

## Do Associations between Sleep and Body Mass Vary by Race/Ethnicity, Gender, or Socioeconomic Status among U.S. Adolescents?

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## BACKGROUND

Obesity is ubiquitous in the U.S. and affects persons from all socioeconomic and demographic groups.<sup>1-3</sup> Members of recent birth cohorts have been especially susceptible to excess weight gain,<sup>4,5</sup> as reflected by the tripling of obesity rates among U.S. adolescents between 1980 and 2000.<sup>6</sup> Among adolescents, there are considerable disparities in the prevalence of obesity among socio-demographic groups,<sup>3,7-12</sup> and recent evidence suggests that these disparities widen considerably in young adulthood.<sup>13,14</sup> By adulthood, non-Hispanic blacks and many Hispanic subgroups have up to twice the odds of non-Hispanic whites of being overweight or obese.<sup>15</sup> Individuals with low incomes and less education also have higher odds of being overweight or obese.<sup>16</sup>

Sleep problems are also common among children and adolescents in the U.S.<sup>17-21</sup> Although 9 hours of sleep is optimal for children aged 10-17,<sup>22</sup> recent data show that sleep duration is insufficient and declines during adolescence, from an average of around 8.1 hours at ages 12-13 to an average of only 7.0 hours at ages 16-17.<sup>23</sup> Some research suggests that sleep duration has also declined among younger children over the past few decades,<sup>24</sup> though such trends have not yet been comprehensively studied. There are also persistent racial/ethnic and socioeconomic disparities in sleep. Non-Hispanic blacks, Hispanics, and persons with low levels of education and income are more likely to report sleeping 6 or fewer hours each night than non-Hispanic whites and persons with higher levels of education and income.<sup>25</sup> Living in an inner city increases the odds of short sleep duration, which may explain in part why non-Hispanic blacks tend to report shorter sleep duration than non-Hispanic whites.<sup>26</sup> Racial/ethnic and socioeconomic (SES) differences in sleep patterns found among adults are also present among children and adolescents, perhaps because children of minority and less educated parents are less likely to have regular bedtimes and bedtime routines.<sup>27</sup> Compared to white children, black children also nap more and receive less nighttime sleep,<sup>10,28</sup> and are at higher risk for sleep-disordered breathing.<sup>29,30</sup> Further, the odds of going to bed at 11 p.m. or later are 4.8 times higher among minority children than nonminority children.<sup>12</sup>

A considerable body of evidence indicates that sleep problems contribute to weight gain and obesity, suggesting that racial/ethnic and SES disparities in obesity may be explained in part by parallel disparities in sleep duration and sleep quality. Recent studies have noted that the decrease in sleep duration has coincided with increases in body mass, raising the possibility that insufficient sleep is partially responsible for the obesity epidemic.<sup>31,32</sup> Studies of children and adolescents have used a diverse array of study designs and populations to conclude that sleep duration independently affects body mass, obesity, and/or weight gain.<sup>33-48</sup> This body of evidence is bolstered by a plausible set of etiological mechanisms that link sleep duration to weight gain and obesity, including (1) increased appetite via hormone dysregulation,<sup>49-52</sup> (2) opportunities to snack during periods of wakefulness,<sup>53,54</sup> (3) reduced calorie expenditure via fatigue and concomitant lower levels of physical activity,<sup>55</sup> as well as thermoregulation effects.<sup>53,54</sup>

Although review studies and meta-analyses have concluded that sleep appears to be independently associated with obesity among both children and adults, methodological limitations (e.g., cross-sectional associations) prevent definitive assertions regarding causation.<sup>32,54-57</sup> In fact, some review studies have emphasized these limitations and argued that current scientific evidence is not sufficient to support claims that changing sleep patterns are causally related to the obesity epidemic.<sup>58,59</sup> Moreover, a recent cross-sectional investigation of this issue using nationally-representative data from the National Longitudinal Study of Adolescent Health (Add Health) concluded that sleep duration is only weakly associated with body mass and obesity among boys, and not at all among girls.<sup>60</sup>

Our study will utilize Add Health data to expand on this finding by assessing the extent to which the association between sleep and body mass varies across key demographic groups defined by

gender, race/ethnicity, and SES. Although we begin with simple cross-sectional analyses, we also extend our research to address longitudinal associations between sleep duration and body mass, which could facilitate an understanding of how sleep contributes to disparities in body mass trajectories that have been observed among various demographic groups.<sup>61</sup>

## HYPOTHESES

The proposed research will utilize data from multiple waves of Add Health to investigate associations between sleep and body mass. Analyses of Add Health data will facilitate testing of our hypotheses, which are the following:

Hypothesis 1: Associations between sleep and body mass will vary among groups categorized by gender, race/ethnicity and SES.

Hypothesis 2: Changes in body mass that are observed over time among groups categorized by gender, race/ethnicity and SES can be partly explained by changes in sleep duration that are observed among these groups.

## METHODS

### *Data*

We will use data from the National Longitudinal Study of Adolescent Health (Add Health). Important characteristics of Add Health include a population-based sampling frame, a longitudinal design, and a wealth of demographic, socioeconomic, and health-related information on research participants. Add Health also provides oversamples of minority racial/ethnic groups, which will provide us with sufficient statistical power to explore racial/ethnic differences in associations between sleep and body mass.

For over a decade, the Add Health study has followed a large, nationally-representative sample of adolescents (grades 7-12), gathering data on a wide range of health risks and an impressive array of indicators that are suspected determinants of various health conditions. In Wave 1 of data collection (1994-95), over 90,000 students from 132 schools were administered a brief in-school questionnaire. Within each school, about 17 students were also selected randomly from strata arranged by grade and sex to participate in the in-home interviews. This process yielded a nationally-representative sample of 12,105 adolescents in grades 7-12, which has served as the core sample in Add Health. Between the core sample and various subsamples, 20,745 adolescents participated in the Wave 1 in-home interviews, which were conducted between April and December, 1995. Add Health investigators conducted another in-home interview (Wave 2) of 14,738 adolescents in 1996. In 2001-02, Wave 3 interviewed 15,170 young adults (age 18-26) who participated in the Wave 1 in-home interview. All participants from the Wave 1 core sample were eligible for participation in the 2007-08 Wave 4 in-home interview (n=15,701).

### *Measures*

Add Health provides a rich array of demographic, socioeconomic, biological, behavioral, and psychosocial measures, including self-reports and biomarkers for several health-related conditions. This includes repeated measures of sleep duration (self-reported), height, and weight (self-reported in Wave 1, measured in Waves 2-4). Prior studies have indicated that the vast majority of adolescents and young adults sleep between 4-12 hours per night.<sup>24,62</sup> Less than 1% of Add Health participants reported sleep durations outside of this range in Wave 1, providing an initial validation of this self-reported measure of sleep.

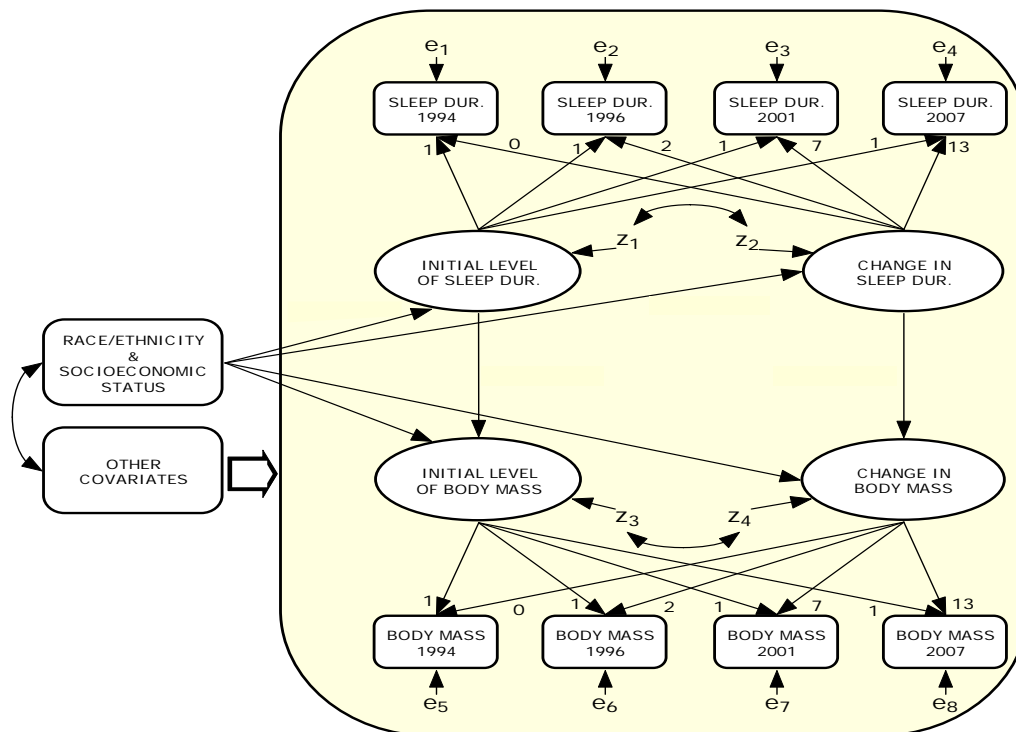
## Analyses

For a baseline understanding of associations between sleep duration and body mass in this nationally-representative population of adolescents, we will estimate ordinary least square (OLS) and logistic regression models to determine (a) the independent effect of sleep duration on BMI/obesity and (b) the extent to which this relationship varies across racial/ethnic and SES groups. These models will control for variables (e.g., pubertal status and family structure) that could potentially confound or suppress associations between sleep duration and body mass.

Next, we will estimate how changes in sleep duration influence changes in body mass across different socio-demographic groups through latent growth curve (LGC) models.<sup>63</sup> A structural equation approach to LGC modeling will enable us to test our hypothesis while accounting for measurement error in self-reported sleep duration across all four waves (Figure 1). Since prior cross-sectional research indicates that associations between sleep and body mass vary by gender among U.S. adolescents,<sup>60</sup> we will stratify these models by gender and impose equality constraints on relevant structural path coefficients to determine if those differences also emerge in longitudinal analyses.

All analyses will employ weighting procedures that permit us to account for both clustering and stratification in Add Health's complex survey design (see Chantala<sup>64</sup>).

**Figure 1. A Latent Growth Curve Model of Associations between Sleep Duration and Body Mass**



## PRELIMINARY FINDINGS

Results from our preliminary, cross-sectional analyses of Wave 2 data affirm that associations between sleep duration and body mass index (BMI standardized by age and gender according to CDC growth charts) differ across groups defined by gender and race/ethnicity. Among girls, race-stratified OLS models of BMI on continuous measures of sleep duration generally replicate earlier findings that hours of sleep per night is not a significant predictor of body mass; note that these models control for age, pregnancy status, menarche, mother's education, family income, and family structure. Despite this general finding, we detect a strong non-linear effect of sleep on body mass among Asian girls ( $\beta_{\text{sleep}} = -0.90, p < 0.05$ ;  $\beta_{\text{sleep}^2} = 0.05, p < 0.05$ ). A weaker and marginally-significant curvilinear effect is detected for Hispanic females, but no such effect is found for either non-Hispanic blacks or whites. Nevertheless, when sleep is dichotomized into a measure of short-sleep duration (less than 7 hours per night vs. more), significant effects emerge for females from all racial/ethnic groups, except non-Hispanic blacks.

Among boys, we find a significant, linear association between sleep duration (continuous) and BMI for non-Hispanic whites only ( $\beta_{\text{sleep}} = -0.10, p < 0.001$ ); these models include the same set of covariates, with the exception that pregnancy is omitted and voice changes are used as an indicator of pubertal status. We also find some evidence of non-linearity among Asian and Hispanic boys – though the effect only reaches a marginal level of statistical significance for each group. Short sleep duration (<7 hours) has a significant effect on body mass for non-Hispanic white and Hispanic boys; this effect is particularly strong for Hispanic boys ( $\beta_{\text{short sleep}} = 0.52, p < 0.001$ ).

These preliminary models suggest that overly general characterizations of associations between sleep and body mass among U.S. adolescents may be misleading, since these associations vary substantially by gender and race/ethnicity, and also depend to some extent on the parameterization of sleep. These models also suggest that understanding the role of sleep as a contributor to socio-demographic disparities in obesity will depend upon our ability to describe how (and explain why) associations between sleep and body mass vary across such groups.

## POTENTIAL STRENGTHS AND LIMITATIONS

Strengths of Add Health data and our analytic approaches include the following: First, Add Health provides a nationally-representative sample of adolescents, with a large number of Hispanics, non-Hispanic blacks, and Asians. Second, Add Health provides a rich array of measures, including measures of height, weight and sleep duration in all four waves, and a large assortment of potential confounders. Third, Add Health has tracked adolescents for 13 years during the transition into young adulthood, permitting us to analyze both cross-sectional associations in adolescence and longitudinal associations relating to the impact of changing sleep patterns on body mass. Fourth, Add Health data permit us to employ multiple modeling approaches that will help us generate robust results.

One potential limitation is the use of self-reported indicators of sleep duration in Add Health. Among adolescents, some research shows that self-reported sleep duration underestimates and correlates imperfectly with sleep duration as recorded in sleep diaries<sup>65</sup> and actigraphy data.<sup>66,67</sup> However, Wolfson et al.<sup>68</sup> found that self-reported sleep duration, sleep onset, and wake times of high school students on school nights did not differ significantly with sleep data recorded via actigraphy or sleep diaries. Another limitation is that Wave 1 includes only self-reported height and weight; estimates of BMI from self-reports have known biases.<sup>69-72</sup> However, it is possible to use Wave 2 data (which includes both reported and measured height and weight) to create BMI corrections, as Reither and colleagues have done for self-reports of height and weight across multiple waves of the National Health Interview Survey.<sup>5,73,74</sup>

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