. She received her doctorate in Human Development and Social Policy from Northwestern University's School of Education and Social Policy. Her research uses culturally and genetically informed designs to understand the dynamic daily interplay between socioemotional experiences and indicators of health and well-being (including physiological stress processes and sleep) in the prediction of subsequent psychopathology, physical health and academic achievement in childhood and adolescence.

Reagan Breitenstein, M.A., is a graduate student at Arizona State University pursuing her Doctorate in Developmental Psychology. Her major research interests include understanding relations between child and adolescent sleep and mental and physical health and psychosocial outcomes. She is also focused on identifying genetic and environmental contributions to associations between sleep indicators and health and psychosocial outcomes in childhood.

Charlie Beekman, Ph.D., manages research analysis at the John F. Kennedy Center for the Performing Arts. He received his doctorate in Developmental Psychology (Methodology emphasis) at the Pennsylvania State University and was a Postdoctoral Scholar in the Department of Psychology at Arizona State University. He is interested broadly in the quantitative analysis of change and developmental methodology. His current major substantive interests include research focused on how genetic and environmental factors and

the arts transact to influence adaptive child social/emotional development and physical/mental health.

Sierra Clifford, Ph.D., received her doctorate in Developmental Psychology and Master of Arts in Psychology at Arizona State University. Her major research interests include childhood temperament, social development, and twin and molecular genetic methodology, with an emphasis on gene-environment interplay.

Trevor Smith, B.S., received his Bachelor's degree in Biochemistry at Arizona State University. His research interests include studying the interplay between genetic and environmental influences in early childhood and adolescence and measuring the long-term health outcomes of children based on these factors. He is focused on identifying areas of intervention for at-risk youth and their families which may be used by physicians and public health officials to promote health development.

Kathryn Lemery-Chalfant, Ph.D., is Professor of Psychology at Arizona State University. She received her doctorate in Psychology from University of Wisconsin-Madison. She uses genetically informative study designs to understand risk and resilience processes across childhood and adolescence. In particular, she focuses on developmental psychopathology, substance use, sleep, and pain.

References

- Acebo C, Sadeh A, Seifer R, Tzischinsky O, Wolfson AR, Hafer A, & Carskadon MA (1999). Estimating sleep patterns with activity monitoring in children and adolescents: How many nights are necessary for reliable measures? *SLEEP*, 22(1), 95–103. doi:10.1093/sleep/22.1.95 [PubMed: 9989370]
- Adam EK, Snell EK, & Pendry P (2007). Sleep timing and quantity in ecological and family context: a nationally representative time-diary study. *Journal of Family Psychology*, 21(1), 4. doi: 10.1037/0893-3200.21.1 [PubMed: 17371105]
- Arman AR, Ay P, Fis NP, Ersu R, Topuzoglu A, Isik U, & Berkem M (2011). Association of sleep duration with socio-economic status and behavioural problems among schoolchildren. *Acta Paediatrica*, 100(3), 420–424. doi:10.1111/j.1651-2227.2010.02023 [PubMed: 20860707]
- Bagley EJ, Kelly RJ, Buckhalt JA, & El-Sheikh M (2015). What keeps low-SES children from sleeping well: the role of presleep worries and sleep environment. *Sleep Medicine*, 16(4), 496–502. doi:10.1016/j.sleep.2014.10.008 [PubMed: 25701537]
- Barnes JC, & Boutwell BB (2013). A demonstration of the generalizability of twin-based research on antisocial behavior. *Behavior Genetics*, 43(2), 120–131. doi:10.1007/s10519-012-9580-8 [PubMed: 23274656]
- Bell BG, & Belsky J (2008). Parents, parenting, and children's sleep problems: Exploring reciprocal effects. *British Journal of Developmental Psychology*, 26(4), 579–593. doi: 10.1348/026151008X285651
- Bernier A, Bélanger MÈ, Bordeleau S, & Carrier J (2013). Mothers, fathers, and toddlers: Parental psychosocial functioning as a context for young children's sleep. *Developmental Psychology*, 49(7), 1375. doi:10.1037/a0030024 [PubMed: 22985297]
- Biggs SN, Lushington K, van den Heuvel CJ, Martin AJ, & Kennedy JD (2011). Inconsistent sleep schedules and daytime behavioral difficulties in school-aged children. *Sleep Medicine*, 12(8), 780–786. doi: 10.1016/j.sleep.2011.03.017 [PubMed: 21862401]
- Biringen Z (2000). Emotional availability: Conceptualization and research findings. *American Journal of Orthopsychiatry*, 70(1), 104. [PubMed: 10702855]

- Borkenau P, Riemann R, Angleitner A, & Spinath FM (2002). Similarity of childhood experiences and personality resemblance in monozygotic and dizygotic twins: A test of the equal environments assumption. *Personality and Individual Differences*, 33(2), 261–269. doi:10.1016/S0191-8869(01)00150-7
- Bradley RH (1994). The Home Inventory: Review and Reflections. *Advances in Child Development and Behavior*, 25, 241–288. [PubMed: 7847171]
- Bradley RH, & Corwyn RF (2002). Socioeconomic status and child development. *Annual Review of Psychology*, 53(1), 371–399. doi:10.1146/annurev.psych.53.100901.135233
- Brooks-Gunn J, & Duncan GJ (1997). The effects of poverty on children. *The Future of Children*, 55–71. doi:10.2307/1602387 [PubMed: 9299837]
- Buckhalt JA (2011). Insufficient sleep and the socioeconomic status achievement gap. *Child Development Perspectives*, 5(1), 59–65. doi:10.1111/j.1750-8606.2010.00151.x
- Buckhalt JA, El-Sheikh M, & Keller P (2007). Children's sleep and cognitive functioning: Race and socioeconomic status as moderators of effects. *Child Development*, 78(1), 213–231. doi:10.1111/j.1467-8624.2007.00993.x [PubMed: 17328701]
- Caldwell BM, & Bradley RH (2003). *Home Inventory Administration Manual*. University of Arkansas for Medical Sciences.
- Calhoun SL, Vgontzas AN, Fernandez-Mendoza J, Mayes SD, Tsaoussoglou M, Basta M, & Bixler EO (2011). Prevalence and risk factors of excessive daytime sleepiness in a community sample of young children: the role of obesity, asthma, anxiety/depression, and sleep. *Sleep*, 34(4), 503–507. doi: 10.1093/sleep/34.4.503 [PubMed: 21461329]
- Cappuccio FP, Taggart FM, Kandala NB, Currie A, Peile E, Stranges S, & Miller MA (2008). Meta-analysis of short sleep duration and obesity in children and adults. *Sleep*, 31(5), 619–626. [PubMed: 18517032]
- Carskadon MA (2011). Sleep in adolescents: the perfect storm. *Pediatric Clinics of North America*, 58, 637–647. doi: 10.1016/j.pcl.2011.03.003 [PubMed: 21600346]
- Chen E, Matthews KA, & Boyce WT (2002). Socioeconomic differences in children's health: how and why do these relationships change with age?. *Psychological Bulletin*, 128(2), 295–329. doi: 10.1037//0033-2909.128.2.295 [PubMed: 11931521]
- Cohen S, Janicki-Deverts D, Chen E, & Matthews KA (2010). Childhood socioeconomic status and adult health. *Annals of the New York Academy of Sciences* (1186), 37–55. doi: 10.1111/j.1749-6632.2009.05334.x
- Conger RD, Conger KJ, & Martin MJ (2010). Socioeconomic status, family processes, and individual development. *Journal of Marriage and Family*, 72(3), 685–704. doi:10.1111/j.1741-3737.2010.00725.x [PubMed: 20676350]
- Conger RD, & Donnellan MB (2007). An interactionist perspective on the socioeconomic context of human development. *Annual Review of Psychology*, 58, 175–199. doi:10.1146/annurev.psych.58.110405.085551
- Crowley SJ, Tarokh L, & Carskadon MA (2014). Sleep during adolescence Sheldon SH, Kryger MH, Ferber R, & Gozal D (Eds). In *Principles and Practice of Pediatric Sleep Medicine 2nd Edition* (pp. 45–51). China: Elsevier Saunders.
- Davies PT, Sturge-Apple ML, & Martin MJ (2013). Family discord and child health: An emotional security formulation In Landale N, McHale S, Booth A (Eds.), *Families and Child Health* (pp. 45–74). Springer: New York. doi:10.1007/978-1-4614-6194-4_5
- Dewald JF, Meijer AM, Oort FJ, Kerkhof GA, & Bögels SM (2010). The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: a meta-analytic review. *Sleep Medicine Reviews*, 14(3), 179–189. doi:10.1016/j.smrv.2009.10.004 [PubMed: 20093054]
- Dumas J, Nissley J, Nordstrom A, Smith E, Prinz R, & Levine D (2005). Home chaos: Sociodemographic, parenting, interactional, and child correlates. *Journal of Clinical Child & Adolescent Psychology*, 34(1), 93–104. doi:10.1207/s15374424jccp3401_9 [PubMed: 15677284]
- El-Sheikh M, Bagley EJ, Keiley M, Elmore-Staton L, Chen E, & Buckhalt JA (2013). Economic adversity and children's sleep problems: Multiple indicators and moderation of effects. *Health Psychology*, 32(8), 849. doi:10.1037/a0030413 [PubMed: 23148451]

- El-Sheikh M, Buckhalt JA, Keller PS, Cummings EM, & Acebo C (2007). Child emotional insecurity and academic achievement: the role of sleep disruptions. *Journal of Family Psychology*, 21(1), 29. doi:10.1037/0893-3200.21.1.29 [PubMed: 17371107]
- El-Sheikh M, Buckhalt JA, Mize J, & Acebo C (2006). Marital conflict and disruption of children's sleep. *Child Development*, 77(1), 31–43. doi:10.1111/j.1467-8624.2006.00854.x [PubMed: 16460523]
- El-Sheikh M, Buckhalt JA, Cummings EM, & Keller P (2007). Sleep disruptions and emotional insecurity are pathways of risk for children. *Journal of Child Psychology and Psychiatry*, 48(1), 88–96. doi:10.1111/j.1469-7610.2006.01604.x [PubMed: 17244274]
- El-Sheikh M and Kelly RJ (2017). Family functioning and children's sleep. *Child Development Perspectives*. doi:10.1111/cdep.12243
- El-Sheikh M, Kelly RJ, Buckhalt JA, & Hinnant J (2010). Children's sleep and adjustment over time: The role of socioeconomic context. *Child Development*, 81(3), 870–883. doi:10.1111/j.1467-8624.2010.01439.x [PubMed: 20573110]
- Erath SA, & Tu KM (2011). The parenting context of children's sleep In El-Sheikh M (Ed.), *Sleep and development: Familial and Socio-Cultural Considerations* (pp.29–48). Oxford, UK: Oxford University Press.
- Evans G, Gonnella C, Marcynyszyn L, Gentile L, & Salpekar N (2005). The role of chaos in poverty and children's socioemotional adjustment. *Psychological Science*, 16(7), 560–565. doi:10.1111/j.0956-7976.2005.01575.x [PubMed: 16008790]
- Evans GW (2006). Child development and the physical environment. *Annual Review of Psychology*, 57, 423–451. doi:10.1146/annurev.psych.57.102904.190057
- Gregory AM, Rijdsdijk FV, Dahl RE, McGuffin P, & Eley TC (2006). Associations between sleep problems, anxiety, and depression in twins at 8 years of age. *Pediatrics*, 118(3), 1124–1132. doi:10.1542/peds.2005-3118 [PubMed: 16951007]
- Gregory AM, Rijdsdijk FV, & Eley TC (2006). A twin-study of sleep difficulties in school-aged children. *Child Development*, 77(6), 1668–1679. doi:10.1111/j.1467-8624.2006.00966.x [PubMed: 17107453]
- Gregory AM, & Sadeh A (2012). Sleep, emotional and behavioral difficulties in children and adolescents. *Sleep Medicine Reviews*, 16(2), 129–136. doi:10.1016/j.smrv.2011.03.007 [PubMed: 21676633]
- Hackman DA, Gallop R, Evans GW, & Farah MJ (2015). Socioeconomic status and executive function: Developmental trajectories and mediation. *Developmental Science*, 18(5), 686–702. doi:10.1111/desc.12246 [PubMed: 25659838]
- Hale L, Berger L, Lebourgeois M, & Brooks-Gunn J (2009). Social and demographic predictors of preschoolers' bedtime routines. *Journal of Developmental and Behavioral Pediatrics: JDBP*, 30(5), 394–402. doi:10.1097/DBP.0b013e3181ba0e64 [PubMed: 19745760]
- Hu LT, & Bentler PM (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, 6(1), 1–55. doi:10.1080/10705519909540118
- Jarrin DC, McGrath JJ, & Quon EC (2014). Objective and subjective socioeconomic gradients exist for sleep in children and adolescents. *Health Psychology*, 33(3), 301. doi:10.1037/a0032924 [PubMed: 23730721]
- Johnson W, Krueger RF, Bouchard TJ, & McGue M (2002). The personalities of twins: Just ordinary folks. *Twin Research and Human Genetics*, 5(2), 125–131. doi:10.1375/1369052022992
- Keller P, & El-Sheikh M (2011). Children's emotional security and sleep: Longitudinal relations and directions of effects. *Journal of Child Psychology and Psychiatry*, 52(1), 64–71. doi:10.1111/j.1469-7610.2010.02263.x [PubMed: 20500540]
- Kelly RJ, & El-Sheikh M (2011). Marital conflict and children's sleep: reciprocal relations and socioeconomic effects. *Journal of Family Psychology*, 25(3), 412. doi:10.1037/a0023789 [PubMed: 21553963]
- Kelly RJ, & El-Sheikh M (2018). Reciprocal relations between parental problem drinking and children's sleep: the role of socioeconomic adversity. *Child Development*. doi:10.1111/cdev.13074

- Kouros CD, & El- Sheikh M (2015). Daily mood and sleep: reciprocal relations and links with adjustment problems. *Journal of Sleep Research*, 24(1), 24–31. doi: 10.1111/jsr.12226 [PubMed: 25212526]
- Lemery-Chalfant K, Clifford S, McDonald K, O'Brien TC, & Valiente C (2013). Arizona Twin Project: A Focus on early resilience. *Twin Research and Human Genetics*, 16(1), 404–411. doi: 10.1017/thg.2012.107 [PubMed: 23394195]
- Liew J, Kwok O, Chang YP, Chang BW, & Yeh YC (2014). Parental autonomy support predicts academic achievement through emotion-related self-regulation and adaptive skills in Chinese American adolescents. *Asian American Journal of Psychology*, 5(3), 214. doi:10.1037/a0034787
- Magee L, & Hale L (2012). Longitudinal associations between sleep duration and subsequent weight gain: A systematic review. *Sleep Medicine Reviews*, 16(3), 231–241. doi:10.1016/j.smrv.2011.05.005 [PubMed: 21784678]
- Marco CA, Wolfson AR, Sparling M, & Azuaje A (2012). Family socioeconomic status and sleep patterns of young adolescents. *Behavioral Sleep Medicine*, 10(1), 70–80. doi: 10.1080/15402002.2012.636298
- Meijer AM, Reitz E, & Deković M (2016). Parenting matters: A longitudinal study into parenting and adolescent sleep. *Journal of Sleep Research*, 25(5), 556–564. doi:10.1111/jsr.12406 [PubMed: 27178659]
- Moore PJ, Adler NE, Williams DR, & Jackson JS (2002). Socioeconomic status and health: the role of sleep. *Psychosomatic Medicine*, 64(2), 337–344. [PubMed: 11914451]
- Muthén B, & Kaplan D (1985). A comparison of some methodologies for the factor analysis of non-normal Likert variables. *British Journal of Mathematical and Statistical Psychology*, 38(2), 171–189. doi:10.1111/j.2044-8317.1985.tb00832.x
- National Sleep Foundation. (2014, March). Sleep in America Poll: Sleep in the Modern Family. Retrieved from: <http://www.sleepfoundation.org/sleep-polls-data/sleep-in-america-poll/2014-sleep-in-the-modern-family>
- Neale MC, & Maes HM (2004). Methodology for Genetic Studies of Twins and Families. Retrieved March 2, 2004, <http://www.vipbg.vcu.edu/~vipbg/mx/book2004a.pdf>.
- O'Brien LM (2009). The neurocognitive effects of sleep disruption in children and adolescents. *Child and Adolescent Psychiatric Clinics of North America*, 18, 813–823. doi:10.1016/j.chc.2009.04.008 [PubMed: 19836689]
- Owens J, Adolescent Sleep Working Group, and Committee on Adolescence. (2014). Insufficient sleep in adolescents and young adults: an update on causes and consequences. *Pediatrics*, 134 (3), e921–e932. doi:10.1542/peds.2014-1696 [PubMed: 25157012]
- Owens JA, Maxim R, Nobile C, McGuinn M, & Msall M (2000a). Parental and self-report of sleep in children with attention-deficit/hyperactivity disorder. *Archives of Pediatrics & Adolescent Medicine*, 154(6), 549–555. doi:10.1001/archpedi.154.6.549 [PubMed: 10850500]
- Owens JA, Spirito A, & McGuinn M (2000b). The Children's Sleep Habits Questionnaire (CSHQ): Psychometric properties of a survey instrument for school-aged children. *SLEEP*, 23(8), 1043–1052. [PubMed: 11145319]
- Petrill S, Pike A, Price T, & Plomin R (2004). Chaos in the home and socioeconomic status are associated with cognitive development in early childhood: Environmental mediators identified in a genetic design. *Intelligence*, 32(5), 445–460. doi:10.1016/j.intell.2004.06.010
- Power C, Manor O, & Matthews S (2003). Child to adult socioeconomic conditions and obesity in a national cohort. *International Journal of Obesity*, 27, 1081–1086. [PubMed: 12917714]
- Preacher KJ, Zyphur MJ, & Zhang Z (2010). A general multilevel SEM framework for assessing multilevel mediation. *Psychological Methods*, 15(3), 209. doi:10.1037/a0020141 [PubMed: 20822249]
- Preacher KJ, Zhang Z, & Zyphur MJ (2011). Alternative methods for assessing mediation in multilevel data: The advantages of multilevel SEM. *Structural Equation Modeling*, 18(2), 161–182. doi: 10.1080/10705511.2011.557329
- Sadeh A, Hauri PJ, Kripke DF, & Lavie P (1995). The role of actigraphy in the evaluation of sleep disorders. *SLEEP*, 18(4), 288–302. doi:10.1093/sleep/18.4.288 [PubMed: 7618029]

- Sadeh A, Sharkey KM, & Carskadon MA (1994). Activity-based sleep-wake identification: An empirical test of methodological issues. *SLEEP*, 17(3), 201–207. doi:10.1093/sleep/17.3.201 [PubMed: 7939118]
- Schaefer SE, Gomez-Camacho R, & Muñoz-Gomez M (2017). Sleep duration and obesity of young Mexican-heritage children in rural California. *Journal of Childhood Obesity*, 2(5), 1–7. doi: 10.21767/2572-5394.100027
- Schreier H, Roy L, Frimer L, & Chen E (2014). Family chaos and adolescent inflammatory profiles: The moderating role of socioeconomic status. *Psychosomatic Medicine*, 76(6), 460–467. doi: 10.1097/PSY.000000000000078 [PubMed: 24979577]
- Smetana JG, Campione-Barr N, & Daddis C (2004). Longitudinal development of family decision making: Defining health behavioral autonomy for middle-class African American adolescents. *Child Development*, 75(5), 1418–1434. doi:10.1111/j.1467-8624.2004.00749.x [PubMed: 15369523]
- Spilsbury JC, Storfer-Isser A, Drotar D, Rosen CL, Kirchner HL, & Redline S (2005). Effects of the home environment on school-aged children's sleep. *SLEEP*, 28(11), 1419–1427. doi:10.1093/sleep/28.11.1419 [PubMed: 16335483]
- Tandon PS, Zhou C, Sallis JF, Cain KL, Frank LD, & Saelens BE (2012). Home environment relationships with children's physical activity, sedentary time, and screen time by socioeconomic status. *International Journal of Behavioral Nutrition and Physical Activity*, 9(1), 88–96. doi: 10.1186/1479-5868-9-88 [PubMed: 22835155]
- Teti DM, Kim BR, Mayer G, & Countermine M (2010). Maternal emotional availability at bedtime predicts infant sleep quality. *Journal of Family Psychology*, 24(3), 307–315. doi:10.1037/a0019306 [PubMed: 20545404]
- Tomfohr LM, Ancoli-Israel S, & Dimsdale JE (2010). Childhood socioeconomic status and race are associated with adult sleep. *Behavioral Sleep Medicine*, 8(4), 219–230. doi: 10.1080/15402002.2010.509236 [PubMed: 20924835]
- Touchette E, Dionne G, Forget-Dubois N, Petit D, Pélusé D, Falissard B, Tremblay RE, Boivin M, Montplaisir JY (2013). Genetic and environmental influences on daytime and nighttime sleep duration in early childhood. *American Academy of Pediatrics*, 131(6), e1874–e1880. doi:10.1542/peds.2012-2284
- Touchette E, Petit D, Paquet J, Boivin M, Japel C, Tremblay R, & Montplaisir J (2005). Factors associated with fragmented sleep at night across early childhood. *Archives of Pediatrics & Adolescent Medicine*, 159(3), 242–249. doi:10.1001/archpedi.159.3.242 [PubMed: 15753267]
- Wang G, Xu G, Liu Z, Lu N, Ma R, & Zhang E (2013). Sleep patterns and sleep disturbances among Chinese school-aged children: Prevalence and associated factors. *Sleep Medicine*, 14(1), 45–52. doi:10.1016/j.sleep.2012.09.022 [PubMed: 23218539]
- Williams KE, Berthelsen D, Walker S, & Nicholson JM (2017). A developmental cascade model of behavioral sleep problems and emotional and attentional self-regulation across early childhood. *Behavioral Sleep Medicine*, 15(1), 1–21. doi: 10.1080/15402002.2015.1065410 [PubMed: 26619760]
- Yeung W, Linver M, & Brooks-Gunn J (2002). How money matters for young children's development: Parental investment and family processes. *Child Development*, 73(6), 1861–1879. doi: 10.1111/1467-8624.t01-1-00511 [PubMed: 12487499]
- Zhang J, Li AM, Fok TF, & Wing YK (2010). Roles of parental sleep/wake patterns, socioeconomic status, and daytime activities in the sleep/wake patterns of children. *The Journal of Pediatrics*, 156(4), 606–612. doi:10.1016/j.jpeds.2009.10.036 [PubMed: 20022339]

Figure 1.

Test of full indirect paths for SES (mean composite of primary caregiver education, secondary caregiver education and income-to-needs ratio at 12 months) on the home environment and all objective and subjective sleep indicators in twins during middle childhood. Covariates were sex, BMI, SES at 8 yrs and race/ethnicity. Full model fit: $X^2(76) = 588.30$, $p < .001$, CFI = 1.00, RMSEA = 0.00, and SRMR within = .026, SRMR between = .067. The indirect path between SES and sleep duration through the HOME Total was significant, $B = .031$, $SE = .014$, $p = .028$. The indirect path between SES and sleep midpoint variability through the HOME Total was significant, $B = -.013$, $SE = .006$, $p = .016$. The indirect paths between SES and sleep latency and sleep problems through the HOME Total were $p = .074$ and $p = .08$, respectively. The indirect path between SES and sleep efficiency through the HOME Total was not significant, $B = -.048$, $SE = .104$, $p = ns$. Note: Unstandardized coefficients are provided. Statistically significant paths are solid lines and non-significant paths are dashed.^aLog transformed values used.^bChild Sleep Habits Questionnaire mean score of sleep problems (Owens et al., 2000).⁺ $p = .07$, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 1

Descriptive statistics and zero-order correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Sleep duration (hours)	-														
2. Sleep efficiency (%)	.62**	-													
3. Sleep latency (minutes) ^a	-.24**	-.12*	-												
4. Sleep midpoint variability	-.21**	-.03	.15**	-											
5. Sleep problems ^b	-.16*	-.03	.15*	.12 ⁺	-										
6. HOME- Total Score	.24**	.04	-.17*	-.21**	-.17**	-									
7. HOME - Emotional Climate	.13*	.08	-.11 ⁺	-.07	-.04	.54**	-								
8. HOME- Physical Environment ^c	.22**	.07	-.15*	-.13 ⁺	-.20*	.63**	.30**	-							
9. HOME- Encouragement of Maturity	.15*	.04	-.06	-.18**	-.13	.34**	.10	.13	-						
10. Socioeconomic Status Composite - 12 months	.22*	.13 ⁺	-.13*	-.17*	-.13 ⁺	.42**	.18**	.32**	-.02	-					
11. Socioeconomic Status Composite - 8 years	.22**	.16**	-.17**	-.14*	-.14*	.50**	.19**	.33**	.09	.81**	-				
12. Sex	.13*	.06	.02	-.03	.05	.08	.07	.03	.13*	-.05	.01	-			
13. Race	.12 ⁺	.01	-.06	-.09	-.01	.14 ⁺	-.07	-.01	-.09	.22**	.19**	.02	-		
14. Body Mass Index	-.17**	-.13*	.02	-.03	.02	-.13 ⁺	.02	-.15*	-.02	-.15*	-.19**	.03	-.05	-	
15. Summer Participation	-.09	-.08	.10	-.05	-.12*	-.01	-.04	-.12	.14*	-.11	-.03	-.01	-.06	.03	-
Mean ^d	8.11	90.33	25.33	.59	1.76	.80	.77	.91	.84	.00	.00	.50	.57	16.80	.29
Standard Deviation	.71	5.44	21.48	.29	.35	.10	.15	.16	.16	.80	.78	-	-	2.85	-
Minimum	5.62	67.18	.86	.08	1.00	.53	.13	.13	.14	-2.06	-1.67	-	-	13.19	-
Maximum	10.01	98.80	128.2	1.93	3.29	.98	1.00	1.00	1.29	1.75	3.16	-	-	31.98	-
Skewness	-.54	-1.12	2.32	1.03	.90	-.53	-.80	-2.32	-1.38	-.15	.60	-	-	1.90	-
Kurtosis	.30	1.53	6.49	1.65	1.44	-.28	.94	5.58	3.15	-.54	.98	-	-	4.84	-

Note. Sleep duration, efficiency, latency and variability were actigraphy-based sleep measures. Sex: Female = 1, Male = 0; Race: White = 1, other race or multiple = 0; SES, socioeconomic status (mean composite of primary caregiver education, secondary caregiver education and income to needs ratio at 12 months or eight years); Summer Participation: participated in summer = 1, participated during school year = 0.

^aLog transformed values used in zero-order correlations and raw scores are presented in descriptive statistics.

^bChild Sleep Habits Questionnaire mean score of sleep problems (Owens et al., 2000).

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

c, Squared transformed values used in zero-order correlations and raw scores are presented in descriptive statistics.

d, Mean for continuous variables and percentage of sample for dichotomous variables.

+ $p \leq .10$;
* $p < .05$;
** $p < .01$;
*** $p < .001$.

Table 2

Descriptive twin intraclass correlations of sleep indicators

	MZ	DZss	DZos
Sleep duration (hours)	.70	.45	.49
Sleep efficiency (%)	.73	.56	.41
Sleep latency (minutes) ^a	.81	.79	.69
Sleep midpoint variability	.83	.72	.71
Sleep problems ^b	.92	.53	.51

Note. $N = 381$ individuals. Sleep duration, efficiency, latency and midpoint variability were actigraphy-based sleep measures. MZ = monozygotic, identical twin intraclass correlations; DZss = same-sex dizygotic, fraternal twin intraclass correlations, DZos = opposite-sex dizygotic, fraternal twin intraclass correlations.

^aLog transformed values used.

^bChild Sleep Habits Questionnaire mean score of sleep problems (Owens et al., 2000).