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The Role of Sleep in the Status Attainment Process

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Princeton, NJ : Princeton University

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THE ROLE OF SLEEP IN THE STATUS ATTAINMENT PROCESS

Sarah Alayne James

A DISSERTATION

PRESENTED TO THE FACULTY

OF PRINCETON UNIVERSITY

IN CANDIDACY FOR THE DEGREE

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Abstract

There is a robust association between parents' socioeconomic status and that of their adult children. While a number of mechanisms have been offered to explain this link, this dissertation proposes an additional pathway for the association: sleep. It is surprising that sleep has been understudied in the status attainment process, for two reasons. First, sleep is amenable to social influence. Sleep is socially structured among both children and adults, with sleep of higher quality and longer duration concentrated among advantaged groups. Second, good sleep, particularly in childhood, is necessary for optimal physical health, mental health, and cognitive performance. These inputs have documented links to achievement and attainment. Therefore, I argue that sleep is a theoretically compelling mechanism in the intergenerational transmission of socioeconomic status.

For sleep to be implicated in the status attainment process, parental socioeconomic status must be associated with the sleep of their children, and children's sleep must be linked to their own socioeconomic status in adulthood net of their parents' socioeconomic status. Using longitudinal cohort data from the United States, I assess each of these propositions in turn. Part I of the dissertation characterizes sociodemographic disparities in childhood and adolescent sleep. I first identify how trajectories of sleep across childhood and adolescence vary for children of different sociodemographic groups. Then, I describe disparities in objectively-measured sleep duration, timing, and quality during adolescence. Part II of the dissertation considers how early life sleep may in turn play a role in adult socioeconomic status, assessing how adolescent sleep is associated with young adult socioeconomic outcomes.

Thus, this dissertation provides preliminary evidence of the role of sleep in the status attainment process. While analyses are not causal, I find that there are large disparities in child

and adolescent sleep and that adolescent sleep is in turn associated with adult socioeconomic outcomes. This pattern is consistent with sleep playing a role in the (re)production of inequality. These findings direct future research toward developmentally-informed research on the short- and long-term effects of concurrent and cumulative sleep duration among children and adolescents.

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Finally, this dissertation would not be complete without acknowledging those who celebrated and commiserated with me through the daily ups and downs of graduate school. To my cohort, my officemates, and all the rest of my colleagues-turned-friends: I couldn't have done it without you.

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Chapter 1

Introduction

Social stratification comes about through a range of processes. Though Parsons (1940) described a theory in which stratification was determined primarily based on occupation and kinship ties, it was not until the pioneering work of Blau and Duncan (1967) that sociologists empirically identified the strength of the association between the occupation and education of fathers and their sons. In light of this pattern, theorists turned to modeling the status attainment processes by which individuals end up in particular social positions (Haller and Portes 1973). Initial theories emphasized the role of education in status attainment (Blau and Duncan 1967; Haller and Portes 1973), but a number of additional mechanisms have now been proposed and empirically verified as important determinants of social position.

One class of mechanisms is largely structural and explains how the social world to which an individual is exposed impacts life chances via social networks (Granovetter 1973) or neighborhood of residence (Wilson 1987). A second set of mechanisms captures how individual factors also matter for achievement and attainment, placing a strong emphasis on how ascribed statuses – including race, ethnicity, and gender – intersect with other structural factors. For example, race and neighborhood combine to determine life chances (Massey and Denton 1993; Wilson 1987). More recent scholarship has also emphasized that the individual traits developed in early life – including non-cognitive skills (Heckman 2006) and physical and mental health (Palloni 2006) – are predictors of adult achievement and attainment even among those of otherwise similar socioeconomic backgrounds. However, much of the status attainment process

remains unexplained after accounting for these factors. Thus, this dissertation proposes an additional mechanism by which parental socioeconomic status is transmitted to their children: sleep.

Theoretical and Empirical Basis for Integrating Sleep in the Status Attainment Model

Both social theory and empirical evidence suggest that sleep is plausibly involved in the status attainment process. Social theorists note that sleep both reflects and influences social position; it is socioeconomically patterned and patterning. Empirical research verifies that sleep is distributed along axes of disadvantage for both adults and children, suggesting that sleep is a socially-structured input into child and adolescent development. Sleep is also linked to mechanisms known to predict later socioeconomic status, though direct effects on subsequent socioeconomic outcomes are largely untested.

Most social theorists who have considered sleep implicitly suggest that sleep both reflects and creates social position. Both social status (Aubert and White 1960) and waking social roles (Williams 2005) influence sleep patterns. According to Aubert and White (1960:12), "…minor differentiations [in sleep] appear with regularity, a regularity associated with status differentials. They seem to symbolize, and probably support, social stratification along a prestige dimension." Similarly, "regulations [of the sleep role] reflect, and, in reflecting, stabilize the 'vertical' or hierarchical order" (Schwartz 1970:496). Status produces sleep patterns to the extent that sleep rights and roles show inequalities based on power and status (Williams 2008), and good sleep is indicative of autonomy (Hale and Hale 2010). At the same time, recent scholarship has suggested that "sleep … is a basic human *right* as well as a *resource*" (Williams 2005:138, emphasis original) given the negative long-term consequences of inadequate sleep.

Indeed, sociodemographic factors are among the strongest predictors of sleep across the life course. Gender, race, socioeconomic status, educational attainment, and marital status are all predictive of nightly sleep duration and quality: women, minorities, the socioeconomically disadvantaged, and those who are less-educated or unmarried all sleep less or more poorly than their male, majority, advantaged, educated, or married peers (Hale, Peppard, and Young 2007). Within the family, negotiations about sleeping spaces and habits are indicative of patterns of power relations both within the couple relationship and between parents and children (Aubert and White 1960; Burgard 2011; Melbin 1987; Rosenblatt 2006; Schwartz 1970; Williams 2005). For example, women sleep for more hours each night but have more interruptions to their sleep than men, largely due to nighttime childcare (Burgard 2011; Burgard and Ailshire 2013). Separately, neighborhood factors, including housing characteristics and neighborhood disadvantage are associated with sleep patterns (Arber, Bote, and Meadows 2009; Knutson 2013).

Though the sociodemographic patterning of sleep is well-established, there is a lack of empirical research directly testing how sleep is associated with subsequent socioeconomic status. Such associations are likely to come about through several more proximate determinants of social position. Sleep quality and quantity predict subsequent cognitive ability (Gruber et al. 2010; Sadeh, Gruber, and Raviv 2003; Touchette et al. 2007) and in turn school performance (Asarnow, McGlinchey, and Harvey 2014; Curcio, Ferrara, and Gennaro 2006; Dewald et al. 2010; Wolfson and Carskadon 2003). Similarly, mental health (Beebe 2011; Dahl 2007; Pilcher and Huffcutt 1996; Yoo et al. 2007) and physical health (Buxton and Marcelli 2010; Grandner et al. 2010; Taheri et al. 2004) are also dependent on adequate nightly sleep. Education, mental health, and physical health are determinants of later socioeconomic status (Blau and Duncan

1967; Case, Lubotsky, and Paxson 2002; Currie 2007; Currie and Stabile 2009; Haller and Portes 1973; McLeod and Fettes 2007; McLeod and Kaiser 2004; Palloni 2006).

Integrating sleep in the status attainment model

Sleep is a promising but unstudied contributor to social stratification. Using a life course approach, I incorporate sleep into the status attainment model. To show that sleep is part of the process of social stratification, I demonstrate that parents' socioeconomic status is related to the sleep of their children, and that in turn childhood and adolescent sleep are associated with adult socioeconomic status. Thus, Part I of the dissertation asks how parental socioeconomic status predicts the child's sleep patterns in childhood and adolescence. Part II considers one aspect of the second half of this process, evaluating how adolescent sleep predicts adult socioeconomic status.

Part I: Identifying disparities in child and adolescent sleep

Part I of the dissertation, including Chapters 2 and 3, demonstrates that parental socioeconomic status is associated with the nightly sleep duration of children and adolescents in the Fragile Families and Child Wellbeing Study, a longitudinal birth cohort of children born in large American cities in 1998-2000. Prior nationally-representative studies have identified disparities in sleep at several points across childhood and adolescence. However, this cross-sectional research does not identify whether children from different sociodemographic groups are on different trajectories across their childhood years.

Chapter 2 provides the first prospective description of sociodemographic disparities in childhood sleep among children in the United States. Using growth curve models of reported sleep duration, I identify demographic disparities in sleep duration measured from early childhood through adolescence. I find that disparities are dynamic over this period. Sex

differences are limited to adolescence, and advantage males. Racial and ethnic disparities are largest in childhood and narrow by adolescence, though black-white gaps remain substantial. Children of immigrant mothers have longer nightly sleep durations at all ages. Socioeconomic disparities in sleep vary across childhood: in early childhood, children of more-educated mothers and higher-income families have the longest sleep durations; in middle childhood, these gaps are closed; and in adolescence the socioeconomic pattern of sleep reverses. This chapter does not identify disparities in childhood sleep by family structure.

Though Chapter 2 provides prospective trajectories of childhood sleep, it relies on parent- or child-reported sleep measurements. Chapter 3 addresses this limitation by identifying demographic disparities in objectively-measured sleep duration among adolescents. I assess disparities in weekday and weekend sleep duration, timing, and quality using actigraphy data collected at approximately age 15. I find that females are advantaged in sleep relative to males, with longer sleep durations, more napping, and earlier and less variable sleep timing. Black-white disparities are complex. Though black adolescents sleep about 19 minutes less per weeknight than white adolescents, this disparity is attenuated by napping such that there is no black-white disparity in 24-hour weekday sleep. On weekends, the black-white disparity is 38 minutes per night and is not eliminated by napping. Differences in adolescent sleep health by family structure are limited to weekend sleep timing or apply to the small group of adolescents no longer living with either biological parent. Adolescents whose primary caregivers have a college degree have lower odds of napping than adolescents whose primary caregiver has less education.

Part II: Child and adolescent sleep as predictors of adult socioeconomic status

Part II of the dissertation examines how sleep in adolescence is associated with socioeconomic status in adulthood. Though a large biomedical literature has identified that sleep duration has causal links to cognitive performance and health, little research has examined whether sleep plays a role in the production of socioeconomic status. Using data from the National Longitudinal Study of Adolescent to Adult Health, a nationally representative sample of students in grades 7-12 in 1994-1995, in Chapter 4 I assess how typical nightly sleep duration in adolescence predicts socioeconomic status in early adulthood. I identify a nonlinear association of sleep duration with educational attainment and occupational prestige. Sleep durations of seven and eight hours per night in adolescence are associated with the highest educational and occupational credentials in young adulthood, while shorter and longer sleep durations are associated with worse outcomes. Links between sleep duration and occupational prestige come about via educational attainment. There is little association between sleep duration and other socioeconomic outcomes. This chapter provides preliminary evidence that sleep plays a role in status attainment, via educational attainment.

Chapter 2

Disparities in Trajectories of Childhood and Adolescent Sleep Duration[1]

To minimize inequality in adult outcomes, it is necessary to ameliorate disparities as they appear. One modifiable behavior with implications for health and wellbeing is sleep (Astill et al. 2012; Dahl 2007; James and Hale 2017). Childhood sleep is a particularly promising time for intervention, as it is linked to adult socioeconomic status (see Chapter 4). While numerous cross-sectional studies have identified disparities in childhood and adolescent sleep durations, snapshots comparing children of different demographic groups do not reveal whether children of different groups are on different trajectories as they age. Not knowing when sleep disparities emerge and how they change with age means that we cannot identify whether (dis)advantages in sleep accumulate across a child's life – potentially rendering their consequences for health and wellbeing much greater than if they were short-lived. Likewise, understanding the nature of these disparities facilitates targeting interventions for maximum benefit.

To compare trajectories of sleep duration across childhood, it is necessary to examine sleep in a cohort of children followed prospectively into adolescence. A lack of longitudinal cohort data on sleep has previously precluded identifying these disparities. Using newly-available data from the Fragile Families and Child Wellbeing Study, however, I am able to estimate disparities in sleep from early childhood through adolescence in a cohort of children born in 1998-2000.

[1] A version of this chapter was presented as "Trajectories of Childhood and Adolescent Sleep Duration by Family Demographic Characteristics" at the Population Association of America 2018 Annual Meeting, April 2018, Denver, Colorado, USA.

Background

Several large, nationally-representative studies have documented disparities in childhood and adolescent sleep duration in the United States. Two studies include both children and adolescents. Adam, Snell, and Pendry (2007) analyze data from children ages 5-19 who participated in the Panel Study of Income Dynamics Child Development Supplement in 1997 and 2002-2003, and Buxton et al. (2015) examine sleep among a nationally-representative internet panel of families with children ages 6-17, the National Sleep Foundation Sleep in America Poll. One analysis includes preschool-age children only, using data on 4-year-olds from the 2005 Early Childhood Longitudinal Study, Birth Cohort (Anderson and Whitaker 2010). Three additional studies draw on nationally-representative data that includes adolescents but not children: the 2007 Youth Risk Behavior Surveillance System (Eaton et al. 2010), the National Longitudinal Study of Adolescent to Adult Health (Maslowsky and Ozer 2014), and Monitoring the Future (Keyes et al. 2015). Across these diverse datasets, there are significant sex, race, ethnicity, nativity, socioeconomic status, and family structure disparities in sleep duration.

Sex

Though there is no sex difference in nightly sleep duration among children ages 5-12 (Adam et al. 2007), adolescent males report longer nightly sleep durations than females (Adam et al. 2007; Eaton et al. 2010; Maslowsky and Ozer 2014). One study found no sex differences in sleep duration in a pooled sample of children ages 6-17 (Buxton et al. 2015). However, analyzing all age groups together precluded the study from identifying disparities that are not consistent across age groups.

Race and ethnicity

At all ages, white children sleep for longer periods each night than black children (Adam et al. 2007; Anderson and Whitaker 2010; Maslowsky and Ozer 2014). There is some uncertainty about white-Hispanic disparities in childhood sleep, however. Two studies suggest that Hispanic children sleep less on average than do white children: Hispanic children are less likely to meet recommended sleep durations than are white children at age 4 (Anderson and Whitaker 2010), at ages 5-12, and ages 12-19. Hispanic children sleep for less time on weekends than do white children (Adam et al. 2007). Yet, a study of high school students finds that Hispanic adolescents sleep longer on weeknights than do whites (Eaton et al. 2010). Thus, it is not surprising that studies comparing the sleep of white children to all non-white children (including black, Hispanic, and other non-white groups) have inconsistent findings. For example, whites sleep longer than nonwhites in a study of successive cohorts of high school students from 1991 to 2012 (Keyes et al. 2015), but a cross-sectional study finds no white-nonwhite difference in sleep at ages 6-17 (Buxton et al. 2015).

Socioeconomic status

Disparities in childhood sleep duration by parental socioeconomic status vary across different facets of parental socioeconomic status. Higher parental education is associated with a higher likelihood of reaching or surpassing recommended sleep durations across childhood and adolescence (Anderson and Whitaker 2010; Buxton et al. 2015; Keyes et al. 2015). Associations between household income and sleep change from childhood to adolescence, however. In early childhood, higher household income is associated with a higher chance of meeting sleep duration recommendations (Anderson and Whitaker 2010). Yet, there is little income difference in sleep duration among children ages 5-11 or ages 12-19 (Adam et al. 2007).

Family structure

Children of all ages living in two-parent households sleep for longer and are more likely to meet recommended sleep durations than children of single mothers (Adam et al. 2007; Anderson and Whitaker 2010; Buxton et al. 2015).

Contributions

Although cross-sectional snapshots provide some information about group differences in childhood and adolescent sleep, comparing sleep disparities among children of different ages cannot differentiate between disparities that are artifacts of compositional differences between groups or disparities that are constant or changing as a cohort ages. For example, even if black children and adolescents sleep less than white children and adolescents at all ages in cross-sectional data, it may not be that case that a given cohort of black adolescents slept, on average, less than their white peers since they were children. This study, which uses repeated measures of sleep in a longitudinal cohort study, identifies disparities in these developmental trajectories of sleep.

Methods

Data

Data come from the Fragile Families and Child Wellbeing Study (FFCWS), a population-based, longitudinal study of 4,898 children born between 1998 and 2000 in large American cities (population > 200,000). The study includes an oversample of non-marital births. Study topics include parental relationships, child outcomes, and the impact of contextual and policy conditions on families and children. Interviews with mothers and fathers occurred at the child's birth and when the child was approximately ages 1, 3, 5, 9, and 15. The child was interviewed at age 9 and 15. Beyond its unique strength as a longitudinal cohort study covering the period of

birth to adolescence, FFCWS is the only national study in the United States that collects longitudinal data on nightly sleep duration at multiple points during childhood and adolescence.

This study uses baseline demographic characteristics to predict the child's trajectory of sleep at the age 5, 9, and 15 study waves. Of the 4,898 families included in the baseline FFCWS sample, 3,595 participated in at least one component of each of the age 5, 9, and 15 study waves. However, questions on sleep were not always asked in the core portion of the interview administered to all families – age 5 sleep data were collected during an in-home visit conducted among a subsample of study participants, age 9 data were reported in the core primary caregiver survey, and age 15 data were reported by adolescents – thus, of those 3,595 individuals only 2,442 participated in the portions of the age 5, 9, and 15 study waves in which sleep data were collected. Among those 2,442 cases, 2,400 provided non-missing information on sleep duration at all three study waves. A further 17 cases have missing values for one or more covariates, resulting in a final analytic sample of 2,383.

Table 2.1 compares baseline sociodemographic characteristics of the full FFCWS cohort (N=4,898) and the analytic sample (N = 2,383). Overall, participants in the analytic sample are more socioeconomically advantaged than baseline participants, with more maternal education and higher baseline incomes. Compared to the baseline sample, the analytic sample has a higher proportion of children with white (non-Hispanic) and black (non-Hispanic) mothers and a lower proportion of children with Hispanic or other race/ethnicity (non-Hispanic) mothers; it also has a substantially smaller share of children whose mothers are foreign-born (primarily due to attrition of children of Hispanic mothers, who comprised the majority of foreign-born mothers). Though the proportion of mothers who were married to the child's father at the child's birth is very similar in the baseline and analytic samples, the analytic sample has more children of mothers

who had no relationship with the child's father at the time of the child's birth and relatively fewer children whose biological parents were cohabiting at the time of their birth.

Measures

Table 2.1 describes the analytic outcome (sleep duration) and covariates in the analytic sample.

Sleep duration

The outcome, sleep duration, is the participant's sleep duration on a typical weeknight. This measure is reported by the child's primary caregiver at the age 5 and 9 study waves and by the adolescent at the age 15 study wave. At the age 5 and age 9 study waves, the child's primary caregiver was asked how many hours the child typically slept on weeknights. At the age 15 study wave, adolescents were asked at what time they typically went to bed on school nights and woke up on school mornings. The difference between these two times was their sleep duration.

In the series of questions in which adolescents reported the hour, minute, and AM/PM of bed- and wake-times, some cases had inconsistencies or likely errors, addressed as follows. There were 5 cases in which the adolescent reported a complete wake time (hour, minute, and AM/PM) but only an hour and minute for the bedtime. All of these cases provided a bedtime of 12:00. Attributing a 12:00 AM (midnight) bedtime to these five adolescents resulted in the cases having sleep durations ranging from 5.5 to 8 hours. Additionally, there were 18 cases with extremely long sleep durations in the range of 18 to 23 hours; hand inspection of these outliers suggested that the adolescent had likely made an incorrect AM/PM attribution on either their bed or wake time (e.g., the adolescent reported waking at 6pm). These outliers were thus recoded with the relevant AM/PM switched, after which those cases had weeknight sleep durations between 6 and 11 hours.

After these adjustments, the extreme 1% of sleep duration values at each study wave were bottom- and top-coded to the extreme low and high values of the remainder of the distribution of sleep duration at each wave. The low and high values were, respectively, 6 and 12 hours at the age 5 study wave, 6 and 12 hours at the age 9 study wave, and 4.5 and 11 hours at the age 15 study wave. Finally, the number of reported hours of sleep was multiplied by 60 to produce a measure of nightly minutes of sleep that is used in analyses.

Covariates

The child's age is measured in months at each study wave; for the purposes of analyses, age is centered on age 9 (108 months). Child sex was recorded at the child's birth. Mother's race/ethnicity includes categories for non-Hispanic white (reference), non-Hispanic black, Hispanic, and any other race/ethnicity. Additionally, mothers report whether they were born in the United States (native born, reference) or not (foreign born). Maternal educational attainment includes categories for college graduate (reference), some college education, high school graduate or GED, and less than a high school degree. Household poverty compares the mother's household income at the time of the child's birth to the poverty line and includes categories for households with an income that was more than 299% of the poverty line (reference), 200-299% of the poverty line, 100-199% of the poverty line, or less than the poverty line. Family structure indicates whether the child's mother was married to (reference), cohabiting with, or in no relationship with the child's biological father at the time of the child's birth. The mother's age was measured at the time of the child's birth.

Analytic strategy

Using growth curve models, defined in Appendix 2A, I assess how sleep trajectories from early childhood through adolescence differ for children born into families with various

demographic characteristics. Table 2.2 compares three nested models. Model 1 shows the bivariate association between child age and sleep duration, including both a linear and nonlinear (squared) term for age. Model 2 adds demographic covariates. Model 3 adds an interaction between child age and each of the demographic characteristics. The analysis of deviance (Appendix 2B) shows that Model 3 is preferred to the prior (nested) models. Model 3 also allows demographic disparities to change across childhood. Thus, the results described subsequently use Model 3, the conceptually and statistically preferred model.

Results

Table 2.2 shows coefficients and standard errors from models of typical weeknight sleep duration among children and adolescents. The upper portion of the table shows fixed-effects estimates, while the lower portion shows the random-effects estimates. Among fixed-effects estimates, there are both main effects and interaction effects. The main fixed effects reflect the association between a given covariate and sleep duration when the age variable equals zero. Because age is centered on 9 years, the tests of statistical significance of the main effects indicate whether there is a statistically significant difference in sleep duration for two groups (e.g., male versus female) when children are 9 years old. The interaction terms show how the slope of a given disparity changes as the child's age changes. To interpret the magnitude of these disparities across childhood, I make predictions that simultaneously account for all of these covariates.

Figures 2.1-2.7 illustrate key results using predicted values from Table 2.2, Model 3. Figure 2.1 shows the sleep trajectory of the average study participant, while Figures 2.2 through 2.7 show disparities in childhood sleep. To create predicted sleep duration values for each age, I hold covariates at their observed mean (for continuous variables) or mode (for categorical

variables). That is, these predictions consider a black (non-Hispanic) boy who was born to a 25-year-old native-born mother with less than a high school degree whose household income was below the poverty line and was not in a relationship with the child's biological father at the time of the child's birth. To show disparities, I hold all but one characteristic[2] constant at the values mentioned previously, varying only the characteristic of interest (e.g., sex). This approach allows the observed disparity in sleep duration to be attributed to that characteristic alone. When describing these curves, I use the term "early childhood" to refer to observations from children in the age 5 study wave (observed at ages 4-6), "middle childhood" to refer to observations from children in the age 9 study wave (observed at ages 9-11), and "adolescence" to refer to observations from adolescents who participated in the age 15 study wave (observed at ages 14-18).

Figures 2.1-2.7 also include a shaded area that indicates the American Academy of Sleep Medicine's recommended range of sleep duration (Paruthi et al. 2016). These sleep recommendations indicate a range of sleep durations that are appropriate for a given developmental stage, with sleep broadly declining from birth to adolescence. For example, the minimum recommended sleep duration for children ages 3-5 is 10 hours, and the minimum recommended sleep duration for children ages 6-13 is 9 hours. These recommendations do not, however, make any claim about how sleep might decline within a given developmental period to reach the amount of sleep expected in the subsequent developmental period. Therefore, for the purposes of comparing smooth trajectories to these stepwise recommendations, I presume a linear decline of the recommended sleep durations within each developmental period. Appendix

[2] Each characteristic has two corresponding terms in the model, both of which vary in each figure: the main effect for the characteristic (e.g., sex) and the interaction term between that characteristic and age (e.g., sex * age).

2C shows the stepwise recommendations provided by Paruthi et al. (2016), and Appendix 2D shows the interpolated values which are included in Figures 2.1-2.7.

Sleep duration across childhood

Average trajectory

As shown in Table 2.1, unadjusted sleep duration in the analytic sample declines from an average of 565 minutes (9 hours, 25 minutes) at the age 5 study wave to 537 minutes (8 hours, 57 minutes) at the age 9 study wave to 482 minutes (8 hours, 2 minutes) at the age 15 study wave. The fixed-effects estimates in Table 2.2, Model 3 indicate that nightly sleep duration decreases with age, and this decrease becomes more rapid at higher ages.

To understand the magnitude of this age gradient, I create predicted sleep duration values for each age, as described previously. Figure 2.1 shows that adjusted nightly sleep durations decline from about 9 hours in early childhood to approximately 8 hours in adolescence, with a slightly slower decline between early and middle childhood than middle childhood and adolescence. Relative to sleep duration recommendations, this average individual in this sample does not meet the minimum sleep duration in early childhood but exceeds the minimum recommended duration at older ages. In part this may be due to some children continuing to nap in early childhood (potentially making their nightly durations shorter); sleep duration recommendations cover the full 24-hour period, including naps (Paruthi et al. 2016).

Variation around average trajectory

As shown in Table 2.1, there is substantial variability in unadjusted sleep duration in this sample, with standard deviations in excess of one hour at all waves. The random-effects estimates in Table 2.2, Model 3 indicate that there is also substantial variation in sleep duration after adjusting for covariates. The standard deviation of the intercept, which indicates the amount

of variability in sleep at the centered age (age 9), is 29 minutes. The standard deviation of the slope, which indicates the amount of variability in the decline of minutes of sleep per month of age at the centered age (age 9), is 0.462 minutes. The correlation between the random intercept and random slope is negative, meaning that children with more sleep at the centered age (age 9) have slower changes in sleep than children with less sleep at the centered age (age 9). Residual variability has a standard deviation of 58 minutes of sleep per night.

Disparities in childhood sleep duration

Figure 2.2 illustrates sex disparities in nightly sleep duration across childhood. Though there are no sex differences in early or middle childhood, in adolescence boys sleep for approximately 5 more minutes per night than girls.

Differences in trajectories of sleep duration by maternal race/ethnicity are shown in Figure 2.3[3]. In early childhood, children of white mothers sleep for about 15 minutes more per night than children of Hispanic mothers and about 35 minutes more per night than children of black mothers. These gaps narrow slightly in middle childhood. In adolescence, children of white mothers converge with the nightly sleep of children of Hispanic mothers, and the gap between children of black mothers and white or Hispanic children is about 10 minutes. Overall, the black-white disparity in sleep duration diminishes by about 75% over this period.

Figure 2.4 shows that children of foreign-born mothers have longer sleep durations across childhood and adolescence than do children of native-born mothers; this gap is about 13 minutes in early and middle childhood, narrowing slightly to about 10 minutes per night in adolescence.

[3] This figure does not show predictions for children of mothers whose race/ethnicity was something other than black (non-Hispanic), white (non-Hispanic), or Hispanic, as that group comprised a very small share (3%) of the analytic sample.

Figure 2.5 depicts trajectories of sleep duration by maternal educational attainment. There is a clear divide between children of college-educated mothers and children whose mothers have any other amount of education. Children who are born to college-educated mothers sleep between 15 and 20 minutes more per night in early childhood than do children of mothers with less education. This gap narrows to a negligible amount in middle childhood. In adolescence, the gap reverses. By the end of adolescence, adolescents whose mothers have a college education sleep for about 20 fewer minutes per night than do children whose mothers have a high school degree or less and 13 minutes per night more than children of mothers with some college education.

Similarly, Figure 2.6 illustrates the sleep duration trajectories of children born in households with different income levels. In early childhood, children born to mothers living in households with incomes greater than 300% of the poverty line have 8 to 15 minute longer nightly sleep durations than children born into households with lower levels of income. Disparities are similar in middle childhood. In adolescence, however, gaps close and suggest a reversal. It appears that rather than children who were born into the highest-income households sleeping the most they sleep a similar amount to or less than those living near the poverty line; it is children born into households living below the poverty line who sleep for about 10 minutes more per night than children born into the highest-income homes.

Finally, there are no notable differences in the sleep durations of children whose biological parents were married versus in no relationship when the child was born, as presented in Figure 2.7.

Mother's age at the time of the child's birth was not statistically significantly associated with childhood sleep duration.

Alternative modeling specification

Dropping age outliers

This study uses FFCWS data from three study waves, conducted when the child was approximately ages 5, 9, and 15. There was some variation in interview timing around the child's 5th, 9th, and 15th birthdays (see Appendix 2E for a distribution of the ages at which children in the analytic sample were observed). At age 5, interviews occurred when children were on average age 61 months old (5 years, 1 month) with a standard deviation of about 2 and half months. At age 9, interviews occurred when children were on average 110 months old (9 years, 2 months), with a standard deviation of about 3 and a third months. At age 15, interviews occurred when children were on average 185 months old (15 years, 5 months), with a standard deviation of almost 7 months. Because the variation in the age the child was observed at the age 15 study wave is much greater than at other waves, and the upper tail is much longer, I also repeated the analyses of Model 3 in a sample restricted to participants whose adolescent (age 15) observation occurred when they were less than 17 years old (N = 2,369). Results of these analyses indicate no substantive differences in patterns of childhood sleep disparities when adolescents over age 17 were excluded from the analytic sample.

Discussion

Using prospective, national data for the United States, this paper provides the first description of sociodemographic disparities in sleep duration in a cohort followed from early childhood to adolescence. Nightly sleep duration declines with age over the period of early childhood through adolescence, as expected (Eaton et al. 2010; Keyes et al. 2015; Paruthi et al. 2016; Williams, Zimmerman, and Bell 2013). This pattern is nonlinear, with sleep duration declining more quickly among older children than younger ones. There are disparities in these

childhood sleep trajectories, however. Sex differences in nightly sleep duration, which advantage boys, are small and only appear in adolescence. The largest and most persistent differences are those by race, ethnicity, and nativity groups. Children of black mothers consistently sleep for shorter periods each night than do children of white mothers, and at all ages children of immigrant mothers sleep longer each night than children whose mothers were born in the United States. Disparities in childhood sleep by socioeconomic status are more complex. In early childhood, children who have college-educated mothers or who live in the highest-income households sleep substantially more each night than children of less-educated mothers or those who live in lower-income households. By adolescence, these trends appear to reverse, with children of the most educated mothers and highest income households sleeping the least.

Reconciling disparities with those previously identified

Similar to patterns in existing literature, sex differences emerge in adolescence and indicate that boys sleep longer than girls. Prior work finds no sex difference in early and middle childhood (Adam et al. 2007), though boys report sleeping longer than girls in adolescence (Adam et al. 2007; Eaton et al. 2010; Maslowsky and Ozer 2014). One study found no sex difference in sleep duration across childhood, but pooled children ages 6-17, obscuring disparities that change with age (Buxton et al. 2015).

Like previous studies of racial and ethnic disparities in sleep, this study finds that there are systematic and persistent differences in nightly sleep duration. White children and adolescents sleep for substantially longer each night than do black children and adolescents, replicating earlier findings (Adam et al. 2007; Anderson and Whitaker 2010; Maslowsky and Ozer 2014). Though white-Hispanic disparities in childhood and adolescent sleep duration are inconsistent in prior literature, this study's finding that white children and adolescents sleep for

longer than Hispanic children and adolescents aligns with the majority of earlier work in this area (Adam et al. 2007; Anderson and Whitaker 2010).

The present study also reveals that children of immigrant mothers sleep for longer than children of native-born parents. This advantage extends across childhood and adolescence and is the only observed disparity that remains relatively constant across these ages. No prior national studies of sleep disparities considered parental nativity.

While prior literature showed that higher parental education was associated with longer sleep durations across childhood and adolescence (Anderson and Whitaker 2010; Buxton et al. 2015; Keyes et al. 2015), the present study confirmed this pattern in early childhood only. In contrast, the present study found that in middle childhood there is little difference in sleep duration by parental education, and in adolescence children of the most educated parents sleep the least. One explanation for different findings in the present study compared to prior research could be that there is a change in who reports the child's sleep from the primary caregiver (early and middle childhood) to the adolescent. However, previous studies also considered both parent- and adolescent-reported sleep durations and found associations unchanged regardless of reporter. Another explanation for differences in the findings of the present study and prior literature is that this study considers maternal educational attainment at the child's birth due to its longitudinal study design. Other studies used reports of maternal or parental educational attainment at the time sleep was assessed.

A nascent trend in prior literature on the association between household income and childhood sleep duration is affirmed in these findings. Previous studies showed that higher income was associated with longer sleep in early childhood; there was no association in middle childhood; and among adolescents there was shorter weekend sleep among children of higher-

income parents (Adam et al. 2007; Anderson and Whitaker 2010). The present study validates this finding in a sample followed prospectively: children in the highest-income households sleep the most in early childhood and the least in adolescence.

The lack of differences in childhood and adolescent sleep duration by family structure is not consistent with previous literature, which found a consistent pattern of longer nightly sleep durations among children living in married or two-parent households (Adam et al. 2007; Anderson and Whitaker 2010; Buxton et al. 2015). That the present study did not replicate this result is especially surprising given that FFCWS was designed to study the implications of nonmarital childbearing and included an oversample of children born to unmarried parents. One likely explanation is that in FFCWS family structure is measured as married, cohabiting, or no relationship between the child's biological parents at the time of the child's birth; prior studies either focused on the marital status of the parent (regardless of whether or not this relationship was with the child's other biological parent) (Adam et al. 2007; Buxton et al. 2015) or compared children living with only one biological parent to children in any other family arrangement (Anderson and Whitaker 2010). Additionally, the present study design measured family structure at the time of the child's birth for clear temporal ordering prior to the measurement of the sleep outcome; other studies on this topic measured it contemporaneously with sleep.

Limitations

While this study is strengthened by its prospective study design, it also has several limitations. Because this birth cohort is comprised of children born in large cities, these findings may not generalize to children or adolescents born in rural areas or smaller cities. Also, the longitudinal nature of this study means that families included in analyses completed all necessary follow-up waves; excluded households were on average more socioeconomically disadvantaged

than those who were included, and there were higher levels of attrition among children whose mothers were Hispanic or foreign born. It is not clear whether or how the sleep disparities of children growing up in these families may be systematically different from those included in the analytic sample.

Additionally, the repeated measures of typical weeknight sleep duration used in this study have several limitations. First, this study uses a reported measure of sleep duration, not an objective measure. Though reported and objective sleep duration measures are correlated, reported measures contain error (Kushnir and Sadeh 2013; Nelson et al. 2014; Short et al. 2012; Tikotzky and Sadeh 2001; Wolfson et al. 2002). Reported sleep durations may also be affected by socially desirability; if this bias in reporting is not the same across groups, it may appear that there are disparities in childhood sleep when sleep does not actually differ. Thus, it is necessary to examine disparities in objectively-measured sleep in population-based studies (see Chapter 3). Second, the study shifted from having primary caregivers report sleep duration in early and middle childhood to having adolescents report their own sleep durations. Though justified by prior literature on sleep measurement among adolescents – parents are less accurate reporters of adolescent sleep than are adolescents themselves (Short et al. 2013) – this change in measurement source complicates the interpretation of these analyses. Third, sleep duration is observed at ages 4-6, 9-11, and 14-18. Consequently, these analyses are not able to identify disparities in early childhood nightly sleep durations prior to age 4, an important developmental period. Likewise, it would be informative to examine disparities in sleep duration between ages 11 and 14, as this study suggests that there may be convergence or reversal of disparities in these years. Fourth, this study did not consider disparities in weekend sleep duration or napping. While adolescents are queried about their typical weekend sleep hours, parents do not report weekend

sleep durations among younger children; likewise, FFCWS does not collect reports of typical napping behavior. Because napping or weekend sleep may be used to compensate for inadequate nightly sleep duration, future work should consider these additional sleep periods. To address these limitations, future studies should collect objective measures (e.g., actigraphy or polysomnography) of full-day sleep duration (including naps) on weekdays and weekends across childhood and adolescence.

Implications

This study identifies disparities in developmental trajectories of weeknight sleep duration in a national birth cohort in the United States. The implications of these sleep disparities for inequality in the downstream mental and physical consequences of sleep requires knowing at which ages and developmental stages sleep matters most for a given outcome. Thus, these findings underscore the need for developmentally-informed and age-specific research on the short- and long-term effects of concurrent and cumulative sleep duration among children and adolescents. Though it is well-established that cumulative sleep deprivation has negative effects on cognition and health (Beebe 2011; Shochat, Cohen-Zion, and Tzischinsky 2014), there are few studies that consider long-term outcomes of typical childhood and adolescent sleep duration. Adolescent sleep duration is prospectively associated with educational attainment in young adulthood (see Chapter 4 as well as Sabia, Wang, and Cesur 2016), but there exists little research on the longer-term consequences of sleep in early or middle childhood for later outcomes.

Determining how changing disparities in sleep across developmental periods matter for disparities in downstream outcomes of sleep will be complex. This study suggests that sleep likely is not implicated in sex disparities in early childhood outcomes, though it may relate to adolescent differences. In contrast, black-white sleep disparities may exacerbate disparities in

other outcomes across childhood and adolescence, and the accumulation of these sleep disparities across development may be related to disparities in adult outcomes. Sleep may also contribute to advantages among children of immigrant mothers. Finally, the evidence of a reversal of socioeconomic patterning of sleep between early childhood and adolescence identified in this study is provocative and may have consequences for social stratification. Nonetheless, developing a nuanced understanding of the age- and outcome- specific importance of sleep will ultimately facilitate identifying at which ages and for which groups interventions may be best targeted to ameliorate inequality.

Table 2.1 Description and comparison of FFCWS samples

	Baseline (N = 4,898)	Analytic (N = 2,383)	T-test[1]
	% or Mean (SD)	% or Mean (SD)	p-value
Outcome			
Sleep duration, age 5 (minutes)	N/A	565.0 (72.8)	N/A
Sleep duration, age 9 (minutes)	N/A	537.2 (65.9)	N/A
Sleep duration, age 15 (minutes)	N/A	481.7 (72.0)	N/A
Covariates			
Child age, age 5 (months)	N/A	61.1 (2.4)	N/A
Child age, age 9 (months)	N/A	109.7 (3.3)	N/A
Child age, age 15 (months)	N/A	185.4 (6.7)	N/A
Child male	52.4%	51.9%	0.435
Mother race/ethnicity			
White, non-Hispanic	21.1%	22.2%	0.062
Black, non-Hispanic	47.6%	51.8%	**0.000**
Hispanic	27.3%	23.0%	**0.000**
Other race/ethnicity, non-Hispanic	4.0%	3.0%	**0.001**
Mother foreign born	17.0%	11.8%	**0.000**
Mother education, at child's birth			
College graduate	10.7%	11.0%	0.533
Some college	24.3%	26.3%	**0.001**
High school or GED	30.3%	31.2%	0.170
Less than high school	34.7%	31.5%	**0.000**
Household income, at child's birth			
>299% poverty line	22.6%	23.8%	**0.045**
200-299% poverty line	15.5%	15.4%	0.791
100-199% poverty line	25.8%	25.8%	0.954
<100% poverty line	36.2%	35.0%	0.111
Parent relationship, at child's birth			
Married	24.2%	24.1%	0.908
Cohabiting	36.4%	34.7%	**0.015**
No relationship	39.3%	41.1%	**0.013**
Mother age, at child's birth	25.3 (6.1)	25.2 (6.0)	0.327

[1] T-tests compare the baseline and analytic samples; bolded p-values are statistically significant at $p<0.05$.

Table 2.2 Coefficients and standard errors from growth curve models of minutes of nightly sleep duration, N = 2,383

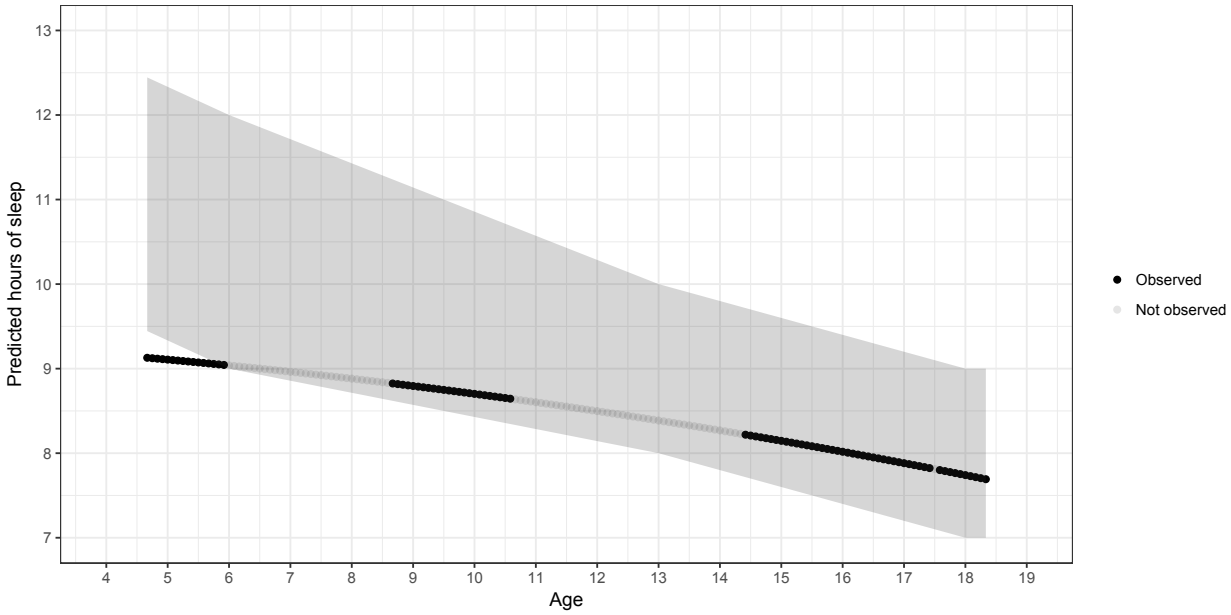
	Model 1	Model 2	Model 3
Fixed-effects estimates			
Main effects			
Child age (months)	-0.64*** (0.02)	-0.64*** (0.02)	-1.05*** (0.12)
Child age (months) squared	-0.001** (0.0004)	-0.001** (0.0004)	-0.001** (0.0004)
Child male		1.94 (1.81)	1.12 (1.85)
Mother race/ethnicity (reference: white, non-Hispanic)			
Black, non-Hispanic		-23.9*** (2.571)	-25.82*** (2.64)
Hispanic		-8.20** (3.10)	-9.38** (3.18)
Other race/ethnicity, non-Hispanic		-20.23*** (5.79)	-19.94*** (5.93)
Mother foreign born		11.48*** (3.28)	11.71*** (3.37)
Mother education (reference: college graduate)			
Some college		-4.06 (3.68)	-6.10 (3.77)
High school or GED		-5.78 (3.90)	-8.93* (3.99)
Less than high school		-2.51 (4.14)	-5.18 (4.24)
Household income (reference: >299% poverty line)			
200-299% poverty line		-7.09* (3.18)	-8.17* (3.26)
100-199% poverty line		-3.36 (3.00)	-4.23 (3.07)

<100% poverty line	-3.17 (3.08)	-5.01 (3.16)
Parent relationship (reference: married)		
Cohabiting	-6.67* (2.84)	-6.94* (2.92)
No relationship	-3.37 (2.94)	-3.75 (3.02)
Mother age	0.11 (0.17)	0.12 (0.18)
Interactions with age		
Child male * child age		0.06* (0.03)
Mother race/ethnicity (reference: white, non-Hispanic)		
Black, non-Hispanic * child's age		0.15*** (0.05)
Hispanic * child's age		0.10† (0.06)
Other race/ethnicity, non-Hispanic * child's age		-0.03 (0.10)
Mother foreign born * child's age		-0.02 (0.06)
Mother education (reference: college graduate)		
Some college * child's age		0.17** (0.07)
High school or GED * child's age		0.26*** (0.07)
Less than high school * child's age		0.22** (0.07)
Household income (reference: >299% poverty line)		
200-299% poverty line * child's age		0.09 (0.06)
100-199% poverty line * child's age		0.07 (0.05)
<100% poverty line * child's age		0.15** (0.06)

Parent relationship (reference: married)			
Cohabiting * child's age			0.02 (0.05)
No relationship * child's age			0.03 (0.05)
Mother age at child's birth * child's age			0.001 (0.003)
Constant	537.89*** (1.34)	557.91*** (6.51)	563.27*** (6.67)
Random-effects estimates			
SD of intercept	32.78	29.22	29.12
SD of slope (age)	0.46	0.46	0.43
Cor intercept and slope	-0.34	-0.27	-0.26
SD of residual	58.24	58.26	58.27
Observations per individual	3	3	3
Log Likelihood	-40,413.62	-40,309.49	-40,259.33
AIC	80,841.23	80,660.98	80,588.66
BIC	80,889.36	80,805.34	80,829.28

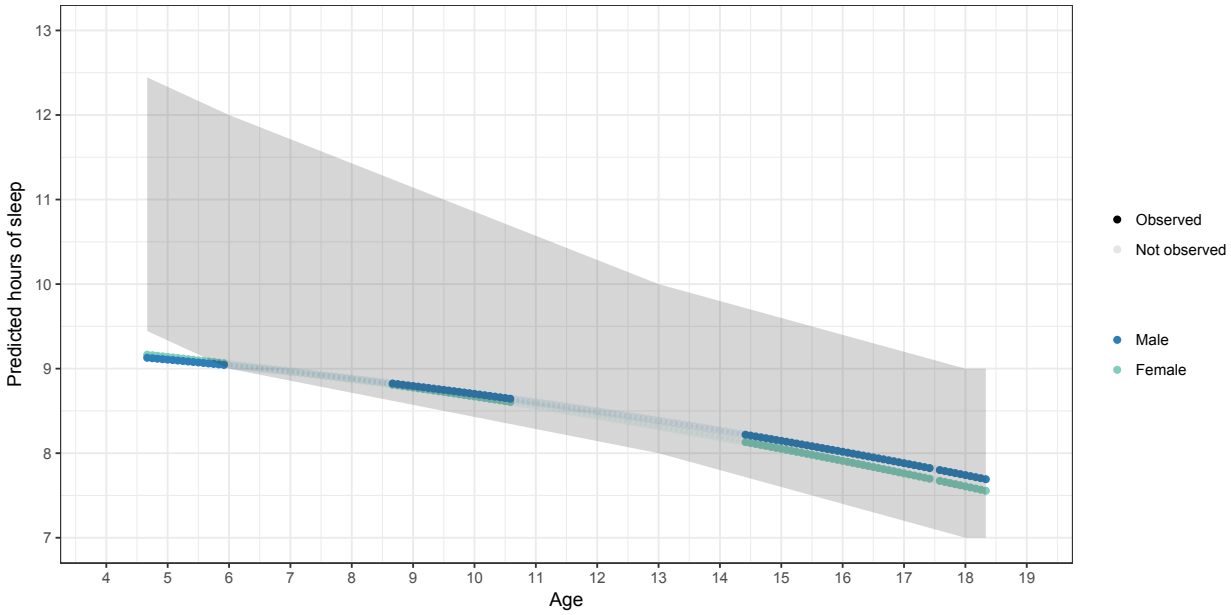
Note: † p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Figure 2.1 Predicted trajectory of sleep duration



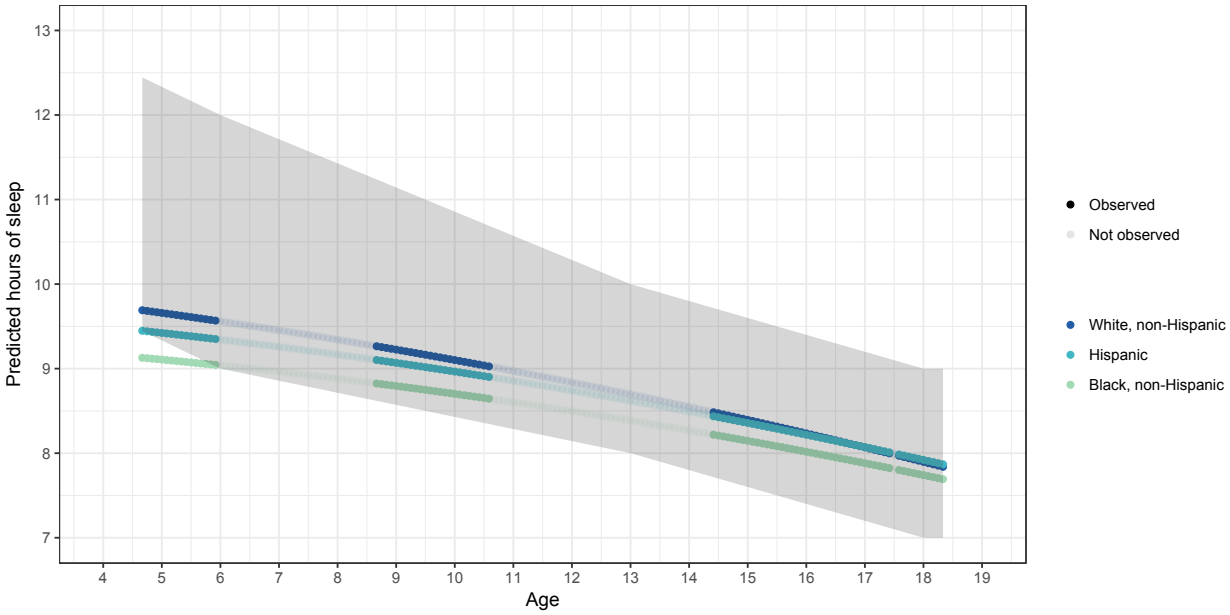
Note: These predicted values hold covariates at their observed mean (for continuous variables) or mode (for categorical variables). That is, these are predictions for a black (non-Hispanic) boy who was born to a 25-year-old native-born mother with less than a high school degree whose household income was below the poverty line and was not in a relationship with the child's biological father at the time of the child's birth. Random effects are set to zero. Shaded areas indicated recommended sleep durations by age (Paruthi et al. 2016), interpolated.

Figure 2.2 Trajectories of sleep duration by child sex



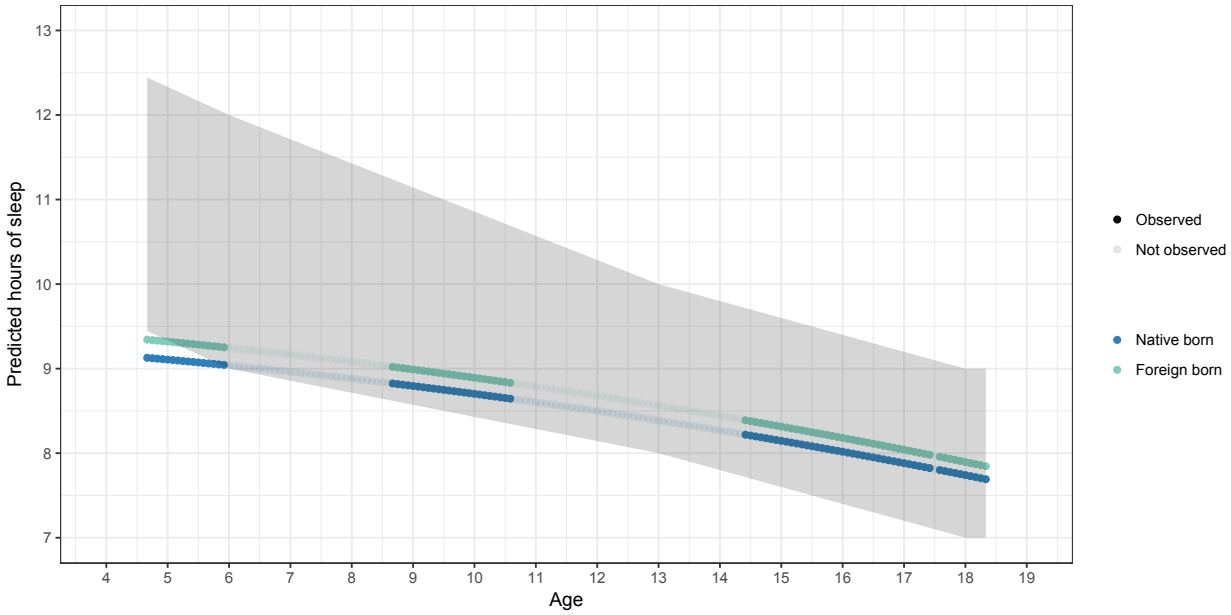
Note: These predicted values hold additional covariates at their observed mean (for continuous variables) or mode (for categorical variables). That is, these are predictions for a black (non-Hispanic) child who was born to a native-born 25-year-old mother with less than a high school degree whose household income was below the poverty line and was not in a relationship with the child's biological father at the time of the child's birth. Random effects are set to zero. Shaded areas indicated recommended sleep durations by age (Paruthi et al. 2016), interpolated.

Figure 2.3 Trajectories of sleep duration by mother's race/ethnicity



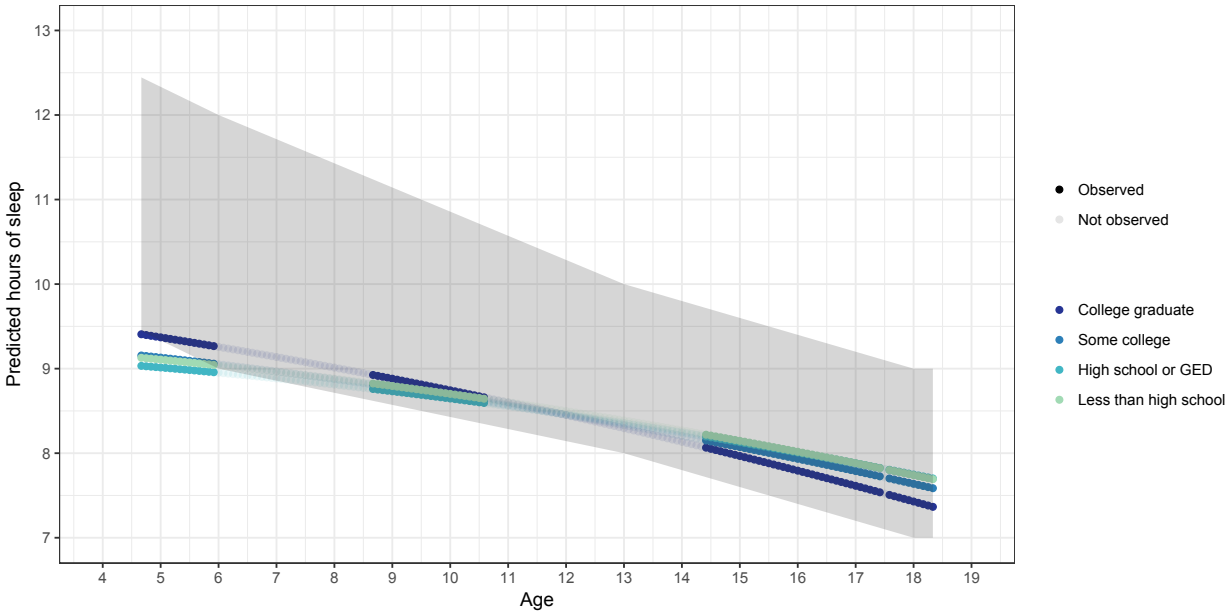
Note: These predicted values hold covariates at their observed mean (for continuous variables) or mode (for categorical variables). That is, these are predictions for a boy who was born to a 25-year-old native-born mother with less than a high school degree whose household income was below the poverty line and was not in a relationship with the child's biological father at the time of the child's birth. Random effects are set to zero. Shaded areas indicated recommended sleep durations by age (Paruthi et al. 2016), interpolated.

Figure 2.4 Trajectories of sleep duration by mother's nativity



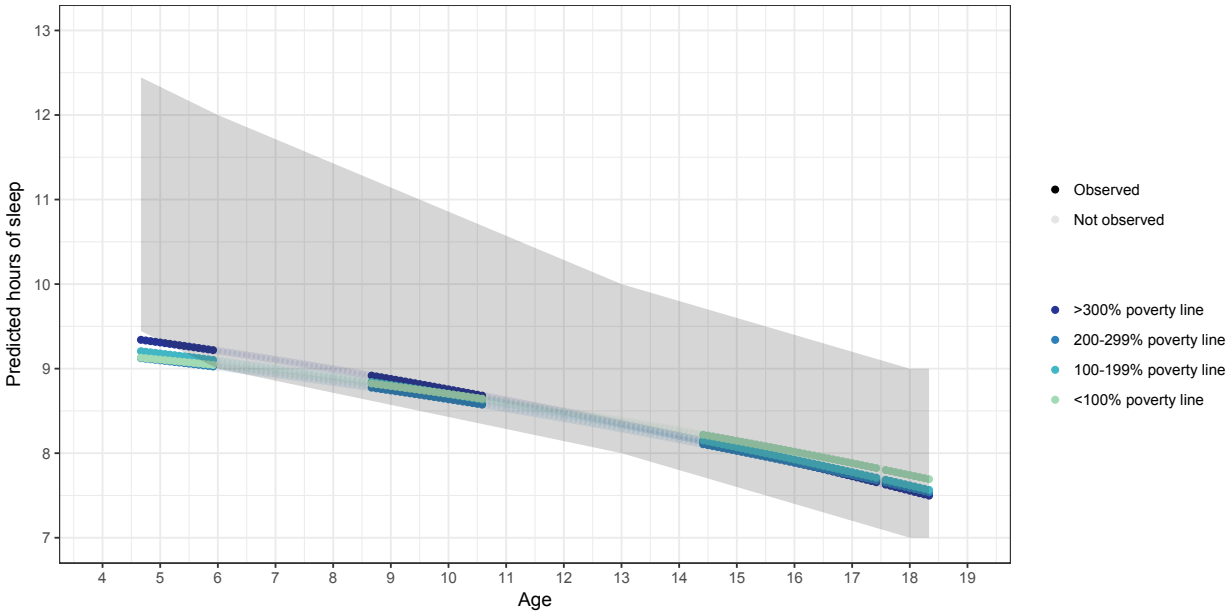
Note: These predicted values hold covariates at their observed mean (for continuous variables) or mode (for categorical variables). That is, these are predictions for a black (non-Hispanic) boy who was born to a 25-year-old mother with less than a high school degree whose household income was below the poverty line and was not in a relationship with the child's biological father at the time of the child's birth. Random effects are set to zero. Shaded areas indicated recommended sleep durations by age (Paruthi et al. 2016), interpolated.

Figure 2.5 Trajectories of sleep duration by mother's education at child's birth



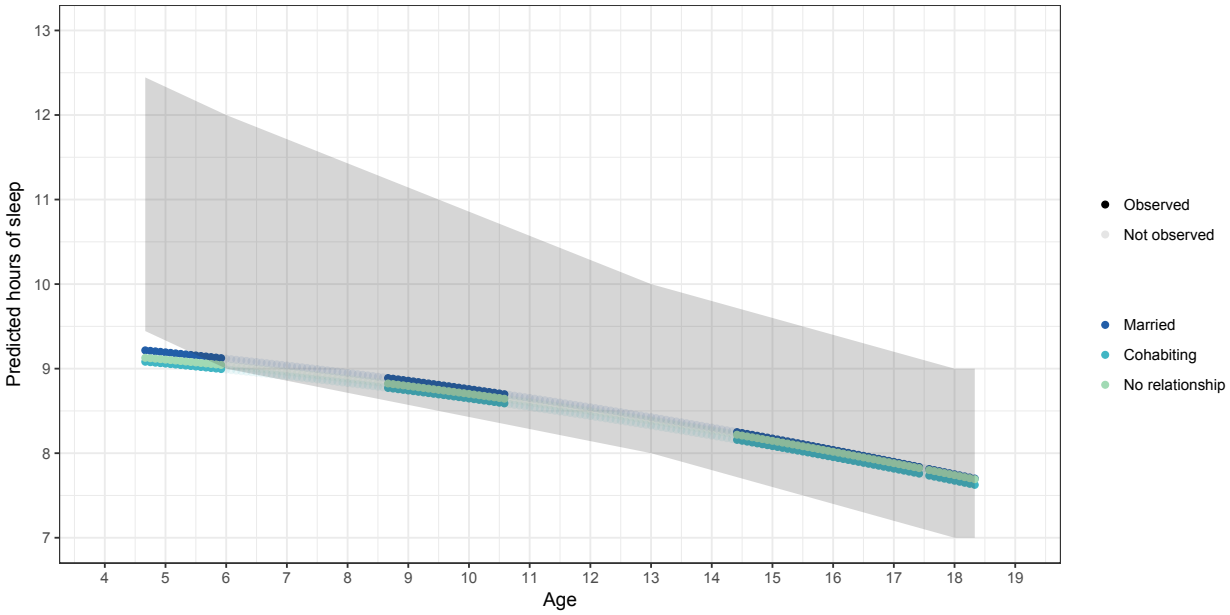
Note: These predicted values hold covariates at their observed mean (for continuous variables) or mode (for categorical variables). That is, these are predictions for a black (non-Hispanic) boy who was born to a 25-year-old native-born mother whose household income was below the poverty line and was not in a relationship with the child's biological father at the time of the child's birth. Random effects are set to zero. Shaded areas indicated recommended sleep durations by age (Paruthi et al. 2016), interpolated.

Figure 2.6 Trajectories of sleep duration by mother's household income at the child's birth



Note: These predicted values hold covariates at their observed mean (for continuous variables) or mode (for categorical variables). That is, these are predictions for a black (non-Hispanic) boy who was born to a 25-year-old native-born mother with less than a high school degree who was not in a relationship with the child's biological father at the time of the child's birth. Random effects are set to zero. Shaded areas indicated recommended sleep durations by age (Paruthi et al. 2016), interpolated.

Figure 2.7 Trajectories of sleep duration by mother's relationship with father at the child's birth



Note: These predicted values hold covariates at their observed mean (for continuous variables) or mode (for categorical variables). That is, these are predictions for a black (non-Hispanic) boy who was born to a 25-year-old native-born mother with less than a high school degree whose household income was below the poverty line at the time of the child's birth. Random effects are set to zero. Shaded areas indicated recommended sleep durations by age (Paruthi et al. 2016), interpolated.

Appendix 2A. Growth curve model

The growth curve model of sleep duration for person *i* at time *t* is given by:

$$Y_{it} = A_i + B_i age + \Gamma age^2 + \varepsilon_{it}$$

where the intercept is:

$$A_i = \alpha_1 x + \alpha_i$$

and the slope is

$$B_i = \beta_1 x + \beta_i$$

where

Y_{it} = sleep duration

x = a vector of sociodemographic covariates, measured at the time of the child's birth

α_i = random component of person *i*'s intercept

β_i = random component of person *i*'s slope

ε_{it} = person *i*'s time-specific error term, $\varepsilon_{it} \sim N(0,\sigma_\varepsilon^2)$

$$\begin{pmatrix} \alpha_i \\ \beta_i \end{pmatrix} \sim N_2 \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_\alpha^2 & \sigma_{\alpha\beta} \\ \sigma_{\alpha\beta} & \sigma_\beta^2 \end{pmatrix} \right)$$

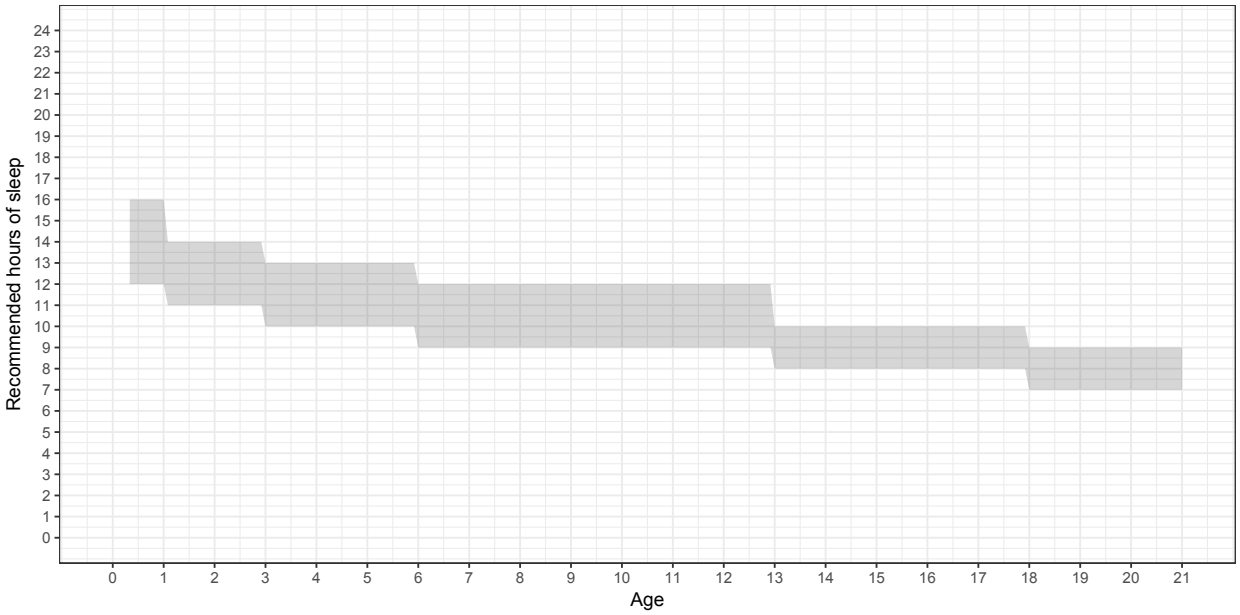
The intercept A_i and slope B_i vary both systematically (based on sociodemographic covariates, as represented by α_1 and β_1) and randomly (beyond sociodemographic covariates, as represented by α_i and β_i). The random components α_i and β_i are assumed to come from a bivariate normal distribution with mean zero and an unstructured covariance matrix; ε_{it} is the individual's time-specific error term.

Appendix 2B. Analysis of deviance

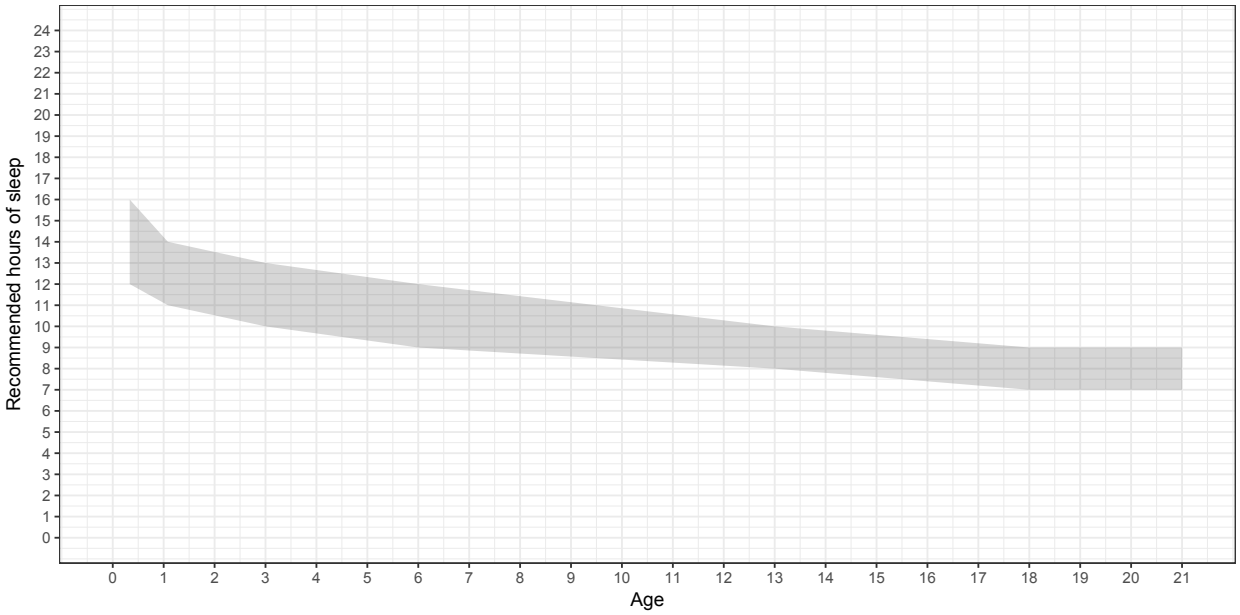
Model	Degrees of freedom	AIC	BIC	Test	Likelihood ratio	p-value[1]
1	7	80841.23	80889.36			
2	21	80660.98	80805.34	1 vs. 2	208.2592	**0.000**
3	35	80588.66	80829.28	2 vs. 3	100.3105	**0.000**

[1] Bolded values are statistically significant at $p<0.05$.

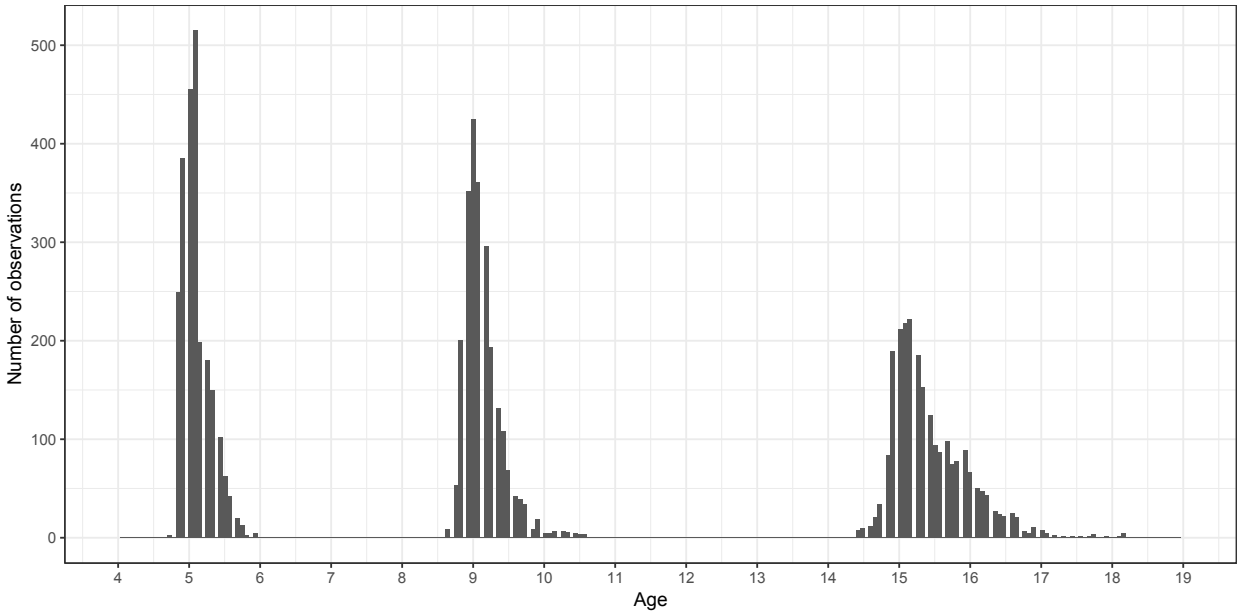
Appendix 2C. Recommended range of pediatric sleep duration (Paruthi et al. 2016)



Appendix 2D. Interpolated recommended range of pediatric sleep duration (Paruthi et al. 2016)



Appendix 2E. Age distribution of analytic sample



Chapter 3

Sociodemographic Disparities in Objectively-Measured Adolescent Sleep Health[4]

There has been relatively little research on the sociodemographic predictors of adolescent sleep health in the United States, with the bulk of extant studies using large national samples of adolescents with self- or parent-reported measures of adolescents' nightly sleep duration, adequacy, or quality. Sex differences are apparent: males report sleeping longer than females in adolescence (Keyes et al. 2015; Maslowsky and Ozer 2014). Ethnoracial background is associated with disparities in adolescent sleep health, with white adolescents reporting longer nightly sleep durations than black or Hispanic adolescents (Guglielmo et al. 2018). Additionally, adolescents living with married parents or two biological parents have higher odds of parent-perceived adequate nightly sleep than adolescents living in other family arrangements (Hawkins and Takeuchi 2016; Singh and Kenney 2013). Socioeconomic status is also associated with adolescent sleep health. Adolescents living in higher-income or more-educated households are less likely to report adequate sleep than are adolescents living in lower-income or less-educated households (Hawkins and Takeuchi 2016; Keyes et al. 2015; Singh and Kenney 2013; Smaldone, Honig, and Byrne 2007).

Although more limited in generalizability, three community studies examine sociodemographic disparities in smaller samples of adolescents for whom objective (i.e., not self-reported) measures of sleep are available. Using a sample of 250 western Pennsylvania adolescents, Matthews et al. (2014) examined sex and racial differences in actigraphic sleep

[4] A version of this chapter is under review as "Disparities in adolescent sleep health by sex and ethnoracial group", co-authored with Anne-Marie Chang, Orfeu Buxton, and Lauren Hale.

duration and quality. Male adolescents in this sample slept for fewer minutes on weekdays and during the full week than did females, though there was no difference in weekend sleep. Males also had more fragmented sleep than did females. Black adolescents had shorter weekday, weekend, and full-week sleep durations and greater sleep fragmentation than white adolescents. Similarly, Moore et al. (2011) examined sex and ethnoracial differences in actigraphic sleep duration and timing using a sample of 247 adolescents living in Cleveland, Ohio. In that sample, males and non-white adolescents slept less on an average night than did females and white adolescents. Additionally, non-white adolescents had more variable sleep timing than white adolescents. Finally, Marco et al. (2012) found that, among 155 New England adolescents, lower socioeconomic status (measured by a latent factor including income, education, number of working adults in home, and neighborhood socioeconomic status) was associated with worse actigraphy-assessed sleep health, including shorter sleep durations, later sleep times, and more sleep variability.

Between these two bodies of research, the direction of sleep disparities among demographic groups is at times inconsistent, complicating our understanding of the social determinants of adolescent sleep. Notably, sex differences go in opposite directions depending on the sleep measurement used. Alhough males report longer sleep durations than females, actigraphy shows that males sleep less and more poorly than females. There is consistent evidence that nonwhite adolescents have shorter nightly sleep durations white adolescents, regardless of sleep measurement. The association of family structure with adolescent sleep has been examined only using parent-reported sleep outcomes. Actigraphic data show that higher socioeconomic status facilitates sleep health; studies of reported sleep outcomes find the same

association with regard to meeting sleep duration guidelines but the opposite for perceived sleep adequacy.

In sum, studies are limited by either the quality of their sleep measures or their generalizability. Prior studies have either (1) used national studies that rely on self- or parent-reported measures of nightly adolescent sleep times, sleep adequacy, or sleep quality or (2) used high-quality sleep measures in studies of community samples. However, given increasingly low-cost methods of collecting objective sleep measurements in natural sleep settings and interest in gathering this type of data at the population level and/or appending it to extant cohort studies, it is now feasible to bring a population-based approach to studies of objective sleep data.

This paper uses newly-collected actigraphy data from a national birth cohort study in the United States, the Fragile Families and Child Wellbeing Study (FFCWS). While prior studies at the national level have relied on self-reported measures of sleep health or have been limited to single-community studies using actigraphy, a primary aim of this analysis is to examine sociodemographic disparities in adolescent sleep using a large, diverse cohort study with objectively-measured sleep data. By using multiple days of actigraphic sleep data, I am also able to conduct analyses of (1) within-person variability in sleep, including how sleep timing changes from one day to the next, and (2) sleep that occurs outside of the nighttime sleep period (i.e., napping), an important component of multifaceted sleep health that has not been examined in prior studies.

I predict that the associations between demographic factors and adolescent sleep health in this national sample will be most similar to those previously identified using objective measures of sleep duration. Therefore, I anticipate that males will have shorter sleep durations and lower quality sleep than females. Similarly, I hypothesize that black and Hispanic adolescents will

sleep less, more poorly, and have more variable sleep timing than non-Hispanic whites. Likewise, I expect that adolescents living in two-parent households will have better sleep health. Finally, prior literature suggests that socioeconomic advantage is most likely to facilitate better sleep health among adolescents.

Methods

Data

Data come from the Fragile Families and Child Wellbeing Study (FFCWS), a cohort study of 4,898 children born between 1998 and 2000 in 20 large American cities (population > 200,000). Recruitment into the broader cohort study included stratified sampling of cities, selection of hospitals within cities, and selection of births within hospitals; due to original study aims, the study oversampled non-marital births, as described by Reichman et al. (2001). FFCWS conducted interviews with parents at the time of the child's birth as well as five follow-up waves when the child was approximately ages 1, 3, 5, 9, and 15. This study analyzes data from participants in the in-home portion of the FFCWS age 15 follow-up.

Families were eligible for inclusion in the broader age 15 follow-up if the child was alive and not legally adopted (95% of baseline sample). Among those 4,663 families, 1,535 families were randomly selected for the in-home component of the study and 1,090 home visits were completed. Of these 1,090 cases, 1,049 consented to participate in actigraphy data collection and 923 adolescents ultimately provided at least one valid day of actigraphy data. Appendix 3A compares the sociodemographic characteristics of the analytic samples with those of home visit participants, the group eligible for actigraphy data collection.

Analyses of weekday sleep considered only the 892 adolescents with weekday actigraphy observation(s). For precision of actigraphy measurements, I further restrict the analytic sample to

the 753 adolescents with at least 3 valid weekdays of actigraphy coverage (Marino et al. 2013). A sensitivity analysis considered other numbers of valid days, as described in the Supplemental analyses section. Of these 753 adolescents, the final analytic sample included the 714 adolescents who also provided complete data on all covariates.

Analyses of weekend sleep began with the 809 adolescents who had any weekend actigraphy sleep observation(s). Next, I limited the analytic sample to the 596 adolescents with at least two nights of weekend actigraphy sleep observation. After dropping cases with missing values on covariates, the analytic sample for weekend sleep included 558 adolescents. I did not conduct a sensitivity analyses for the valid number of weekend night actigraphy observations for two reasons. First, adolescents were instructed to wear the actigraphy device for 7 days, meaning that the study design did not include more than two weekend nights. Second, it was not possible to analyze adolescents who wore the device for only one weekend night, as there was no measure of sleep timing variability available for those adolescents.

Measures

Table 3.1 describes the analytic samples.

Sleep

Data on adolescent sleep was collected using one week of actigraphy data collection (Actiwatch Spectrum, Philips Respironics). Each record was independently scored by two individuals, and discrepancies between scorers (N = 16) were adjudicated by a third scorer. Sleep intervals were defined as those periods that began with a 30-second epoch of high activity (>10 activity counts) prior to at least five 30-second epochs of little to no activity (< 10 activity counts). To adjudicate between sleep intervals and low-activity wake periods, scorers used a combination of (1) visual inspection, (2) changes in light levels detected by the device, and (3)

within-person similarity in activity levels across potential sleep intervals. Within each sleep interval, the duration of sleep was calculated in SAS (version 9.4, SAS Institute, 2008) using an algorithm that was validated against polysomnography in a young adult sample (Marino et al. 2013). All sleep intervals with at least 30 minutes of sleep were included in analyses. The main sleep interval is the sleep interval with the most nighttime sleep (overlapping the period of 10pm-8am); other sleep intervals at least 60 minutes away from the main interval and on the same day are treated as naps.

The analytic sample for weekday sleep included adolescents who provided at least three valid days of weekday actigraphy data, and the analytic sample for weekend sleep included adolescents who provided at least two valid days of weekend actigraphy data. Valid actigraphy days included days on which there was no device malfunction (i.e., data were able to be retrieved and downloaded), no device failure (i.e., no false activity patterns indicating battery failure), and the adolescent compliance with actigraphy procedures (i.e., the adolescent did not remove the device for more than 4 hours per day and did not have an off-wrist period of more than 1 hour within 10 minutes of the beginning or end of the main sleep interval).

Variables measuring average sleep duration included the adolescent's nightly sleep minutes, whether nightly sleep duration was between 8 and 10 hours (the range recommended by two consensus panels on adolescent sleep duration (Hirshkowitz et al. 2015; Paruthi et al. 2016)), whether the adolescent ever napped, and 24-hour sleep minutes,. Of note, only 15 adolescents, or 2% of the adolescent weekday sample, slept for an average of 10 hours or more on weeknights, and only 25 adolescents, or 4% of the adolescent weekend sample, slept for an average of 10 hours or more on weekend nights.

Additionally, I considered the adolescent's sleep timing. Sleep timing is measured by two aspects of the midpoint of the adolescent's sleep, a behavioral marker of circadian system timing (Burgess et al. 2003). Sleep midpoint of the adolescent's sleep period was calculated as the midpoint between sleep onset and sleep offset. I modeled both the mean, measured in decimal time (e.g., 12:00am is coded as 0, 12:30pm is coded as 12.5), and standard deviation (SD), measured in hours, of the midpoint of the adolescent's sleep.

I also measured the adolescent's nightly time spent awake after sleep onset (WASO), measured in minutes. Roughly one third of the FFCWS actigraphy sample had low (less than 30 minutes), medium (30-45 minutes), or high (45 minutes or more) WASO on weekdays and on weekends; these WASO categories align with those used by Buxton et al. (2018) In analyses, this measure is dichotomized into low and non-low (i.e., medium or high) WASO.

Sociodemographic factors

Demographic characteristics of the adolescent included sex and ethnoracial group, with the latter including categories for non-Hispanic white (reference), non-Hispanic black, Hispanic, and non-Hispanic of some other racial group. Family structure indicated whether the adolescent lived with both biological parents (reference), one biological parent and that parent's romantic partner, a single biological parent, or a non-biological-parent primary caregiver. The primary caregiver's educational attainment included categories for college graduate (reference), some college, a high school diploma or GED, and less than a high school degree. Household income was measured relative to the poverty line, with adolescents living in households whose income exceeds 299% of the poverty line serving as the reference group and additional categories for households whose income to poverty ratio is 200-299%, 100-199%, or less than 100%.

Supplemental health covariates

In supplemental analyses, I also included as covariates several health factors previously identified to be associated with adolescent sleep. Adolescents were classified as overweight (BMI percentile greater than or equal to 85) or not overweight (BMI percentile less than 85) (reference) based on in-home measurements of height and weight. The adolescent's depressive symptomology was measured using a modified 5-item Center for Epidemiologic Studies Depression Scale (CES-D) score (Cronbach's alpha = 0.77 for full age 15 sample), while anxiety was assessed using a modified 6-item Brief Symptom Inventory 18 (BSI) score (Cronbach's alpha = 0.76 for full age 15 sample).

Analytic strategy

I modeled the adolescent's nightly sleep minutes, 24-hour sleep minutes, midpoint of night sleep, and standard deviation of midpoint of night sleep using linear regression. For binary outcomes – whether the adolescent's nightly sleep duration was within the recommended range, the adolescent napped, or the adolescent's WASO was medium to high – I used logit models. Models of WASO and napping controlled for nightly sleep minutes.

Results

Results are presented in five tables. Table 3.1 includes descriptive statistics for the weekday and weekend night actigraphy analytic samples. Tables 3.2 and 3.4 present results from analyses of sociodemographic disparities in adolescent sleep duration on weekday and weekend nights, respectively. These outcomes include night sleep minutes, whether the adolescent's nightly sleep duration fell within the recommended range, whether the adolescent napped, and the adolescent's 24-hour sleep minutes. Tables 3.3 and 3.5 present results from analyses of sociodemographic disparities in adolescent sleep timing and WASO on weekday and weekend nights, respectively. Sleep timing included the midpoint of sleep and the standard deviation of

midpoint of sleep, while sleep quality was indicated by medium to high WASO (>=30 minutes) vs. low WASO (<30 minutes).

Sleep health in a national sample of adolescents

Sleep durations on weekday and weekend nights are very similar: on average, adolescents sleep for approximately 7 hours and 45 minutes each night and 8 hours and 6 minutes per 24-hour period on both weekdays and weekends. Consequently, 63% of adolescents do not sleep within the recommended range for their age group on weekday nights, while 62% do not meet the same requirements on weekend nights. However, these similar means obscure differences in variability between weekday and weekend nights, because there is more variation in weekend sleep durations than weekday sleep durations. On weekdays, half of adolescents nap; on weekends, a third of adolescents nap.

Sleep timing is later and more variable on weekend nights than weekday nights. On average, adolescents have a sleep midpoint of 4:30am on weekday nights and 4:48am on weekend nights. The standard deviation of sleep midpoint is 1 hour and 9 minutes on weekday nights and 1 hour and 20 minutes on weekend nights.

Sleep quality is similar across weekday and weekend nights. Seventy-one percent of adolescents have medium to high WASO on weekday nights while 69% of adolescents have medium to high WASO on weekend nights.

Disparities in sleep health

Sex

On both weekday and weekend nights, male adolescents sleep less than female adolescents. Males sleep on average 15 minutes less each weeknight (Table 3.2, Model 1) and have 52% lower odds of napping on weekdays (Table 3.2, Model 3) than females. Therefore, in a

24-hour weekday period males sleep for 22 minutes less than females (Table 3.2, Model 4). On weekend nights, sex disparities are even more pronounced: males sleep for 26 minutes less each night (Table 3.4, Model 1) and have 49% lower odds of napping (Table 3.4, Model 3) than females; overall, males sleep for 36 minutes less in each 24-hour weekend period than females (Table 3.4, Model 4).

There are also consistent sex differences in sleep timing on both weekday and weekend nights, with males having nightly sleep midpoints that are 20 minutes later than females on weekday nights (Table 3.3, Model 1) and 18 minutes later than females on weekend nights (Table 3.5, Model 1) and exhibiting more variability in sleep timing than females on both weekday and weekend nights (Table 3.3, Model 2 and Table 3.5, Model 2). There were no statistically significant sex differences in WASO on weekday or weekend nights, however (Table 3.3, Model 3 and Table 3.5, Model 3).

Ethnoracial background

Ethnoracial background is strongly associated with weekday and weekend adolescent sleep duration. On weekday nights, non-Hispanic black adolescents sleep for 19 minutes less each night (Table 3.2, Model 1) and have 41% lower odds of sleeping within the recommended range of nightly sleep duration (Table 3.2, Model 2) than non-Hispanic white adolescents. However, non-Hispanic black adolescents have more than twice the odds of napping than their non-Hispanic white counterparts (Table 3.2, Model 3), meaning that in a 24-hour period there is no difference in sleep duration between these groups (Table 3.2, Model 4). Notably, these disparities are larger on weekends. On each weekend night, non-Hispanic black adolescents sleep for 38 minutes less each night than do non-Hispanic white adolescents (Table 3.4, Model 1) and thus have 51% lower odds of sleeping within the recommended range (Table 3.4, Model 2).

Because there is little difference in weekend napping behavior among ethnoracial groups (Table 3.4, Model 3), there remain large disparities in sleep duration across the 24-hour sleep period (Table 3.4, Model 4), with non-Hispanic black adolescents sleeping for 22 minutes less per 24-hour weekend period than non-Hispanic white adolescents. Additionally, other non-Hispanic adolescents sleep for 32 minutes less each weekend night than do non-Hispanic white adolescents (Table 3.4, Model 1).

There are also ethnoracial disparities in adolescent sleep timing and quality. On weekday nights, Hispanic adolescents and other non-Hispanic adolescents have less variable sleep timing than non-Hispanic white adolescents (Table 3.3, Model 2). On weekend nights other non-Hispanic adolescents have more variable sleep timing than non-Hispanic white adolescents (Table 3.5, Model 2). On weeknights, non-Hispanic black adolescents have more than twice the odds of having medium to high WASO than non-Hispanic white adolescents (Table 3.3, Model 3); there are no significant ethnoracial disparities in weekend night WASO (Table 3.5, Model 3).

Family structure

Family structure is associated with sleep duration on weekdays. Compared to adolescents living with both of their biological parents, those living with one biological parent and that parent's romantic partner sleep for 13 minutes longer in each 24-hour period (Table 3.2, Model 4). Those in the small group of adolescents whose primary caregiver is someone other than their biological parent sleep about 28 minutes more each night than those living with their two biological parents (Table 3.2, Model 1). Consequently, adolescents living with a non-biological-parent primary caregiver have more than twice the odds of meeting or exceeding the recommended sleep duration than adolescents living with both of their biological parents (Table

3.2, Model 2). Weeknight sleep timing and quality do not vary significantly by family structure, however.

On weekends, family structure is associated with sleep timing only. Adolescents whose primary caregiver is a single biological parent have 26 minute later sleep midpoints, but adolescents living with a non-biological-parent primary caregiver have 52-minute earlier sleep midpoints than adolescents living with both of their biological parents (Table 3.5, Model 1). Weekend sleep timing is more variable among adolescents whose biological parent has a new partner, compared to adolescents whose two biological parents are in a relationship (Table 3.5, Model 2). Family structure is not significantly associated with weekend night sleep duration or quality.

Primary caregiver educational attainment

Adolescents whose primary caregiver has less than a college degree have about twice the odds of napping on weekdays as adolescents whose primary caregiver has a college degree (Table 3.2, Model 3). Similarly, on weekends both adolescents whose primary caregiver has some college education or less than a high school degree have more than twice the odds of napping as adolescents whose primary caregivers have a college degree (Table 3.4, Model 3). Additionally, adolescents whose primary caregiver has a high school degree or GED have more than twice the odds of having medium to high WASO on weekend nights than adolescents whose primary caregiver has a college degree (Table 3.5, Model 3). There are no statistically significant differences in other weekday or weekend sleep duration, timing, or quality measures between these groups.

Household income

Sleep disparities among adolescents living in households with different levels of economic resources are limited to napping behaviors. Adolescents living in households with incomes just above the poverty line have 1.88 times the odds of napping on weekdays (Table 3.2, Model 3) and 1.8 times the odds of napping on weekends than adolescents living in the highest-income households (Table 3.4, Model 3). There are no other significant differences in sleep duration, timing, or quality on weekdays or weekends by household income.

Supplemental analyses

Health covariates

The first set of additional analyses incorporates adolescent physical and mental health measures. These measures include overweight, depression, and anxiety, as described in the Measures section. Due to small amounts of missingness on these measures, the analytic samples are N = 699 for analyses of weeknight sleep and N = 544 for analyses of weekend sleep. On the whole, disparities in both weekday and weekend night sleep duration are similar when these measures are included in the models.

For weekday nights, there are three differences in findings when health covariates are included in the models. The 24-hour sleep duration disparity between adolescents living with both biological parents and one biological parent and a new partner is no longer statistically significant. The disparity in night sleep variability between adolescents whose primary caregivers have less than high school education and a college degree is no longer statistically significant, while disparities in weeknight WASO emerge, which suggest that adolescents with less-educated caregivers have worse sleep quality than those with the most educated caregivers.

For weekend nights, the disparities in night sleep minutes and sleep timing variability between other non-Hispanic adolescents and non-Hispanic white adolescents are no longer statistically significant after including health covariates. All previously-identified family structure disparities in weekend night sleep timing are accounted for by health factors, though after accounting for health covariates three newly statistically significant associations between family structure and sleep timing emerge. Compared to adolescents living with both biological parents, adolescents living with single parents experience more weekend night sleep timing variability and those living with non-parental primary caregivers have significantly earlier and less variable sleep timing. Additionally, sex disparities in weeknight sleep midpoint are no longer significant. Finally, the association between parental education and weekend WASO is no longer significant after including health covariates.

Different numbers of valid actigraphy days

I conducted sensitivity analyses using different cutoffs for sufficient number of days of actigraphy observation for adequate precision in measuring average weekday night sleep variables. For analyses of weekday night sleep, the analytic sample was limited to adolescents with at least 4 (N = 619) or 5 (N = 466) valid actigraphy weekdays. By comparison, the focal analyses required adolescents to have 3 valid actigraphy weekdays (N = 714).

As compared to the focal analyses using at least 3 valid weekday actigraphy observations, disparities in sleep health are very similar in analyses of adolescents who provided at least 4 valid actigraphy days. The black-white disparity in nightly sleep duration is larger in this sample, at 23 minutes per night compared to 15 minutes per night in the focal analyses. Also, the difference in likelihood of napping between adolescents whose primary caregivers have a college

degree and those who have some college or less than high school education is no longer statistically significant in this reduced sample.

Analyses of the smaller sample of adolescents with at least 5 valid weekday actigraphy observations generally suggest differences in sleep duration, timing, and WASO are less precisely identified as compared to the focal analyses, with a number of associations no longer reaching statistical significance. However, black-white gaps in nightly sleep duration are larger in these analyses than in the focal analyses, although there is no statistically significant difference in napping behavior between these groups. Similarly, associations between sex and nightly sleep timing are larger in this sample than in the main analyses.

School week vs. non-school week actigraphy data collection

The final sensitivity analysis assessed whether any of the associations differed among adolescents observed during a school week or a non-school week. Because school attendance was determined based on a supplemental daily diary survey, which not all adolescents completed, information on whether the adolescent wore the actigraph during a school week is only available for a subset of adolescents. Consequently, this sensitivity analysis included 599 individuals in the weeknight sleep analytic sample (84% of the weekday sample) and 468 individuals in the weekend night sleep analytic sample (84% of the weekend sample).

Appendix 3B describes actigraphic sleep and the demographic characteristics on school and non-school weeks. I identified school weeks based on the adolescent's report of attending school on one or more weekdays during their actigraphy data collection. Overall, 67% of weekday and 69% of weekend actigraphy observations took place during school weeks. The likelihood of being observed during a school week did not vary significantly by sex; t-tests show

that Hispanics were significantly more likely to be observed on school weeks than other ethnoracial groups.

After verifying that findings from the main analyses were similar in this reduced sample, I added a covariate indicating whether or not an individual's actigraphy data collection occurred during a school week. Disparities in the napping behavior of adolescents with less than high school and college graduate primary caregivers were no longer statistically significant in this sample, and disparities in weekend sleep timing by family structure and income were similarly eliminated when accounting for school week observation. Also, the black-white disparity in weekend 24-hour sleep duration was less precisely estimated at $p=0.057$ when a school week covariate was included in the model, likely due to the smaller sample size in this analysis. Additionally, this analysis revealed three results that were suppressed in the main analyses. For weekday sleep, Hispanics had 18 minutes longer 24-hour sleep and 23 minutes later sleep midpoints than white non-Hispanics when the school week covariate was included in the model. These analyses also revealed income disparities in weekend sleep timing, with adolescents living in households with 100-199% or 200-299% of the poverty line having earlier sleep midpoints and more sleep timing variability than adolescents in the highest-income households.

Discussion

Using data from a population-based sample of American adolescents born in large cities between 1998 and 2000, I identify disparities in objectively-measured adolescent sleep duration, timing, and quality. I find that sex differences in adolescent sleep are pronounced and advantage females. Ethnoracial disparities in adolescent sleep are complex. Though non-Hispanic black adolescents slept for 19 minutes less each weeknight than non-Hispanic white adolescents, they offset this difference by napping; on weekends, a 38-minute disparity in nightly sleep duration

was not eliminated by napping. Both sex and ethnoracial disparities in sleep duration were larger on weekend nights than weekday nights. Differences in sleep timing and quality by ethnoracial group are less consistent; non-Hispanic black adolescents have higher odds of having medium to high WASO on weeknights than white non-Hispanic adolescents. Differences in adolescent sleep health by family structure are limited, with distinct sleep patterns among the small group of adolescents not living with either biological parent. Finally, adolescents whose primary caregivers are the most educated have lower odds of napping and more variable sleep timing than adolescents whose primary caregiver has less than a college degree.

With regard to sex disparities, these findings both replicate and extend prior research on adolescent sleep health. Sex differences are consistent with prior literature on disparities in adolescents' actigraphic nightly sleep duration (Matthews et al. 2014; Moore et al. 2011); however, I elucidate the crucial role of napping in exacerbating sex disparities. Notably, these findings are the opposite of those observed in self-reported studies, in which adolescent males report sleeping longer than adolescent females (Keyes et al. 2015; Maslowsky and Ozer 2014). There are many potential reasons for these opposite sex differences between self- and objectively-measured sleep.

One set of explanations relates to the limitations of various sleep measurements. Several studies indicate that the correlation between actigraphy and other sleep measures is less strong among adolescent males than females (Guedes et al. 2016; Johnson et al. 2007; Short et al. 2012), possibly because higher levels of movement among males during sleep are incorrectly rendered as WASO when using actigraphy (Short et al. 2012) (thus underestimating total sleep time). However, though I find large sex differences in night- and 24-hour sleep time, I do not identify any sex differences in the odds having medium to high WASO. It is also possible that

males erroneously self-report longer sleep durations because their sleep schedules are more variable than those of females. Or, males may take more short naps (<30 minutes) than females; analyses do not include naps lasting less than 30 minutes. The second set of explanations suggests that there are systematic differences in the sleep hygiene behaviors of adolescent males and females. Males may have worse sleep hygiene than females, e.g., consuming more caffeine, spending more time using screens, etc. These findings suggest that gendered reasons for differences in nighttime sleep and constraints in napping deserve additional investigation.

Similarly, the large disparities in nightly sleep duration by ethnoracial group that I identify are similar to those found in previous studies of actigraphic adolescent sleep (Matthews et al. 2014; Moore et al. 2011) and self-reported adolescent sleep duration (Guglielmo et al. 2018). However, the role of naps in reducing ethnoracial differences in sleep duration on weekday nights is a new and notable finding among adolescents. One prior study showed that, among children ages 2-8, differences in napping behavior compensated for large ethnoracial differences in nightly sleep duration such that there was no difference in 24-hour sleep duration among ethnoracial groups (Crosby, Lebourgeois, and Harsh 2005). The present findings suggest that this pattern persists into adolescence and raise questions about whether such behavior may extend into adulthood.

Though prior studies of self- or parent-reported adolescent sleep identified that a two-parent family structure is associated with better adolescent sleep health than living with a single parent (Hawkins and Takeuchi 2016; Singh and Kenney 2013), this finding in large part did not replicate when using actigraphic sleep measurements. There were no significant differences in weekend or weekday sleep duration or quality by family structure; adolescents living with both biological parents slept at earlier hours on weekend nights than those with single parents,

however. Unexpectedly, I found that adolescents whose primary caregiver is not their biological parent have longer sleep durations than adolescents living with their biological parents. These large differences raise questions about the antecedent reasons adolescents have come to have non-biological-parent caregivers. FFCWS does not determine for what reasons biological parents do not provide care for adolescents or whether such an arrangement arose due to parental absence or incapacity or to the adolescent's own characteristics. Thus, this previously unexamined group warrants additional investigation among larger cohorts with more information about adolescents in this caregiving arrangement.

With regard to the socioeconomic status of adolescents' households, I find that adolescents living in the most socioeconomically advantaged households nap less and have more variable weeknight sleep than adolescents living in less advantaged households. Though this finding is consistent with the negative correlation between socioeconomic status and adolescent sleep duration documented in Chapter 2, it is inconsistent with the prior objectively-measured sleep study on this topic. Marco et al. (2012) found that higher socioeconomic status was associated with better sleep health among adolescents when measuring socioeconomic status using a composite index that incorporated both household and neighborhood socioeconomic characteristics. The present study did not include neighborhood attributes.

These analyses have several limitations. First, the study design does not allow me to identify the pathways through which sociodemographic differences in sleep come about, although I account for many covariates that may contribute to disparities in adolescent sleep health. Second, while actigraphy provides an objective and valid assessment of nighttime sleep, its ability to distinguish periods of low activity from nap periods is weaker, it does not capture perceived sleep quality (e.g., restorativeness), and there is a lack of consensus on preferred

methods of actigraphy validation in large samples of adolescents. Finally, although this study uses data from a large national sample of adolescents with objectively-measured sleep, the sample consists of adolescents who were born in urban areas. For this reason, findings cannot be generalized to all adolescents in the United States.

Nonetheless, these results underscore the magnitude and heterogeneity of disparities in adolescent sleep across a variety of indicators and dimensions of sleep health. Future research should investigate the underlying mechanisms through which such differences come about. Behavioral mechanisms, such as screen time, physical activity, and diet, can be identified using repeated within-person measures. Contextual mechanisms (i.e., the differential distribution of exposure to sleep-inhibiting or sleep-promoting family, household, neighborhood, school, and peer environments) can be explored in studies linking sleep data to rich population-level data. Understanding these pathways will elucidate opportunities for intervention to ameliorate disparities in adolescent sleep health.

Table 3.1 Analytic sample descriptions

	Weekday sample N = 714	Weekend sample N = 558
	% or Mean (SD)	% or Mean (SD)
Outcomes		
Sleep duration		
Night sleep (minutes)	465.72 (64.73)	466.15 (82.78)
Night sleep duration recommended		
Not within recommended range	62.6%	61.5%
Within recommended range	37.4%	38.5%
Napping		
Does not nap	49.3%	65.4%
Napper	50.7%	34.6%
24-hour sleep (minutes)	488.73 (61.26)	489.28 (79.05)
Sleep timing		
Night sleep onset (decimal time)	0.40 (1.71)	0.92 (1.81)
Night sleep offset (decimal time)	8.22 (1.84)	8.77 (1.87)
Midpoint of night sleep (decimal time)	4.28 (1.70)	4.80 (1.73)
SD of midpoint of night sleep (hours)	1.15 (0.80)	1.33 (1.28)
Sleep quality		
WASO		
Low	28.7%	31.2%
Medium or high	71.3%	68.8%
Demographic factors		
Adolescent demographics		
Sex		
Female	53.8%	51.1%
Male	46.2%	48.9%
Ethnoracial group		
White, non-Hispanic	17.7%	16.3%
Black, non-Hispanic	47.2%	46.2%
Hispanic	25.9%	28.9%
Other, non-Hispanic	9.2%	8.6%

Primary caregiver demographics		
Family structure		
2 biological parents	32.1%	33.7%
Biological parent and new partner	23.7%	22.4%
Single biological parent	40.5%	40.7%
Other primary caregiver	3.8%	3.2%
Educational attainment		
College graduate	19.8%	19.95%
Some college	45.2%	44.3%
High school or GED	17.9%	18.8%
Less than high school	17.1%	17.0%
Income relative to poverty line (PL)		
> 299% PL	28.2%	27.2%
200-299% PL	14.2%	15.2%
100-199% PL	27.5%	27.2%
< 100% PL	30.3%	30.3%
Health factors		
Weight status		
Not overweight	54.0%	53.9%
Overweight	46.0%	46.1%
Depression score	3.06 (2.94)	3.01 (2.90)
Anxiety score	4.86 (3.75)	4.76 (3.65)

Table 3.2 Coefficients and 95% confidence intervals from linear regression models and odds ratios and 95% confidence intervals from logistic regression models of demographic factors and adolescent weekday sleep duration, N = 714

	Model 1	Model 2	Model 3	Model 4
	Night sleep minutes	**Night sleep duration in recommended range**	**Any naps**	**24-hour sleep minutes**
	Linear β (95%CI)	*Logistic OR (95%CI)*	*Logistic OR (95%CI)*	*Linear β (95%CI)*
Adolescent demographics				
Male	-15.40** (-24.80, -6.01)	0.84 (0.61, 1.14)	0.48*** (0.35, 0.67)	-22.31*** (-31.15, -13.48)
Ethnoracial group (ref: white, non-Hispanic)				
Black, non-Hispanic	-18.62** (-32.59, -4.65)	0.59* (0.37, 0.94)	2.21** (1.36, 3.58)	-4.77 (-17.92, 8.37)
Hispanic	6.92 (-8.43, 22.26)	1.25 (0.76, 2.05)	1.16 (0.68, 1.96)	14.24 (-0.20, 28.68)
Other, non-Hispanic	-11.96 (-31.14, 7.22)	0.67 (0.35, 1.27)	1.01 (0.52, 1.96)	-4.32 (-22.37, 13.73)
Primary caregiver demographics				
Family structure (ref: 2 bio parents)				
Bio parent and new partner	7.14 (-5.97, 20.26)	1.43 (0.92, 2.20)	0.80 (0.51, 1.26)	12.71* (0.37, 25.04)
Single bio parent	6.43 (-5.85, 18.70)	1.27 (0.84, 1.92)	0.85 (0.56, 1.30)	7.35 (-4.20, 18.91)
Other primary caregiver	28.09* (2.40, 53.79)	2.89* (1.25, 6.65)	0.63 (0.26, 1.53)	27.67* (3.50, 51.84)
Educational attainment (ref: college graduate)				

Some college	-10.33 (-23.99, 3.32)	0.81 (0.51, 1.27)	1.85* (1.15, 2.96)	-0.96 (-13.81, 11.89)
High school or GED	-4.10 (-20.68, 12.48)	0.84 (0.49, 1.46)	2.76*** (1.56, 4.91)	9.35 (-6.24, 24.95)
Less than high school	-0.32 (-18.40, 17.76)	1.16 (0.64, 2.09)	2.12* (1.14, 3.93)	4.01 (-13.00, 21.02)
Income relative to poverty line (ref: >299% PL)				
200-299% PL	-1.68 (-17.65, 14.30)	0.94 (0.55, 1.61)	0.94 (0.55, 1.61)	-4.46 (-19.49, 10.57)
100-199% PL	-3.40 (-17.50, 10.71)	1.09 (0.68, 1.74)	1.88* (1.16, 3.05)	7.01 (-6.26, 20.28)
< 100% PL	1.60 (-13.06, 16.26)	1.23 (0.76, 1.99)	1.19 (0.73, 1.95)	2.31 (-11.49, 16.10)
Weeknight sleep minutes			0.99*** (0.99, 0.99)	
Constant	481.74*** (466.65, 496.83)	0.66 (0.40, 1.08)	20.22*** (5.13, 79.61)	487.05*** (472.85, 501.25)

Note: * p<0.5, ** p<0.01, *** p<0.001

Table 3.3 Coefficients and 95% confidence intervals from linear regression models and odds ratios and 95% confidence intervals from logistic regression models of demographic factors and adolescent weekday sleep timing and quality, N = 714

	Model 1	Model 2	Model 3
	Midpoint of night sleep	**SD of midpoint of night sleep**	**Medium to high WASO**
	Linear *β (95%CI)*	*Linear* *β (95%CI)*	*Logistic* *OR (95%CI)*
Adolescent demographics			
Male	0.36** (0.11, 0.61)	0.15* (0.03, 0.26)	1.42 (0.98, 2.05)
Ethnoracial group (ref: white, non-Hispanic)			
Black, non-Hispanic	-0.02 (-0.39, 0.35)	-0.14 (-0.32, 0.03)	2.42** (1.42, 4.13)
Hispanic	0.12 (-0.29, 0.53)	-0.29** (-0.48, -0.10)	1.18 (0.66, 2.09)
Other, non-Hispanic	-0.27 (-0.79, 0.24)	-0.35** (-0.59, -0.11)	0.94 (0.48, 1.87)
Primary caregiver demographics			
Family structure (ref: 2 bio parents)			
Bio parent and new partner	-0.03 (-0.38, 0.32)	0.11 (-0.05, 0.28)	1.19 (0.72, 1.98)
Single bio parent	0.22 (-0.11, 0.55)	0.12 (-0.03, 0.27)	1.10 (0.69, 1.75)
Other primary caregiver	-0.21 (-0.90, 0.47)	-0.07 (-0.39, 0.25)	0.57 (0.22, 1.46)
Educational attainment (ref: college graduate)			
Some college	-0.07 (-0.44, 0.29)	0.24** (0.07, 0.41)	1.53 (0.92, 2.54)

High school or GED	-0.06 (-0.50, 0.39)	0.14 (-0.07, 0.34)	1.38 (0.74, 2.57)
Less than high school	-0.24 (-0.72, 0.25)	0.23* (0.01, 0.46)	1.20 (0.61, 2.38)
Income relative to poverty line (ref: > 299% PL)			
200-299% PL	-0.03 (-0.45, 0.40)	0.03 (-0.17, 0.23)	0.97 (0.53, 1.76)
100-199% PL	0.35 (-0.03, 0.72)	0.11 (-0.07, 0.28)	1.20 (0.69, 2.07)
< 100% PL	0.27 (-0.12, 0.66)	0.04 (-0.14, 0.22)	1.11 (0.64, 1.95)
Weeknight sleep minutes			1.02*** (1.01, 1.02)
Constant	3.95*** (3.55, 4.36)	0.96*** (0.78, 1.15)	0.0003*** (0.000, 0.002)

Note: * p<0.5, ** p<0.01, *** p<0.001

Table 3.4 Coefficients and 95% confidence intervals from linear regression models and odds ratios and 95% confidence intervals from logistic regression models of demographic factors and adolescent weekend sleep duration, N = 558

	Model 1	Model 2	Model 3	Model 4
	Night sleep minutes	**Night sleep duration in recommended range**	**Any naps**	**24-hour sleep minutes**
	Linear β (95%CI)	*Logistic OR (95%CI)*	*Logistic OR (95%CI)*	*Linear β (95%CI)*
Adolescent demographics				
Male	-26.29*** (-39.78, -12.79)	0.63* (0.44, 0.90)	0.51*** (0.34, 0.75)	-35.72*** (-48.57, -22.88)
Ethnoracial group (ref: white, non-Hispanic)				
Black, non-Hispanic	-37.53*** (-58.23, -16.83)	0.49** (0.28, 0.83)	1.76 (0.96, 3.22)	-22.24* (-41.95, -2.54)
Hispanic	-4.46 (-26.51, 17.59)	1.19 (0.68, 2.07)	0.64 (0.33, 1.25)	-3.56 (-24.55, 17.44)
Other, non-Hispanic	-31.96* (-60.86, -3.06)	0.63 (0.30, 1.32)	1.49 (0.65, 3.42)	-16.44 (-43.95, 11.07)
Primary caregiver demographics				
Family structure (ref: 2 bio parents)				
Bio parent and new partner	3.72 (-15.32, 22.75)	1.27 (0.78, 2.08)	0.64 (0.36, 1.11)	-3.62 (-21.74, 14.50)
Single bio parent	3.57 (-13.56, 20.70)	1.10 (0.70, 1.72)	0.90 (0.55, 1.45)	4.67 (-11.64, 20.98)
Other primary caregiver	4.18 (-35.57, 43.93)	0.55 (0.17, 1.82)	1.01 (0.34, 2.96)	7.36 (-30.48, 45.20)
Educational attainment (ref: college graduate)				
Some college	-1.18 (-20.90, 18.54)	0.87 (0.52, 1.45)	2.33** (1.30, 4.19)	13.89 (-4.89, 32.66)

High school or GED	-5.02 (-28.53, 18.49)	0.81 (0.44, 1.51)	1.97 (0.99, 3.91)	5.69 (-16.69, 28.07)
Less than high school	4.98 (-20.92, 30.87)	1.11 (0.57, 2.17)	2.60* (1.22, 5.53)	20.62 (-4.03, 45.27)
Income relative to poverty line (ref: > 299% PL)				
200-299% PL	-4.91 (-27.37, 17.56)	0.89 (0.50, 1.60)	1.62 (0.86, 3.05)	-1.18 (-22.57, 20.20)
100-199% PL	-7.10 (-27.49, 13.29)	0.81 (0.48, 1.38)	1.80* (1.01, 3.20)	2.66 (-16.75, 22.07)
< 100% PL	-6.51 (-27.73, 14.71)	0.80 (0.46, 1.39)	1.07 (0.58, 1.97)	-9.11 (-29.31, 11.09)
Weekend night sleep minutes			0.99*** (0.99, 1.00)	
Constant	503.25*** (480.98, 525.52)	1.23 (0.70, 2.17)	5.43* (1.35, 21.77)	509.64*** (488.44, 530.85)

Note: * p<0.5, ** p<0.01, *** p<0.001

Table 3.5 Coefficients and 95% confidence intervals from linear regression models and odds ratios and 95% confidence intervals from logistic regression models of demographic factors and adolescent weekend sleep timing and quality, N = 558

	Model 1	Model 2	Model 3
	Midpoint of night sleep	**SD of midpoint of night sleep**	**Medium to high WASO**
	Linear β (95%CI)	*Linear β (95%CI)*	*Logistic OR (95%CI)*
Adolescent demographics			
Male	0.30* (0.02, 0.59)	0.21* (0.002, 0.43)	0.89 (0.58, 1.35)
Ethnoracial group (ref: white, non-Hispanic)			
Black, non-Hispanic	-0.15 (-0.58, 0.29)	0.16 (-0.16, 0.49)	1.04 (0.55, 1.99)
Hispanic	0.07 (-0.40, 0.53)	0.18 (-0.17, 0.52)	1.07 (0.54, 2.15)
Other, non-Hispanic	-0.51 (-1.12, 0.10)	0.46 (0.01, 0.92)	0.99 (0.42, 2.30)
Primary caregiver demographics			
Family structure (ref: 2 bio parents)			
Bio parent and new partner	0.08 (-0.32, 0.48)	0.41** (0.11, 0.71)	1.28 (0.71, 2.31)
Single bio parent	0.44* (0.07, 0.80)	-0.09 (-0.36, 0.18)	1.57 (0.94, 2.65)
Other primary caregiver	-0.86* (-1.70, -0.02)	-0.20 (-0.83, 0.42)	1.14 (0.34, 3.90)
Educational attainment (ref: college graduate)			
Some college	0.14 (-0.27, 0.56)	-0.23 (-0.53, 0.08)	1.47 (0.82, 2.63)

High school or GED	0.26 (-0.23, 0.76)	-0.26 (-0.63, 0.11)	2.78** (1.34, 5.78)
Less than high school	0.08 (-0.47, 0.62)	-0.24 (-0.64, 0.17)	1.11 (0.50, 2.45)
Income relative to poverty line (ref: > 299% PL)			
200-299% PL	-0.28 (-0.75, 0.19)	0.28 (-0.07, 0.64)	1.10 (0.57, 2.14)
100-199% PL	-0.13 (-0.56, 0.30)	0.25 (-0.07, 0.57)	1.15 (0.62, 2.13)
< 100% PL	0.14 (-0.30, 0.59)	0.21 (-0.12, 0.55)	1.71 (0.89, 3.31)
Weekend night sleep minutes			1.028*** (1.01, 1.02)
Constant	4.49*** (4.02, 4.96)	1.03*** (0.68, 1.38)	0.001*** (0.0001, 0.004)

Note: * p<0.5, ** p<0.01, *** p<0.001

Appendix 3A. Comparisons of home visit participants and analytic samples

	Home visit N = 1,090	Weekday sample N = 714	Weekend sample N = 558
Adolescent demographics			
Sex			
Female	49.5%	53.8%	51.1%
Male	50.6%	46.2%	48.9%
Ethnoracial group			
White, non-Hispanic	17.4%	17.7%	16.3%
Black, non-Hispanic	47.0%	47.2%	46.2%
Hispanic	27.2%	25.9%	28.9%
Other, non-Hispanic	8.4%	9.2%	8.6%
Primary caregiver demographics			
Family structure			
2 bio parents	31.2%	32.1%	33.7%
Bio parent and new partner	24.0%	23.7%	22.4%
Single bio parent	40.7%	40.5%	40.7%
Other primary caregiver	4.1%	3.8%	3.2%
Educational attainment			
College graduate	19.4%	19.8%	19.9%
Some college	44.2%	45.2%	44.3%
High school or GED	18.9%	17.9%	18.8%
Less than high school	17.6%	17.1%	17.0%
Income relative to poverty line (PL)			
> 299% PL	27.6%	28.2%	27.2%
200-299% PL	14.6%	14.2%	15.2%
100-199% PL	27.2%	27.5%	27.2%
< 100% PL	30.6%	30.3%	30.3%

Appendix 3B. Comparisons of adolescents observed during school and non-school weeks

	Weekday sample N = 599		Weekend sample N = 468	
	School week	Not school week	School week	Not school week
Type of observation week	67.4%	32.6%	68.6%	31.4%
Outcomes				
Sleep duration				
Night sleep (minutes)	456.5	486.5	462.4	481.3
Night sleep duration recommended				
Not within recommended range	57.2%	38.5%	53.0%	52.4%
Within recommended range	42.8%	61.5%	47.0%	47.6%
Napping				
Does not nap	54.0%	45.1%	67.0%	63.3%
Napper	46.0%	54.9%	33.0%	36.7%
24-hour sleep (minutes)	477.1	511.7	484.0	508.1
Sleep timing				
Night sleep onset (decimal time)	-0.3	1.6	0.5	1.8
Night sleep offset (decimal time)	7.4	9.8	8.3	9.9
Midpoint of night sleep (decimal time)	3.6	5.6	4.4	5.7
SD of midpoint of night sleep (hours)	1.1	1.3	1.4	1.1
Sleep quality				
WASO				
Low	34.4%	19.5%	35.2%	24.5%
Medium or high	65.6%	80.5%	64.8%	75.5%
Demographic factors				
Adolescent demographics				
Sex				
Female	52.7%	56.4%	50.8%	55.1%
Male	47.3%	43.6%	49.2%	44.9%
Ethnoracial group				
White, non-Hispanic	17.8%	22.6%	17.1%	21.1%
Black, non-Hispanic	42.8%	47.7%	43.0%	44.9%
Hispanic	29.2%	20.0%	30.2%	23.8%
Other, non-Hispanic	10.1%	9.7%	9.7%	10.2%

Primary caregiver demographics				
Family structure				
2 bio parents	35.4%	31.3%	35.8%	33.3%
Bio parent and new partner	25.0%	21.5%	23.7%	21.8%
Single bio parent	36.1%	44.6%	36.4%	43.5%
Other primary caregiver	3.5%	2.6%	4.0%	1.4%
Educational attainment				
College graduate	19.1%	24.6%	18.7%	24.5%
Some college	46.3%	45.6%	47.0%	42.2%
High school or GED	18.1%	17.9%	19.0%	19.0%
Less than high school	16.6%	11.8%	15.3%	14.3%
Income relative to poverty line (PL)				
> 299% PL	30.9%	28.7%	29.9%	25.9%
200-299% PL	16.1%	14.4%	16.5%	15.6%
100-199% PL	26.5%	27.2%	25.9%	29.3%
< 100% PL	26.5%	29.7%	27.7%	29.3%

Chapter 4

Sleep Duration and the Production of Socioeconomic Status: Evidence from Adolescence to Early Adulthood[5]

The individual traits developed in early life – including non-cognitive skills (Heckman 2006) and physical and mental health (Palloni 2006) – contribute to the production and maintenance of socioeconomic status. Despite the recognized importance of childhood and adolescent characteristics as inputs in the development of adult socioeconomic outcomes, little research on social stratification has considered one of the most fundamental requirements for child and adolescent development: sleep.

Sleep is causally associated with health and cognition across the life course. A substantial literature has identified links between sleep and wellbeing, establishing that inadequate nightly sleep is associated with all-cause mortality (Alves da Silva et al. 2016; Liu et al. 2017; Shen, Wu, and Zhang 2016), a range of morbidities (Buxton and Marcelli 2010; Grandner et al. 2010), numerous mental health conditions (Gregory and Sadeh 2012; Shochat et al. 2014), and cognitive performance (Astill et al. 2012; Giuntella, Han, and Mazzonna 2017; Lo et al. 2016). Experimental sleep restriction studies have identified the physiological and neurological pathways through which these associations come about (Krause et al. 2017; Schmid, Hallschmid, and Schultes 2015). Likewise, an emerging correlational literature suggests that overly long sleep durations exacerbate the risk of childhood physical and mental health conditions (James and

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Hale 2017) as well as adult sleep duration and obesity, cardiovascular disease, and all-cause mortality (Buxton and Marcelli 2010; Grandner et al. 2010; Taheri et al. 2004). Due to the difficulty of inducing longer sleep durations in clinical settings, the pathways by which these associations come about are less well understood.

Thus, because adolescent health and health behaviors are key determinants of adult health and socioeconomic status (Harris 2010), it is likely that sleep contributes to social stratification. This is especially likely to be the case for adolescent sleep, which is foundational for the development of decision-making skills, social-emotional competencies (Dahl and Lewin 2002), and health (Owens 2014). However, we do not know to what extent sleep may play a role in the status attainment process. The most similar prior research has considered how sleep duration is associated with a small set of educational outcomes, although studies are primarily cross-sectional. There is a lack of studies that prospectively link sleep duration to other dimensions of socioeconomic status, such as occupational prestige or income. This dearth of research on the association between sleep duration and status attainment is largely due to a lack of available data. Evaluating this association requires population-based studies to assess both sleep duration and socioeconomic outcomes longitudinally and to have data spanning a large swath of the life course.

This study addresses these limitations by providing the first empirical assessment of a prospective link between typical nightly sleep duration and a range of socioeconomic outcomes. Using the National Study of Adolescent to Adult Health, a nationally representative cohort study of adolescents in the United States, I evaluate how sleep duration in adolescence is associated with educational attainment, earnings, occupational prestige, and perceived socioeconomic status in early adulthood. I find that adolescents who sleep in the range of 7 and 8 hours per night have

the highest probability of completing a college degree or holding a professional or managerial position in early adulthood and the lowest probability of having a high school degree or less or working in service or craft/operative/laborer occupations. Adolescents with sleep durations outside of this range have worse educational and occupational outcomes. Associations with occupational prestige appear to come about via strong links between sleep duration and educational attainment. In contrast, young adult earnings and perceived socioeconomic status do not appear to be a function of adolescent sleep.

Background

Determinants of Adolescent Sleep

The proportion of adolescents experiencing inadequate sleep increased in recent decades. Currently, two-thirds of adolescents report that they do not get enough sleep (Keyes et al. 2015). In part, this pattern comes about through biology. During puberty, adolescents develop a later circadian preference, preferring to go to sleep and to wake up at later times than younger children or adults. Additionally, the sleep-promoting hormone melatonin is released later in adolescence than in childhood, exacerbating this pattern. However, the majority of the determinants of adolescent sleep are social.

Sleep is first a function of other adolescent behaviors, including time use and other health behaviors. Adolescents who have high levels of homework sleep less and more poorly than adolescents with less homework (Maume 2013). Likewise, adolescents who are employed sleep less and more poorly than do adolescents who are not employed (Maume 2013). Adolescent screen use (e.g., television, computer, cell phone), particularly immediately before going to bed or while in bed, has the potential to delay or disrupt sleep (Owens 2014). Caffeine use is also associated with shorter nightly sleep durations, though findings with regard to other substances

(tobacco, alcohol, etc.) are mixed (Bartel, Gradisar, and Williamson 2015; Owens 2014). Additionally, physical activity is associated with earlier bedtimes (Bartel et al. 2015).

Likewise, both physical and mental health comorbidities are important determinants of adolescent sleep. Associations between sleep and health are complex and reciprocal. For example, obesity is positively associated with obstructive sleep apnea, which lowers sleep duration and quality (Owens 2014); in turn, short sleep durations increase appetite by disrupting satiety-related hormones (Taheri, Lin, Austin, Young, & Mignot, 2004). Similarly, sleep is both cause and consequence of mood disorders (Dahl and Lewin 2002; Owens 2014).

Sleep is also a function of the family, school, and community contexts in which adolescents are embedded. Family structure and parenting are important for adolescent sleep. Adolescents living with a single parent (Troxel et al. 2014) or who have recently experienced a change in family structure (Maume 2013) sleep less than do adolescents living in a two-parent or stable family structure. One reason family structure may matter for adolescent sleep is due to its associations with parental monitoring, in general, and parental bedtime setting, in particular (Maume 2013). Adolescents with parent-set bedtimes sleep for more hours each night and have better sleep quality than do adolescents whose parents do not set a bedtime (Bartel et al. 2015; Owens 2014; Short et al. 2011). Schools matter for sleep in several ways. In addition to the role of homework time, school start times also play a substantial role in determining adolescent sleep duration on school nights. The combined effects of later circadian preference among adolescents and early secondary school start times contribute to a high prevalence of chronically inadequate sleep among this population (Kelley et al. 2015; Owens 2014), and rates of inadequate sleep increase as students progress from grades 9 through 12 (Basch et al. 2014). Notably, this trend can be modified by changing school start time policies, an intervention that is low cost and

highly effective compared to other interventions intended to improve academic and health outcomes in adolescence (Hafner, Stepanek, and Troxel 2017; Kelley et al. 2015). Schools also matter for sleep insofar as adolescents who have more peers who want to achieve academic success have longer nightly sleep durations than do adolescents who have less positive peer associations (Maume 2013). Finally, neighborhood disadvantage is associated with shorter and inadequate nightly sleep durations, more variable sleep patterns, and lower quality sleep among adolescents (Bagley et al. 2016; Marco et al. 2012; McLaughlin Crabtree et al. 2005; Rubens et al. 2018, 2014; Singh and Kenney 2013).

Consequences of Adolescent Sleep

Consequently, long-term effects of adolescent sleep on adult outcomes may be larger than those of sleep in earlier formative developmental periods (e.g., early childhood) due to both the temporal proximity of adolescence to adulthood and exceptionally high rates of non-optimal sleep during adolescence. Yet, few studies have evaluated the long-term effects of habitually inadequate nightly sleep in adolescence (Dahl and Lewin 2002; Shochat et al. 2014), with an even smaller set of studies considering the distal consequences of extended nightly sleep in adolescence. With regard to socioeconomic outcomes, prior studies have linked adolescent sleep duration only to educational outcomes.

Hypothesized pathways

There are three pathways through which a link between adolescent sleep and adult outcomes may come about. First, experimental evidence shows that inadequate sleep in adolescence impairs cognitive performance in many domains, including working memory, memory consolidation after learning, and response times (de Bruin et al. 2017; Dewald-Kaufmann, Oort, and Meijer 2013). Second, both inadequate and overly long sleep contribute to

subsequent physical and mental health conditions (Dahl and Lewin 2002). Though associations between health and sleep are highly reciprocal, even within-person and between-twin differences in sleep duration predict worse outcomes among those who sleep less (Barnes and Meldrum 2014; Fredriksen et al. 2004). Third, sleep patterns established in adolescence may set lifelong sleep habits. Sleep in adolescence predicts higher odds of inadequate sleep in young adulthood (Sivertsen et al. 2017), and two cohort studies suggest substantial stability in sleep among both adolescents and adults. For example, sleep patterns in childhood are stronger predictors of adolescent sleep than family, school, time use, or pubertal development factors (Maume 2013), and sleep durations are stable among about 60% of adults when followed for 20 years (Zomers et al. 2017).

Sleep duration and educational outcomes

Associational studies have considered the short-term and, to a lesser extent, the long-term associations between sleep and academic outcomes. In the shorter term, adolescents who sleep for fewer hours or who have worse sleep quality have lower grade point averages (GPAs) than do those who sleep for more hours each night or have better quality sleep (Curcio et al. 2006; Dewald et al. 2010; Fredriksen et al. 2004; Shochat et al. 2014; Wolfson and Carskadon 2003). Notably, curtailing nightly sleep negatively impacts school performance even if an adolescent's sleep is restricted due to spending more time studying (Gillen-O'Neel, Huynh, and Fuligni 2013). In the longer term, one study finds that sleep duration in adolescence has a nonlinear association with the probability of high school graduation and college attendance, suggesting that both short and long sleep durations may contribute to poor academic outcomes (Sabia et al. 2016).

Researchers have also used quasi-experimental strategies to identify causal associations between sleep duration and academic outcomes. Much of this scholarship finds that adolescents' weeknight sleep durations are typically curtailed by school start times. Adolescents tend to go to bed around the same time on weekdays regardless of when they need to wake up for school, meaning that the later the school day begins the more hours most adolescents sleep each night (Wolfson and Carskadon 2003). Therefore, several studies have examined academic outcomes before and after high schools delayed their morning start times. In the year(s) following a start time delay, GPA increased compared to the year(s) immediately prior to the start time change, whether measured within individuals or between schools (Wahlstrom 2002; Wahlstrom et al. 2014; Wahlstrom, Wrobel, and Kubow 1998).

However, these estimates rely on schools or school districts that choose to change their start times. This necessarily conflates other school and district characteristics with start times for between-school analyses. Thus, researchers have also used random assignment of students to morning classes within schools (Carrell, Maghakian, and West 2011), changes to start times due to the logistics of bus scheduling within districts (Edwards 2012), and within-state time zone boundary discontinuities in sunrise time (Heissel and Norris 2017) as exogenous sources of variation in school start time, and thus sleep duration, among adolescents. Much like the associational work discussed previously, these studies find that students whose school days start later (and presumably sleep for more hours each night) have better test scores and grades than do students who experience earlier start times.

Contributions

Despite a number of plausible cognitive and health pathways by which adolescent sleep and adult socioeconomic status might be linked, few empirical studies have considered that

socioeconomic status may be a function of prior sleep duration. Extant studies are limited to outcomes related to school performance and educational outcomes, are mainly cross-sectional, and generally rely on community samples. No studies have considered how sleep may predict other aspects of socioeconomic status, such as occupational prestige or income. In part, this may be because education is a key determinant of occupation and earnings; however, to situate sleep in a model of social stratification it is important to investigate a variety of socioeconomic outcomes. Moreover, almost no research has examined the longer-term consequences of long adolescent sleep durations, though an emerging literature suggests that extended sleep durations are associated with adverse health and mortality across the life course. This paper extends prior literature by considering whether both short and long sleep durations in adolescence are prospectively associated with a range of adult socioeconomic status measures, situating sleep in the model of social stratification.

Methods

Data

Data come from The National Longitudinal Study of Adolescent to Adult Health (Add Health), a nationally representative sample of adolescents in grades 7-12 selected from a sample of 80 high schools and 52 middle schools during the 1994-1995 school year. In-home interviews were completed in 1995, with follow-up waves in 1996 (Wave II), 2001-2002 (Wave III, ages 18-26[6]), and 2008-2009 (Wave IV, ages 24-32[7]). Parents of Add Health participants were interviewed at Wave I; in the analytic sample, 84% of parents were adolescents' biological mothers.

[6] 24 respondents were 27-28 years old at the time of the Wave III interview.
[7] 52 respondents were 33-34 years old at the time of the Wave IV interview.

Add Health is appropriate for assessing the association of adolescent sleep with adult socioeconomic status as it follows participants from their school years to adulthood and collects relevant measures. Respondents report their typical nightly sleep duration at each survey wave, and a range of socioeconomic status indicators is measured in the most recent study wave, when respondents were ages 24-32. Importantly, parental socioeconomic characteristics are measured at the study's outset; thus, analyses can account for parental socioeconomic status when modeling the socioeconomic status of their children.

The analytic sample includes 9,079 adolescents who participated in the Wave I and IV in-home interviews, were not incarcerated or serving in the military at wave IV, had a parent interview, and provided valid data on all socioeconomic status outcomes and the sleep duration predictor used in these analyses. Analyses are weighted to be nationally representative. Missing covariates were imputed using chained equations (M = 20) in Stata 14 (StataCorp 2015), and the frequency of missing data is presented in Appendix 4A.

Measures

Table 4.1 presents descriptive statistics for the analytic sample.

Outcome: Socioeconomic status

The four indicators of socioeconomic status used as outcomes in these analyses are measured at Wave IV. Educational attainment is the respondent's highest level of completed education, including less than a high school degree, high school degree, any post-high-school vocational training, some college education, college degree, and any post-graduate training. Occupational prestige comes from the respondent's most recent job description. Respondents selected the closest match among the 472 occupations of the Census 2000's special version of the Equal Employment Opportunity Commission's 2000 EEO-1 Job Categories (Bureau 2000),

and these occupations were coded into the nine EEO-1 job categories. Due to small sample sizes for some occupations, the nine groups were further collapsed into five occupational prestige categories for analyses, ordered as follows: service workers; craft workers, operatives, laborers, helpers; sales and administrative support workers; professionals and technicians; and officials and managers. Earnings measures the respondent's total earnings before taxes (i.e., wages or salaries) in dollars, for the prior calendar year. This measure is logged in analyses. Finally, the socioeconomic status ladder from the MacArthur Scale of Subjective Social Status (Adler and Stewart 2007) captures a global measure of a respondent's perceived socioeconomic status. This measure allows respondents to report their relative socioeconomic rank based on their unique combination of socioeconomic characteristics. Respondents received the following prompt:

> "Think of this ladder as representing where people stand in the United States. At the top of the ladder (step 10) are the people who have the most money and education, and the most respected jobs. At the bottom of the ladder (step 1) are the people who have the least money and education, and the least respected jobs or no job. Where would you place yourself on this ladder? Pick the number for the step that shows where you think you stand at this time in your life, relative to other people in the United States."

Responses could range from one to 10, with higher values indicating higher perceived socioeconomic status.

Predictor: Sleep duration

Sleep duration is measured at Wave I, when respondents report their nightly sleep duration, in whole hours of sleep, on a typical night. The small share of reported sleep durations shorter than four hours (0.57% of the analytic sample) or greater than 12 hours (0.14% of the analytic sample) were bottom- and top-coded to four and 12 hours, respectively. The distribution

of sleep duration after this bottom- and top-coding is shown in Figure 4.1. All analyses also include a quadratic term for hours of sleep squared, thus capturing nonlinear associations of sleep duration with the outcomes.

Covariates: Adolescent and parent demographics

At Wave I, respondents report their gender, race, Hispanic ethnicity, nativity, and age. Additional Wave I covariates capture parental, household, and neighborhood socioeconomic status. Parents report their age, whether or not they were born in the United States, educational attainment (less than high school degree, high school degree, vocational training including high school and post-high-school, some college education, college degree, or any post-graduate training), and household income (logged in analyses). The respondent's family structure includes categories for two biological parents, two parents including stepparents, single mother, single father, and other. Neighborhood poverty rate comes from the proportion of families in the respondent's Census tract with incomes below the poverty level in 1989. The interviewer indicates whether the respondent's household is located in an urban, suburban, rural, or other type of neighborhood setting.

Covariates: Other sleep-related measures

To account for other factors that may be associated with adolescent sleep duration, analyses also include as covariates measures of time use, cognitive skills, and health at Wave I. Three time use variables measure obligations that may limit adolescent sleep duration: the interviewer reports whether or not the respondent's school year was in session at the time of the interview, and adolescents indicate whether or not they work 10 or more hours per week (in either summer or non-summer employment) and whether or not their parent(s) let them make their own decisions about what time to go to bed on weeknights. Adolescent cognitive ability is

assessed using the Peabody Picture Vocabulary Test. Self-rated health includes categories of poor, fair, good, very good, and excellent health (coded such that higher values indicate better health). Body mass index (BMI) was calculated using self-reported height and weight measurements, then categorized into normal weight (BMI >= 18.5 and < 25.0), underweight (BMI < 18.5), overweight (BMI >= 25.0 and < 30.0), and obese (BMI >= 30.0). Depressive symptomology was measured using 18 items from the CES-D: whether the respondent felt depressed, thought life had been a failure, felt sad, couldn't shake off the blues, was bothered by things, felt life was not worth living, felt hopeful about the future (reverse coded), was happy (reverse coded), enjoyed life (reverse coded), felt just as good as others (reverse coded), did not feel like eating, had trouble keeping on task, felt fearful, found it hard to get started on things, felt lonely, talked less than usual, felt others were unfriendly, and felt disliked – coded from zero (never or rarely) to three (most or all of the time) and summed.

Analytic strategy

I model educational attainment and occupational prestige using ordered logit models, while earnings and perceived socioeconomic status are modeled using linear regression. All models include both a linear and quadratic term for hours of sleep, in order to capture nonlinear associations of sleep duration with socioeconomic status. Analyses are weighted to be nationally representative. All analyses were conducted using Stata 14 (StataCorp 2015). Tables 4.2 and 4.3 present a series of nested models for each outcome. Beginning with the bivariate association between sleep duration and the outcome, I then adjust for adolescent and parent demographic characteristics measured at Wave I and other sleep-related factors. Table 4.4 adds levels of other Wave IV outcomes in each model, as follows: the final model of occupational prestige accounts for educational attainment; the final model of earnings controls for educational attainment and

occupational prestige; and the final model of perceived socioeconomic status includes educational attainment, earnings, and occupational prestige as covariates. The final model of educational attainment does not control for any of the other socioeconomic outcomes, as the process of educational attainment at the lower levels of educational attainment (e.g., less than a high school degree) concluded prior to the measurement of the other outcomes.

Results

Tables 4.2, 4.3, and 4.4 show the association between sleep duration and the outcomes. Table 4.2 displays proportional odds ratios and standard errors from ordered logit models of educational attainment and occupational prestige including a series of nested demographic and sleep-related covariates. Table 4.3 presents coefficients and standard errors from linear regressions of sleep duration on log earnings and perceived socioeconomic status that control for a series of nested demographic and sleep-related covariates. Table 4.4 shows odds ratios and standard errors from an ordered logit model of occupational prestige and coefficients and standard errors from OLS models of log earnings and perceived socioeconomic status with covariates for levels of the other outcome variables. Appendices 4.B, 4.C, and 4.D include corresponding values for all covariates in the models from Tables 4.2, 4.3, and 4.4, respectively.

Educational attainment

There is a nonlinear association of sleep duration with educational attainment across all model specifications (Table 4.2). Associations in the bivariate model (Model 1) are slightly attenuated when controlling for demographic and sleep-related covariates (Models 2 and 3) and remain statistically significant. To illustrate the magnitude of these associations, Figure 4.2 uses Table 4.2, Model 3 to predict the probability of educational attainment levels by number of hours of sleep. All other covariates are held at sample means.

In Figure 4.2, there is a U- and inverse U-shaped association of sleep duration with the probability of educational attainment. Adolescents who sleep for seven to eight hours per night are predicted to have a higher probability of achieving college education or more and the lowest probability achieving levels of education below some college education (less than high school, high school graduate, and any/complete post-high-school vocational training). Notably, these associations are U- or inverse U-shaped; both adolescents who sleep for the shortest or longest number of hours of sleep per night are less likely to complete college and more likely not to attend college than are their peers who sleep for seven to eight hours per night.

Occupational prestige

Similar to the findings for educational attainment, there is a nonlinear association between sleep duration and occupational prestige (Table 4.2) in bivariate models (Model 4) and those including demographic characteristics (Model 5) and other sleep-related (Model 6) factors. Associations are slightly attenuated with the addition of these covariates. To illustrate the magnitude of these associations, Figure 4.3 uses Table 4.2, Model 6 to predict the probability of each level of occupational prestige for each number of hours of sleep. As in Figure 4.2, all other covariates are held at sample means.

Figure 4.3 shows that the association between adolescent sleep duration and young adult occupational prestige is nonlinear. Adolescents who sleep between 7 and 8 hours each night have the lowest probability of attaining a low prestigious occupation (service work, craft worker/operative/laborer) and the highest probability of holding professional/technical or official/managerial jobs. There is little difference in the likelihood of holding sales/administrative support jobs by adolescent sleep duration. Similar to the pattern of associations between adolescent sleep duration and young adult educational attainment, these

nonlinear associations reveal that adolescents with extremely short or long sleep durations are more likely to have less prestigious (and conversely less likely to have more prestigious) occupations compared with adolescents who sleep for 7 to 8 hours each night.

When adding to Table 4.2, Model 6 a covariate for educational attainment measured concurrently with occupational prestige, the association between adolescent sleep duration and young adult occupational prestige is no longer statistically significant (Table 4.4, Model 1). This pattern suggests that adolescent sleep duration is related to young adult occupational prestige insofar as adolescent sleep duration matters for young adult educational attainment, which in turn is a determinant of occupational prestige.

Earnings

In contrast to the statistically significant associations between adolescent sleep duration and young adult educational attainment and occupational prestige (before including educational attainment), the association between adolescent sleep duration and young adult earnings is close to zero (Table 4.3, Models 1-3; Table 4.4, Model 2).

Perceived socioeconomic status

There is a nonlinear bivariate association between hours of sleep and perceived socioeconomic status (Table 4.3, Model 4) that is partially attenuated as demographic factors are included in the model (Model 5). When other sleep-related covariates are taken into account, this association is no longer statistically significant (Model 6; Table 4.4, Model 3).

Alternative model specifications

Averaging sleep duration over two waves

The measure of sleep duration used in these analyses comes from the adolescent's self-reported typical hours of sleep, in whole hours. Because there is mixed evidence on how strongly

self-reported sleep duration is correlated with actual sleep duration (Arora et al. 2013; Lauderdale et al. 2008; Nascimento-Ferreira et al. 2016), the first sensitivity analysis addresses the concern that self-reports of sleep duration may be imprecise. To mitigate this concern, I consider models in which sleep duration is measured by averaging the individual's self-reported nightly hours of sleep at Wave I (the measure used in the main analyses) and at Wave II, which was conducted one year later among a subset of adolescents. Among the 6,926 adolescents who were eligible for and reported sleep durations at both waves, 34% of adolescents report the same number of hours of sleep at the two waves, while only 10% report sleep durations that differ by more than two hours. The average difference is 1.09 fewer hours of sleep in Wave II than Wave I. Results, presented in Appendices 4E and 4F, are similar to those from the main analyses.

Measuring sleep categorically

The factors that contribute to shorter sleep duration may differ from those that lead to longer sleep durations, both in terms of social factors (e.g., early school start times likely curtail but do not extend nightly sleep duration in adolescents (Wolfson and Carskadon 2003)) and health (e.g., inflammation predicts long but not short sleep durations in older adults (Dowd, Goldman, and Weinstein 2011)). Because of the different potential etiologies underlying these short and long sleep durations, I also consider models in which the predictor identifies adolescents sleeping outside the range of nightly sleep durations that may be appropriate for his or her age, based on the recommendations of Hirshkowitz et al. (2015). In the analytic sample, 11.9% of adolescents have extremely short sleep durations and 1.3% of adolescents report extremely long sleep durations. With this modeling approach (Appendices 4G and 4H), I find that adolescents who sleep more or less than may be appropriate for their age groups are at risk

of worse educational outcomes; associations with occupational prestige are not statistically significant, though point estimates are in the expected direction.

Controlling for perceived sleep adequacy and trouble sleeping

Finally, I consider two measures that may indicate sleep disorders or sleep disruptions: perceived sleep adequacy and frequency of trouble sleeping. The first measure is whether the adolescent feels that he or she usually gets enough sleep (74% of the sample reports adequate sleep). Reports of inadequate sleep may reflect a sleep disorder, such as sleep apnea, that inhibits high-quality sleep even if the adolescent sleeps for many hours or it may simply indicate an insufficient number of hours of sleep. The second measure indicates whether, in the last 12 months, the adolescent had trouble falling or staying asleep never (reference, 40% of sample), just a few times (36%), about once a week (15%), almost every day (8%), or every day (3%). Adolescents who have trouble sleeping may either report shorter sleep durations if they perceive they wake (or are awakened) frequently during the night, or they may report longer sleep durations if they stay in bed longer to attempt to offset trouble sleeping. Results were extremely similar to the analyses presented here when either of these covariates was included in the models; Appendices 4I and 4J include a covariate for sleep adequacy, and Appendices 4K and 4L include a control for trouble sleeping.

Gender moderation

The reproduction of socioeconomic status is gendered, and the factors that matter for the adult socioeconomic outcomes differ by gender. However, models that interact sleep duration with gender find no significant differences in these associations for men and women, suggesting that the role of sleep in the production of socioeconomic status does not differ by gender.

Discussion

Using nationally representative data from the United States, I find that sleep duration in adolescence is associated with educational attainment and occupational prestige in young adulthood. This association is nonlinear: adolescents who sleep between seven and eight hours per night have a higher likelihood of achieving college education or more as well as a higher likelihood of holding a professional or managerial position than do their peers with shorter or longer sleep durations. These associations are modest in the range in which most adolescents sleep (6-9 hours per night), yet are notable given the more than 10-year lag between the measure of adolescent sleep duration – which is a coarse measure, as sleep is measured by self-report and in whole hours – and young adult outcomes.

The prospective association of sleep duration with educational attainment is consistent with prior research that finds sleep duration is causally linked to school and test performance (Carrell et al. 2011; Edwards 2012; Heissel and Norris 2017). However, in this study the association of sleep duration with educational attainment persists even after accounting for baseline cognitive skills. This finding suggests that sleep matters for education beyond cognitive ability (as measured by the PPVT).

The most similar prior literature on the association of sleep duration with occupation explores how occupational scheduling characteristics (especially shift work) (Coveney 2014), work-family conflict (Barnes, Wagner, and Ghumman 2012; Crain et al. 2014; Jacobsen et al. 2014; Maume, Sebastian, and Bardo 2010), or work-related stress (Burgard and Ailshire 2009; Knudsen, Ducharme, and Roman 2007) are associated with nightly sleep in adults. This body of research is extended by this paper's prospective link assessed earlier in the life course. Because

many occupations require specific levels of educational attainment, it is not surprising that sleep duration appears to be associated with occupational attainment via educational attainment.

Although I identified nonlinear and bivariate associations of sleep duration with perceived socioeconomic status, these associations did not persist in a multivariate framework. Additionally, I did not find any statistically significant association between adolescent sleep duration and young adult earnings. This may be because there is truly no association of sleep duration with these outcomes, or it may be that such an association is more pronounced at older ages. Indeed, at ages 24-32 the respondents are only in the nascent stages of adult socioeconomic status development and are still building human capital. Although educational attainment for all but postgraduate education is largely complete by these ages, the dividends of higher education may not yet be realized in earnings, wealth, or other material signals. In turn, perceived socioeconomic status may also not yet be associated with sleep duration. Thus, it is important for future research to return to this question in samples followed from adolescence to middle age and beyond.

Due to the study design of the original Add Health data collection, it is not possible to identify which mechanisms underlie the association between sleep duration and educational attainment or occupational prestige identified in this study. Given the age of study participants at baseline, adolescents who achieved less than a high school degree or completed only a high school degree completed that process very soon after the sleep duration measures were collected, and there was not an intermediary study wave to assess mechanisms in a temporally-ordered manner. Ideally, sleep would be measured at one point in childhood or adolescence (e.g., age 11), mechanisms assessed at a subsequent study wave (e.g., at age 14, prior to any possibility of

high school dropout), and socioeconomic status would be measured in adulthood, when educational attainment is complete and earnings have been realized.

Nonetheless, likely pathways between sleep and socioeconomic outcomes can be hypothesized. In so doing, I underscore that the measure of sleep used in this study (usual nightly sleep duration) represents a cumulative exposure to inadequate, adequate, or long sleep. Therefore, the mechanisms through which sleep acts on other outcomes are more likely to be the sum of many small repeated consequences on a daily basis rather than operating through any single moment which permanently alters a socioeconomic pathway. Additionally, because the production of socioeconomic status is also understood to be a cumulative process whereby educational attainment is sequential, occupation is a function of education as well as other skills and preferences, and income reflects labor market experience and credentialing, the potential pathways through which habitual exposure to any particular sleep duration comes to be associated with a specific indicator of socioeconomic status are numerous.

A few plausible examples follow, but this list is not exhaustive. Cognitive performance is the most promising mechanism underlying the association between sleep duration and educational attainment. One manner in which this pathway might operate is that poor performance on high-school assignments and exams following repeated nights of inadequate sleep might ultimately lead to failing classes or a lower GPA, which in turn may lead to a failure to graduate or a less-competitive college application. Physical health may also be a pathway through which sleep contributes to socioeconomic outcomes. Health is a primary determinate of socioeconomic status (Palloni 2006), and both short and long sleep are linked to inflammation (Bakour et al. 2017) and a wide range of morbidities, including obesity, diabetes, hypertension, and cardiovascular disease (Buxton and Marcelli 2010). In terms of mental health, problematic

sleep durations are linked to elevated rates of depression and anxiety as well as lower rates of psychological wellbeing (such as satisfaction) (Hamilton et al. 2007); over a long period of time, this likely wears down motivation to perform well, be that in secondary or higher education, in the workplace (e.g., not seeking promotions) or in pursuing a higher income. Another likely pathway related to mental health operates through risky behaviors. Inadequate sleep is associated with higher rates of risky behavior – such as impulsivity, substance use, and drowsy driving (Womack et al. 2013) – which may impede both short and long-term outcomes. Finally, it is possible that habits of adolescent sleep are directly linked to patterns of adult sleep for at least some adolescents, and it may be that there is no direct effect of sleep in adolescence on a particular outcome but rather that adolescent sleep provides an approximation of adult sleep duration, which in its own right may be linked to socioeconomic status.

These results are strengthened by the use of a large, nationally representative sample; nonetheless, this study has several limitations. First, this study uses a self-reported measure of sleep duration, in whole hours. Because this measure is coarse and imprecise, associations identified in this study likely underestimate the true association between adolescent sleep duration and young adult socioeconomic status. I have attempted to address this issue by also considering analyses which average sleep duration measures at two study waves that occurred in quick succession, measure sleep categorically, or control for sleep adequacy or trouble sleeping. Longitudinal and population-based studies should consider using objective measures of sleep duration, such as actigraphy or polysomnography, to address this concern. Second, this study is not able to ascertain what factors cause adolescents to have particular sleep durations. Although I control for a number of factors that may constrain or extend adolescents' nightly sleep durations, I am un able to account for all possible factors. Notably, data on several important school-related

factors, including start time, homework time, and peer academic engagement, is not available in this dataset, although I control for whether school was in session at the time of the report of sleep duration. Additionally, covariates are measured concurrently with sleep duration, and thus the direction of causality is unclear. For example, it is possible that students who expect to drop out of high school may change their sleep behavior; this study is unable to test whether such an anticipatory shift occurs. To address these deficits, future research should use a prospective cohort design that records relevant sleep predictors in the childhood years, collects high-quality sleep data in adolescence, and then follows the cohort well into adulthood. However, no such dataset currently exists. Third, as mentioned previously, the ages of participants and timing of study waves precludes an exploration of the pathways underlying the associations identified in these analyses. Subsequent studies should evaluate through which pathways sleep duration comes to matter for educational attainment by collecting data on both sleep and relevant mechanisms at earlier ages and following participants prospectively. Finally, this study cannot establish whether the identified associations are causal, even though the temporal order of the measures used – sleep duration is reported in adolescence and socioeconomic status is measured in early adulthood – suggests a possible causal association. Future research using experimental methods or exploiting exogenous variation is needed to identify whether there is a causal link between adolescent sleep duration and adult socioeconomic status.

In sum, this study provides evidence that adolescent sleep matters for young adult educational attainment and occupational prestige. Prior research has shown that inadequate sleep duration contributes to subsequent health as well as cognitive and school performance (Shochat et al. 2014). This study suggests that sleep is also implicated in the production of socioeconomic status insofar as it contributes to educational attainment and occupational prestige. Thus, sleep

also deserves the attention of scholars of social stratification. Moreover, it is important that social scientists help develop and support the policies and practices which promote sleep of adequate duration among adolescents.

Table 4.1 Sample description, N = 9,079

	Wave of measure	% or Mean
Outcomes		
Educational attainment	Wave IV	
Less than high school (ref)		8.2%
High school degree		16.4%
Any post-high-school vocational training		9.5%
Some college education		35.1%
College degree		19.5%
Any post-graduate training		11.3%
Occupational prestige	Wave IV	
Service worker (ref)		21.1%
Craft worker, operative, laborer, helper		23.6%
Sales and administrative support		19.2%
Professionals and technicians		23.3%
Officials and managers		12.7%
Earnings	Wave IV	$34,962
Perceived socioeconomic status	Wave IV	4.93
Predictors		
Sleep duration	Wave I	7.86
Adolescent demographics		
Female	Wave I	47.3%
Race	Wave I	
White (ref)		80.9%
Black		14.8%
Native American		1.6%
Asian		2.7%
Hispanic	Wave I	10.8%
Foreign born	Wave I	5.1%
Age	Wave I	15.34
Parent demographics		
Parent age	Wave I	41.52
Parent foreign born	Wave I	10.3%
Parent educational attainment	Wave I	
Less than high school (ref)		14.4%
High school degree		32.5%
Vocational training		11.2%

Some college education		19.5%
College degree		13.7%
Any post-graduate training		8.7%
Parent household income	Wave I	$46,331
Family structure	Wave I	
Two biological parents (ref)		55.7%
Two parents, including stepparents		17.3%
Single mother		20.1%
Single father		2.8%
Other		4.0%
Census tract poverty rate	Wave I	11.3%
Neighborhood type	Wave I	
Urban (ref)		29.4%
Suburban		38.8%
Rural		28.5%
Other		3.3%
Sleep-related covariates		
Working 10 or more hours per week	Wave I	51.6%
School in session	Wave I	37.5%
Has bedtime	Wave I	36.4%
PPVT score	Wave I	101.78
Self-rated health	Wave I	2.88
BMI category	Wave I	
Normal weight (ref)		62.8%
Underweight		14.6%
Overweight		15.1%
Obese		7.5%
Depressive symptomology	Wave I	10.03

Table 4.2 Selected odds ratios and standard errors from ordered logit models of sleep duration predicting educational attainment and occupational prestige, N = 9,079

	Educational attainment			**Occupational prestige**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep	2.04*** (0.26)	1.93*** (0.26)	1.66*** (0.22)	1.48** (0.19)	1.35* (0.17)	1.29* (0.16)
Hours of sleep^2	0.95*** (0.01)	0.96*** (0.01)	0.97*** (0.01)	0.97*** (0.01)	0.98** (0.01)	0.98* (0.01)
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Table 4.3 Selected coefficients and standard errors from OLS models of sleep duration predicting log earnings and perceived socioeconomic status, N = 9,079

	Log earnings			**Perceived socioeconomic status**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep	0.12 (0.08)	0.06 (0.07)	0.01 (0.07)	0.32* (0.14)	0.28* (0.13)	0.18 (0.13)
Hours of sleep^2	-0.01† (0.01)	-0.004 (0.004)	-0.001 (0.004)	-0.02* (0.01)	-0.02† (0.01)	-0.01 (0.01)
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Table 4.4 Selected odds ratios and standard errors from ordered logit model of sleep duration predicting occupational prestige and selected coefficients and standard errors from OLS models of sleep duration predicting log earnings and perceived socioeconomic status with concurrent socioeconomic status covariates, N = 9,079

	Model 1	Model 2	Model 3
	Occupational prestige	**Log earnings**	**Perceived socioeconomic status**
	Ordered logit	*OLS*	*OLS*
Hours of sleep	1.11 (0.13)	-0.06 (0.06)	1.05 (0.12)
Hours of sleep^2	0.99 (0.01)	0.003 (0.004)	1.00 (0.01)
Educational attainment (ref = less than high school)			
High school degree	1.18* (0.09)	0.19* (0.09)	1.29* (0.14)
Any post-high-school vocational training	1.20† (0.13)	0.42*** (0.08)	1.41** (0.15)
Some college education	1.60*** (0.13)	0.37*** (0.09)	1.56*** (0.14)
College degree	5.31*** (0.54)	0.66*** (0.10)	2.65*** (0.28)
Any post-graduate training	6.37*** (0.74)	0.57*** (0.10)	4.77*** (0.56)
Occupational prestige (ref = service worker)			
Craft worker, operative, laborer, helper		0.40*** (0.07)	1.17* (0.09)
Sales and administrative support		0.17** (0.06)	1.06 (0.08)
Professionals and technicians		0.39*** (0.06)	1.51*** (0.10)
Officials and managers		0.57*** (0.06)	1.43*** (0.12)
Earnings			1.36*** (0.04)

Perceived socioeconomic status		7.48*** (0.63)	0.80 (0.61)
All demographic and sleep covariates	✓	✓	✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Figure 4.1 Distribution of sleep duration

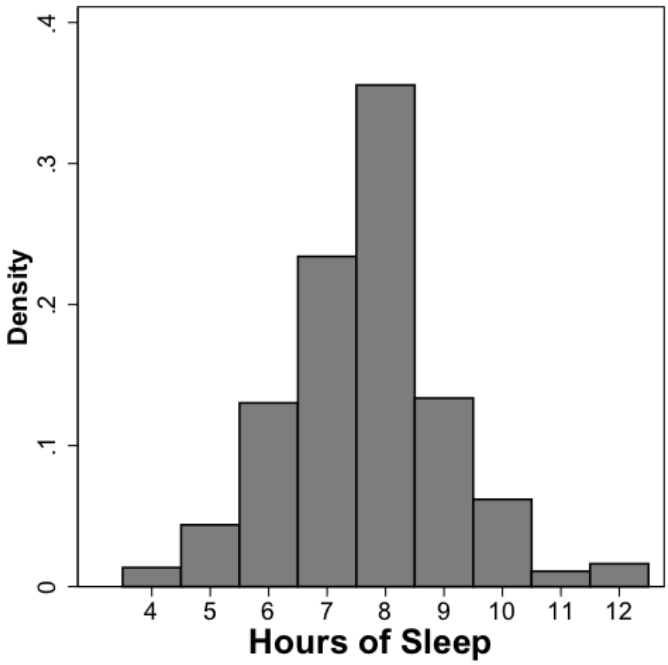


Figure 4.2 Predicted probability of educational attainment by hours of sleep

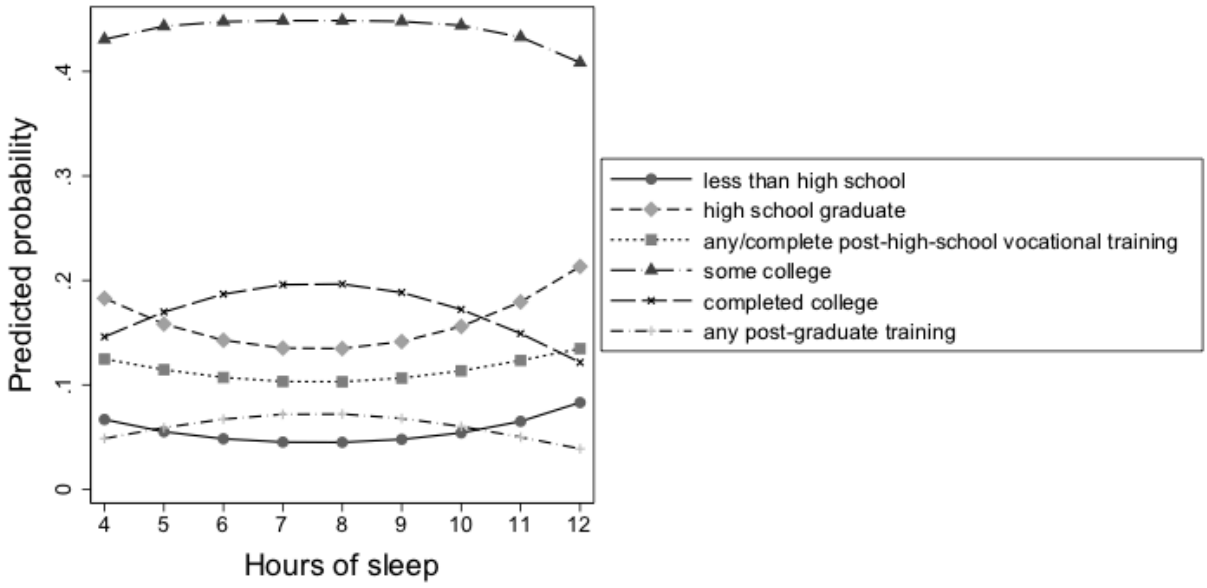
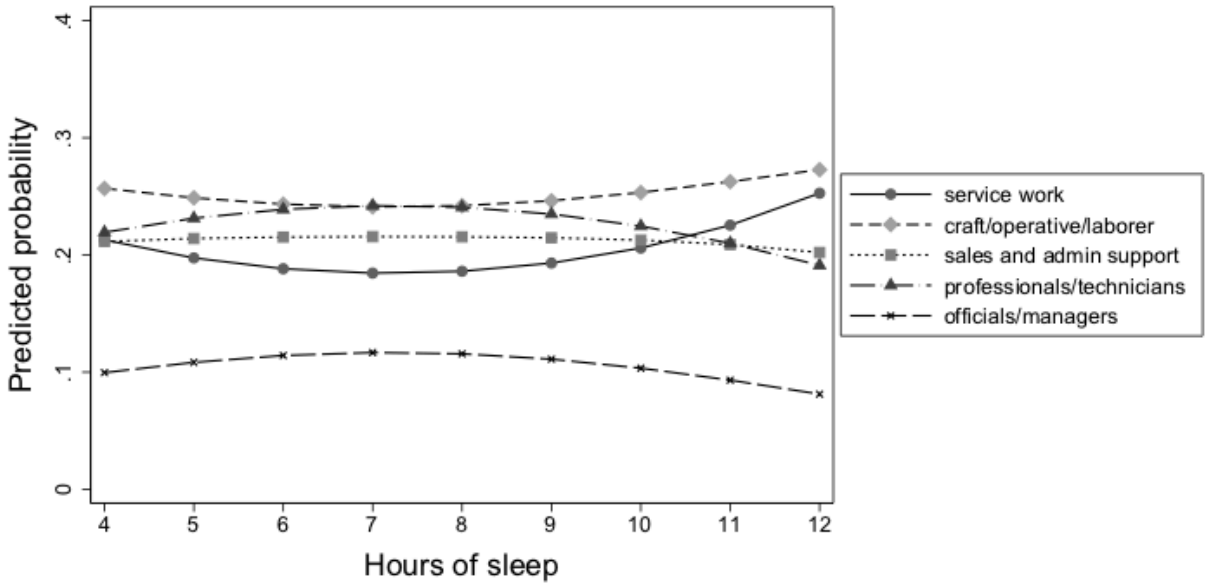


Figure 4.3 Predicted probability of occupational prestige by hours of sleep



Appendix 4A. Covariate imputation in analytic sample, N = 9,079

	N imputed	% imputed
Adolescent demographics		
Female	0	0.00%
Race	115	1.21%
Hispanic	23	0.24%
Foreign born	358	3.77%
Age	27	0.28%
Parent demographics		
Parent age	73	0.77%
Parent foreign born	23	0.24%
Parent educational attainment	71	0.75%
Parent household income	1,202	12.67%
Family structure	0	0.00%
Census tract poverty rate	73	0.77%
Neighborhood type	72	0.76%
Sleep-related covariates		
Working 10 or more hours per week	94	0.99%
School in session	0	0.00%
Has bedtime	102	1.08%
PPVT score	409	4.31%
Self-rated health	1	0.01%
BMI category	192	2.02%
Depressive symptomology	24	0.25%

Appendix 4B. Odds ratios and standard errors from ordered logit models of sleep duration predicting educational attainment and occupational prestige, N = 9,079

	Educational attainment			Occupational prestige		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep	2.04*** (0.26)	1.93*** (0.26)	1.66*** (0.22)	1.48** (0.19)	1.35* (0.17)	1.29* (0.16)
Hours of sleep^2	0.95*** (0.01)	0.96*** (0.01)	0.97*** (0.01)	0.97*** (0.01)	0.98** (0.01)	0.98* (0.01)
Adolescent demographics						
Female		1.79*** (0.10)	2.02*** (0.11)		1.35*** (0.08)	1.38*** (0.08)
Race (ref = white)						
Black		1.39** (0.15)	1.82*** (0.19)		1.05 (0.11)	1.18 (0.12)
Native American		0.76 (0.16)	0.89 (0.19)		0.85 (0.16)	0.90 (0.18)
Asian		1.16 (0.23)	1.38† (0.25)		1.17 (0.15)	1.24† (0.15)
Hispanic		1.07 (0.10)	1.28* (0.13)		1.25* (0.13)	1.37** (0.14)
Foreign born		1.12 (0.17)	1.40* (0.20)		0.89 (0.12)	0.99 (0.13)
Age		1.01 (0.02)	1.02 (0.03)		1.02 (0.02)	1.02 (0.02)
Parent demographics						
Parent age		1.03*** (0.01)	1.02*** (0.01)		1.01* (0.004)	1.01* (0.004)
Parent foreign born		1.23† (0.14)	1.23† (0.14)		1.30* (0.14)	1.31** (0.13)
Parent educational attainment (ref = less than high school)						
High school degree		1.71*** (0.14)	1.39*** (0.12)		1.33** (0.12)	1.22* (0.11)

Vocational training	2.32*** (0.27)	1.78*** (0.22)	1.23* (0.13)	1.09 (0.11)
Some college education	2.87*** (0.27)	2.12*** (0.20)	1.47*** (0.14)	1.27* (0.12)
College degree	5.06*** (0.58)	3.53*** (0.41)	2.01*** (0.23)	1.66*** (0.19)
Any post-graduate training	8.84*** (1.15)	5.72*** (0.77)	2.57*** (0.30)	2.05*** (0.25)
Parent household income	1.52*** (0.07)	1.41*** (0.07)	1.25*** (0.06)	1.19*** (0.06)
Family structure (ref = two biological parents)				
Two parents, including stepparents	0.58*** (0.04)	0.62*** (0.05)	0.77*** (0.06)	0.79** (0.06)
Single mother	0.76** (0.06)	0.79** (0.07)	0.95 (0.07)	0.96 (0.07)
Single father	0.40*** (0.07)	0.48*** (0.08)	0.97 (0.14)	1.09 (0.16)
Other	0.46*** (0.07)	0.55*** (0.08)	0.72* (0.09)	0.78* (0.10)
Census tract poverty rate	0.26*** (0.10)	0.42* (0.18)	0.46** (0.14)	0.46** (0.14)
Neighborhood type (ref = urban)				
Suburban	1.24* (0.11)	1.24* (0.11)	1.02 (0.07)	1.02 (0.06)
Rural	1.05 (0.11)	1.05 (0.10)	1.00 (0.07)	1.00 (0.07)
Other	0.86 (0.11)	0.84 (0.11)	1.02 (0.15)	1.01 (0.16)
Sleep-related covariates				
Working >=10 hours/week		1.04 (0.07)		0.98 (0.06)
School in session		1.08 (0.08)		0.98 (0.05)
Has bedtime		0.92 (0.06)		0.91 (0.05)
PPVT score		1.04*** (0.003)		1.02*** (0.002)

Self-rated health	1.22*** (0.04)	1.10** (0.03)
BMI category (ref = normal weight)		
Underweight	0.96 (0.08)	0.93 (0.07)
Overweight	0.93 (0.07)	0.93 (0.07)
Obese	0.85 (0.10)	0.87 (0.08)
Depressive symptomology	0.97*** (0.004)	0.99* (0.004)

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4C. Coefficients and standard errors from OLS models of sleep duration predicting log earnings and perceived socioeconomic status, N = 9,079

	Log earnings			**Perceived socioeconomic status**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep	0.12 (0.08)	0.06 (0.07)	0.01 (0.07)	0.32* (0.14)	0.28* (0.13)	0.18 (0.13)
Hours of sleep^2	-0.01† (0.01)	-0.004 (0.004)	-0.001 (0.004)	-0.02* (0.01)	-0.02† (0.01)	-0.01 (0.01)
Adolescent demographics						
Female		-0.36*** (0.03)	-0.33*** (0.03)		0.003 (0.05)	0.05 (0.05)
Race (ref = white)						
Black		-0.08 (0.07)	-0.03 (0.07)		0.14† (0.07)	0.16* (0.07)
Native American		-0.03 (0.13)	-0.01 (0.14)		-0.35* (0.16)	-0.29* (0.14)
Asian		-0.002 (0.08)	0.04 (0.08)		0.04 (0.13)	0.12 (0.12)
Hispanic		0.02 (0.06)	0.06 (0.06)		0.15† (0.08)	0.19* (0.09)
Foreign born		0.10 (0.07)	0.14* (0.07)		0.03 (0.12)	0.05 (0.11)
Age		0.05*** (0.01)	0.04*** (0.01)		0.07*** (0.02)	0.06** (0.02)
Parent demographics						
Parent age		0.004 (0.002)	0.003 (0.002)		0.01* (0.004)	0.01* (0.004)
Parent foreign born		0.27*** (0.05)	0.27*** (0.05)		0.36*** (0.07)	0.35*** (0.07)
Parent educational attainment (ref = less than high school)						
High school degree		0.21*** (0.05)	0.17*** (0.05)		0.13 (0.09)	0.07 (0.09)

Vocational training	0.15† (0.09)	0.09 (0.09)	0.20† (0.10)	0.13 (0.10)
Some college education	0.21*** (0.06)	0.14* (0.06)	0.26** (0.09)	0.17† (0.09)
College degree	0.23*** (0.06)	0.14* (0.06)	0.56*** (0.11)	0.45*** (0.10)
Any post-graduate training	0.29*** (0.06)	0.18** (0.07)	0.83*** (0.11)	0.68*** (0.12)
Parent household income	0.19*** (0.04)	0.17*** (0.04)	0.20*** (0.04)	0.18*** (0.04)
Family structure (ref = two biological parents)				
Two parents, including stepparents	-0.13* (0.05)	-0.10* (0.05)	-0.31*** (0.07)	-0.27*** (0.07)
Single mother	-0.02 (0.05)	-0.0004 (0.05)	-0.23** (0.07)	-0.20** (0.07)
Single father	-0.13 (0.08)	-0.07 (0.08)	-0.48** (0.15)	-0.39** (0.14)
Other	-0.16 (0.11)	-0.11 (0.11)	-0.33** (0.12)	-0.26* (0.12)
Census tract poverty rate	-0.44* (0.21)	-0.31 (0.22)	-0.61* (0.24)	-0.38 (0.24)
Neighborhood type (ref = urban)				
Suburban	0.04 (0.04)	0.03 (0.04)	0.21*** (0.06)	0.20*** (0.06)
Rural	0.02 (0.05)	0.01 (0.05)	0.09 (0.07)	0.07 (0.07)
Other	0.08 (0.08)	0.07 (0.07)	0.05 (0.11)	0.05 (0.11)
Sleep-related covariates				
Working >=10 hours/week		0.11*** (0.03)		0.16** (0.06)
School in session		0.02 (0.04)		-0.01 (0.05)
Has bedtime		-0.07* (0.03)		-0.03 (0.05)

PPVT score	0.01*** (0.002)	0.004* (0.002)
Self-rated health	0.07*** (0.02)	0.18*** (0.03)
BMI category (ref = normal weight)		
Underweight	-0.05 (0.05)	-0.01 (0.06)
Overweight	0.05 (0.04)	-0.07 (0.08)
Obese	-0.03 (0.09)	-0.20* (0.09)
Depressive symptomology	-0.01*** (0.002)	-0.01*** (0.004)

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4D. Odds ratios and standard errors from ordered logit model of sleep duration predicting occupational prestige and coefficients and standard errors from OLS models of sleep duration predicting log earnings and perceived socioeconomic status with concurrent socioeconomic status covariates, N = 9,079

	Model 1	Model 2	Model 3
	Occupational prestige	**Log earnings**	**Perceived socioeconomic status**
	Ordered logit	*OLS*	*OLS*
Hours of sleep	1.11 (0.13)	-0.06 (0.06)	1.05 (0.12)
Hours of sleep^2	0.99 (0.01)	0.003 (0.004)	1.00 (0.01)
<u>Adolescent demographics</u>			
Female	1.16* (0.07)	-0.32*** (0.04)	1.03 (0.05)
Race (ref = white)			
Black	1.04 (0.09)	-0.08 (0.07)	1.05 (0.06)
Native American	0.95 (0.19)	0.03 (0.15)	0.76† (0.11)
Asian	1.14 (0.15)	0.02 (0.09)	1.06 (0.11)
Hispanic	1.34** (0.14)	0.02 (0.06)	1.13 (0.09)
Foreign born	0.88 (0.11)	0.11† (0.07)	0.92 (0.10)
Age	1.02 (0.02)	0.03** (0.01)	1.04† (0.02)
<u>Parent demographics</u>			
Parent age	1.00 (0.004)	0.001 (0.002)	1.00 (0.004)
Parent foreign born	1.24* (0.12)	0.24*** (0.05)	1.23** (0.09)

Parent educational attainment (ref = less than high school)			
High school degree	1.19† (0.11)	0.11* (0.05)	0.97 (0.08)
Vocational training	1.01 (0.10)	0.02 (0.09)	1.02 (0.10)
Some college education	1.11 (0.11)	0.05 (0.06)	1.02 (0.09)
College degree	1.24† (0.14)	0.01 (0.06)	1.17 (0.11)
Any post-graduate training	1.30* (0.16)	0.003 (0.07)	1.23† (0.13)
Parent household income	1.07 (0.05)	0.13*** (0.04)	1.04 (0.04)
Family structure (ref = two biological parents)			
Two parents, including stepparents	0.92 (0.06)	-0.05 (0.05)	0.90† (0.06)
Single mother	1.04 (0.07)	0.02 (0.05)	0.86* (0.06)
Single father	1.35* (0.19)	-0.03 (0.07)	0.80† (0.10)
Other	0.92 (0.12)	-0.05 (0.11)	0.93 (0.10)
Census tract poverty rate	0.53* (0.14)	-0.23 (0.20)	0.87 (0.18)
Neighborhood type (ref = urban)			
Suburban	0.97 (0.06)	0.01 (0.04)	1.17** (0.06)
Rural	0.99 (0.07)	-0.004 (0.05)	1.07 (0.06)
Other	1.09 (0.17)	0.09 (0.07)	1.09 (0.12)
Sleep-related covariates			
Working >=10 hours/week	0.98 (0.06)	0.10*** (0.03)	1.14* (0.06)
School in session	0.99 (0.05)	0.02 (0.04)	0.97 (0.04)

Has bedtime	0.95 (0.05)	-0.05 (0.03)	1.02 (0.05)
PPVT score	1.01*** (0.002)	0.002 (0.002)	0.99** (0.002)
Self-rated health	1.03 (0.03)	0.05*** (0.01)	1.12*** (0.03)
BMI category (ref = normal weight)			
Underweight	0.96 (0.08)	-0.05 (0.05)	1.05 (0.06)
Overweight	0.98 (0.07)	0.06 (0.04)	0.95 (0.07)
Obese	0.93 (0.09)	-0.002 (0.09)	0.89 (0.08)
Depressive symptomology	1.00 (0.004)	-0.01** (0.002)	1.00 (0.003)
<u>Wave IV socioeconomic status</u>			
Educational attainment (ref = less than high school)			
High school degree	1.18* (0.09)	0.19* (0.09)	1.29* (0.14)
Any post-high-school vocational training	1.20† (0.13)	0.42*** (0.08)	1.41** (0.15)
Some college education	1.60*** (0.13)	0.37*** (0.09)	1.56*** (0.14)
College degree	5.31*** (0.54)	0.66*** (0.10)	2.65*** (0.28)
Any post-graduate training	6.37*** (0.74)	0.57*** (0.10)	4.77*** (0.55)
Occupational prestige (ref = service worker)			
Craft worker, operative, laborer, helper		0.40*** (0.07)	1.17* (0.09)
Sales and administrative support		0.17** (0.06)	1.06 (0.08)
Professionals and technicians		0.39*** (0.06)	1.51*** (0.10)
Officials and managers		0.57*** (0.06)	1.43*** (0.12)

Earnings		1.36*** (0.04)
Perceived socioeconomic status	7.48*** (0.63)	0.80 (0.61)

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4E. Selected odds ratios and standard errors from ordered logit models of averaged sleep duration predicting educational attainment and occupational prestige, N = 6,926

	Educational attainment			**Occupational prestige**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep (averaged)	2.96*** (0.72)	2.66*** (0.62)	2.01** (0.45)	2.17*** (0.49)	1.80* (0.42)	1.67* (0.39)
Hours of sleep (averaged)^2	0.93*** (0.01)	0.94*** (0.01)	0.96** (0.01)	0.95*** (0.01)	0.96* (0.01)	0.97* (0.01)
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4F. Selected coefficients and standard errors from OLS models of averaged sleep duration predicting log earnings and perceived socioeconomic status, N = 6,926

	Log earnings			**Perceived socioeconomic status**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep (averaged)	0.28 (0.17)	0.16 (0.16)	0.05 (0.16)	0.41† (0.23)	0.33 (0.23)	0.14 (0.24)
Hours of sleep (averaged)^2	-0.02† (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.03† (0.02)	-0.02 (0.02)	-0.01 (0.02)
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4G. Selected odds ratios and standard errors from ordered logit models of sleep duration category predicting educational attainment and occupational prestige, N = 9,079

	Educational attainment			**Occupational prestige**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Sleeps less than appropriate number of hours for age	0.83* (0.06)	0.78** (0.06)	0.80** (0.06)	0.97 (0.08)	0.94 (0.08)	0.95 (0.08)
Sleeps more than appropriate number of hours for age	0.46*** (0.10)	0.50** (0.13)	0.63† (0.15)	0.65† (0.14)	0.74 (0.16)	0.80 (0.18)
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4H. Selected coefficients and standard errors from OLS models of sleep duration category predicting log earnings and perceived socioeconomic status, N = 9,079

	Log earnings			**Perceived socioeconomic status**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Sleeps less than appropriate number of hours for age	-0.03 (0.06)	0.001 (0.05)	0.01 (0.05)	-0.12 (0.08)	-0.14† (0.08)	-0.09 (0.08)
Sleeps more than appropriate number of hours for age	-0.20† (0.12)	-0.07 (0.12)	-0.02 (0.11)	-0.51* (0.25)	-0.38 (0.25)	-0.33 (0.25)
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4I. Selected odds ratios and standard errors from ordered logit models of sleep duration and perceived sleep adequacy predicting educational attainment and occupational prestige, N = 9,079

	Educational attainment			**Occupational prestige**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep	2.18*** (0.27)	1.98*** (0.26)	1.74*** (0.23)	1.56*** (0.20)	1.38* (0.17)	1.32* (0.17)
Hours of sleep^2	0.95*** (0.01)	0.96*** (0.01)	0.97*** (0.01)	0.97*** (0.01)	0.98** (0.01)	0.98* (0.01)
Perceived sleep adequacy	✓	✓	✓	✓	✓	✓
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4J. Selected coefficients and standard errors from OLS models of sleep duration and perceived sleep adequacy predicting log earnings and perceived socioeconomic status, N = 9,079

	Log earnings			**Perceived socioeconomic status**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep	0.13† (0.08)	0.10 (0.07)	0.03 (0.07)	0.36** (0.14)	0.30* (0.13)	0.22† (0.13)
Hours of sleep^2	-0.01* (0.01)	-0.01 (0.004)	-0.002 (0.004)	-0.02** (0.01)	-0.02* (0.01)	-0.01 (0.01)
Perceived sleep adequacy	✓	✓	✓	✓	✓	✓
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4K. Selected odds ratios and standard errors from ordered logit models of sleep duration and trouble sleeping predicting educational attainment and occupational prestige, N = 9,079

	Educational attainment			**Occupational prestige**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep	1.88*** (0.25)	1.80*** (0.24)	1.63*** (0.22)	1.47** (0.20)	1.36* (0.17)	1.32* (0.16)
Hours of sleep^2	0.96*** (0.01)	0.96*** (0.01)	0.97*** (0.01)	0.97*** (0.01)	0.98** (0.01)	0.98* (0.01)
Trouble sleeping	✓	✓	✓	✓	✓	✓
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Appendix 4L. Selected coefficients and standard errors from OLS models of sleep duration and trouble sleeping predicting log earnings and perceived socioeconomic status, N = 9,079

	Log earnings			**Perceived socioeconomic status**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Hours of sleep	0.10 (0.08)	0.05 (0.07)	0.02 (0.07)	0.26† (0.14)	0.25† (0.14)	0.18 (0.13)
Hours of sleep^2	-0.01† (0.01)	-0.004 (0.004)	-0.002 (0.004)	-0.02* (0.01)	-0.01† (0.01)	-0.01 (0.01)
Trouble sleeping	✓	✓	✓	✓	✓	✓
Wave I demographics		✓	✓		✓	✓
Other sleep-related factors			✓			✓

Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Chapter 5

Conclusion

This dissertation situates sleep in the status attainment process, providing evidence that sleep both socially structured and structuring. Part I identifies sociodemographic disparities in child and adolescent sleep, considering both differentials in childhood to adolescent sleep trajectories (Chapter 2) and objectively-measured adolescent sleep (Chapter 3). Part II of the dissertation asks to what extent sleep in early life is associated with adult outcomes (Chapter 4).

There are several similarities in the findings presented in Chapters 2 and 3. Taken together, Chapters 2 and 3 show that there is a large and persistent black-white disparity in nightly sleep across childhood and adolescence. Chapter 3 finds that napping ameliorates this gap among adolescents, but also raises intriguing questions about whether and how napping may be an important and understudied factor in well-established black-white sleep disparities across the life course. Likewise, both chapters show no white-Hispanic sleep disparity in adolescence and find little association between family structure and child and adolescent sleep.

Evidence from Part I is inconsistent with regard to sex disparities in sleep, however. Chapter 2 identifies smaller sex gaps that advantage males, but Chapter 3 finds larger sex gaps that advantage females. This differential direction of sex gaps depending on sleep measurement is a more general pattern in the literature. It is possible that actigraphy measurements are less accurate for males than females, as discussed in Chapter 3. Additionally, because objective sleep data shows that males have later and more variable sleep timing than do females, it is plausible that males' self-reported sleep durations are less accurate.

Associations between socioeconomic status and adolescent sleep duration are limited to self-reported data. Adolescents with more educated and higher-income parents report sleeping the least (Chapter 2), but objective sleep data suggests no difference in nightly sleep, instead identifying that more advantaged adolescents have lower odds of napping (Chapter 3). The reason for these disparate findings is unclear. In part, these differences may be a consequence of methodological differences between chapters; analyses of self-reported sleep data are based on socioeconomic status at the time of the child's birth while analyses of objective sleep measurements use concurrent socioeconomic status.

Chapter 4 evaluates how nightly sleep duration in adolescence is associated with different socioeconomic status at ages 24-32, including educational attainment, income, and occupation, net of parental socioeconomic status. I find that adolescent sleep is associated with young adult educational attainment in a nonlinear fashion, and with occupation via educational attainment. A large prior literature has shown that sleep is important for physical and mental health and cognition at all ages; this work establishes that sleep also contributes directly to human capital acquisition.

Future Research Directions

Interpreting these findings raises three broad questions that highlight data and methodological limitations in existing literature and identify opportunities for future research.

First, are the sleep disparities identified in this dissertation substantively meaningful? Prior literature provides little guidance on the importance of these differences, as there is an acute lack of research on what magnitude of sleep disparity, and during which developmental periods, is most important for which outcomes. The bulk of research on the causal effects of sleep on child and adolescent outcomes examines adolescents' cognitive functioning using acute

sleep deprivation or restriction experiments that shorten sleep durations by multiple hours or more for a brief period of time (de Bruin et al. 2017). This approach bears little resemblance to the accumulation of smaller but repeated differences in nightly sleep duration identified in this dissertation. Another literature considers exogenous shocks that affect sleep durations (such as changes in school start times (Minges and Redeker 2016)); like the experimental literature, these studies primarily consider adolescents and rarely analyze changes in sleep duration of less than an hour. Moreover, both sets of studies are limited to sleep duration, meaning that there is even less research on the potential consequences of disparities in poor sleep quality or inconsistent sleep timing. Additional research in this area should compare the cumulative effects of small differences in sleep at different ages or developmental stages on subsequent outcomes.

Which childhood and adolescent sleep disparities contribute to disparities in other outcomes? Despite hypotheses that childhood sleep disparities contribute to health (Hale, Parente, and Phillips 2013) and educational (Buckhalt 2011) disparities across the life course, these questions are essentially unstudied, in large part to due to issues of data availability. The lack of sleep data on large samples followed prospectively from childhood into adulthood has limited the feasibility of these studies. Answering this question is necessary to identify which sleep disparities may be promising opportunities for intervention to reduce disparities in adult outcomes.

After determining which disparities are most important, how do we intervene to ameliorate these gaps? Prior research has indicated that family routines and relationships (El-Sheikh and Kelly 2017; Koulouglioti et al. 2014; Short et al. 2011), school scheduling and homework demands (Hoyt et al. 2018; Owens 2014), housing and neighborhood characteristics (Hale et al. 2019; Wilson et al. 2014), sleep-related health behaviors (e.g., caffeine, exercise,

screens) (Bartel et al. 2015), and physical and mental health conditions (Chaput et al. 2016) are all linked to child and adolescent sleep. There is limited research directly testing how the differential distribution of these sleep-promoting or sleep-inhibiting factors between sociodemographic groups contributes to childhood sleep disparities, however (Hale et al. 2013). Likewise, behavioral and policy interventions to extend nightly sleep among children and adolescents are typically intended to improve sleep among all groups. However, there is little attention to how such interventions might ameliorate or exacerbate disparities.

Implications

This dissertation provides preliminary evidence of how sleep may play a role in the status attainment process. While analyses are not causal, I find that there are large disparities in child and adolescent sleep and that adolescent sleep is in turn associated with adult socioeconomic outcomes. This pattern is consistent with sleep playing a role in the (re)production of inequality. Thus, this dissertation's findings raise provocative questions about how sleep may play a role in social stratification and direct future research toward developmentally-informed and age-specific research on the short- and long-term effects of concurrent and cumulative sleep duration among children and adolescents. Future research should identify which factors contribute to disparities in child and adolescent sleep and target behavioral and policy interventions accordingly.

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