Shorter Sleep Duration Is Associated With Increased Risk for Being Overweight at Ages 9 to 12 Years

Julie C. Lumeng, Deepak Somashekar, Danielle Appugliese, Niko Kaciroti, Robert F. Corwyn and Robert H. Bradley

*Pediatrics* 2007;120;1020-1029
DOI: 10.1542/peds.2006-3295

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://www.pediatrics.org/cgi/content/full/120/5/1020
Shorter Sleep Duration Is Associated With Increased Risk for Being Overweight at Ages 9 to 12 Years

Julie C. Lumeng, MD\textsuperscript{a,b}, Deepak Somashekar, BS\textsuperscript{a}, Danielle Appugliese, MPH\textsuperscript{c}, Niko Kaciroti, PhD\textsuperscript{d}, Robert F. Corwyn, PhD\textsuperscript{d}, Robert H. Bradley, PhD\textsuperscript{e}

\textsuperscript{a}Center for Human Growth and Development and \textsuperscript{b}Department of Pediatrics and Communicable Diseases, University of Michigan, Ann Arbor, Michigan; \textsuperscript{c}Data Coordinating Center, Boston University, Boston, Massachusetts; \textsuperscript{d}Department of Psychology and \textsuperscript{e}Center for Applied Studies in Education, University of Arkansas, Little Rock, Arkansas

The authors have indicated they have no financial relationships relevant to this article to disclose.

ABSTRACT

OBJECTIVE. The potential association between short sleep duration or sleep problems and childhood overweight has not been well described. The objective of this study was to test the independent associations of sleep duration and problems with overweight risk in children.

METHODS. Data from the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development were analyzed. In 3rd and 6th grades, sleep duration and problems were obtained by maternal report, and height and weight were measured, with overweight defined as a BMI of \( \geq 95 \)th percentile for age and gender. Logistic regression evaluated the association of sleep duration and problems with overweight at 6th grade cross-sectionally adjusting for gender, race, and maternal education. Additional covariates tested individually included the level of chaos at home, the quality of the home environment, the lax-parenting subscale score of the Raising Children Checklist, and the Child Behavior Checklist internalizing and externalizing subscale scores. Logistic regression also evaluated the relationship of sleep duration at 3rd grade and overweight at 6th grade, adjusting for gender, race, maternal education, and the child’s BMI \( z \) score in 3rd grade.

RESULTS. Of 785 children, 50% were male, 81% were white, and 18% were overweight in 6th grade. Shorter sleep duration in 6th grade was independently associated with a greater likelihood of overweight in 6th grade. Shorter sleep duration in 3rd grade was also independently associated with overweight in 6th grade, independent of the child’s weight status in 3rd grade. Sleep problems were not associated with overweight.

CONCLUSION. One preventive approach to overweight may be to ensure adequate sleep in childhood.

www.pediatrics.org/cgi/doi/10.1542/peds.2006-3295
doi:10.1542/peds.2006-3295

Key Words
obesity, overweight, sleep, NICHD Study of Early Child Care

Abbreviations
SES—socioeconomic status
NICHD-SECCYD—National Institute of Child Health and Human Development Study of Early Child Care and Youth Development
CSHQ—Children’s Sleep Habits Questionnaire
HOME—Home Observation for Measurement of the Environment
CBCL—Child Behavior Checklist
OR—odds ratio
CI—confidence interval

Accepted for publication May 29, 2007
Address correspondence to Julie C. Lumeng, MD, 300 N Ingalls Building, 10th Floor, University of Michigan, Ann Arbor, MI 48109-0406. E-mail: jlumeng@umich.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275). Copyright © 2007 by the American Academy of Pediatrics.
Emerging research has revealed sleep to be an important regulator of many physiologic functions, including energy balance, appetite, and weight maintenance. The relationship between sleep and weight has become a topic of great interest as US obesity rates reach record levels and chronic sleep deprivation affects a growing percentage of American youth and adults. Several studies have demonstrated that even modest reductions in sleep duration are associated with significant increases in obesity risk among adults. Sleep curtailment has also been linked to alterations in leptin and ghrelin levels and impaired glucose tolerance, suggesting that long-term reductions in sleep may set up hormonal changes that lead to weight gain. The link between sleep duration and obesity has been well established in adults, but comparatively little is known about this relationship in adolescents and younger children. Several studies involving 8000 Japanese children of the Toyama Birth Cohort showed an association between shorter sleep duration and increased overweight risk in age ranges of 3 to 7 years. Similar findings were reported using the Avon Longitudinal Study of Parents and Children, a cohort of British children (96% white) that examined sleep duration at 30 months and overweight risk at 7 years. Three studies have demonstrated this relationship in US children. Two of these demonstrated a concurrent association in racially diverse cohorts, although neither evaluated the potential confounding role of socioeconomic status (SES). Among 60 overweight children aged 10 to 17 years compared with matched control subjects, overweight was associated with significantly shorter sleep duration, and among 383 children aged 11 to 16 years, decreased sleep duration was associated with increased overweight risk, independent of age, gender, and race. The single US study that evaluated the potential longitudinal relationship between sleep and overweight found that among 150 children (primarily white and with well-educated parents), shorter sleep duration between the ages of 2 and 5 years was associated with increased overweight risk at age 9.5 years.

Collectively, these studies provide evidence for an association between shorter sleep duration and an increased likelihood of overweight in children, but their interpretation is limited by racial and/or socioeconomic homogeneity within the US cohorts or a lack of longitudinal data. Children's reported sleep habits and sleep problems differ by race and SES. Black children are reported to nap more frequently and until older ages than white children but get less sleep at night. Hispanic adolescents are reported to have more insomnia than other ethnic groups, and children of lower SES have later sleep onset and shorter sleep duration than children of higher SES. Because the prevalence of overweight in the United States also differs significantly by race and SES, the association between sleep duration and overweight risk may be confounded by these characteristics. Our primary aim was to test the hypothesis that shorter sleep duration is associated with increased likelihood of overweight in US grade-school children independent of race and SES.

A secondary goal of this study was to evaluate the potential association between reported sleep problems and childhood overweight risk. Poor sleep quality has been associated with a lowered sense of well-being and decreased quality of life in young adults, but its role in obesity is not well understood. Several studies have shown a link between obesity and obstructive sleep apnea in both adults and children; however, the highly specific nature of sleep apnea makes it difficult to extrapolate such findings to the report of more general sleep problems such as night waking, delayed sleep onset, and restlessness. Two studies with sample sizes of fewer than 500 subjects evaluated general sleep quality by using questionnaires in adults or wrist actigraph measurements in children/adolescents and found no association between poor sleep quality and obesity; however, a recent study that used both questionnaire and actigraphy in 60 children between the ages of 10 and 17 years found a positive association between sleep disturbance and overweight. More recent work indicated that excessive daytime sleepiness in adults is associated with a higher prevalence of obesity, independent of obstructive sleep apnea and sleep duration. We sought to test the hypothesis that the report of more sleep problems would be associated with increased risk for overweight in grade-school children.

Finally, we sought to determine whether the relationship between short sleep duration and increased likelihood of overweight, if identified, persisted when controlling for measures of quality of the home environment, parenting, and child behavior problems. We hypothesized that an identified relationship between shorter sleep duration and overweight may simply reflect an underlying lack of structure or suboptimal parenting in the home and therefore sought to test the potential confounding role of these factors. Sleep disturbance is a defining feature of affective disorders, and behavior problems and affective disorders have been associated with an increased risk for overweight in children. We hypothesized that behavior problems may underlie both short sleep duration and increased risk for overweight and therefore also sought to test this factor as a potential confounder.

METHODS

The sample was composed of children and their parents who were enrolled in the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development (NICHD-SECCYD), a longitudinal study of relations between child behavior and development, particularly in relation to child care.
experience. Families were recruited shortly after the birth of a child in 1991 from 10 areas of the United States, both urban and rural, and data were collected prospectively from birth onward. Details of the recruitment methods and sampling plan are available elsewhere.\textsuperscript{34} The initial sample included 1364 children and was representative of the demographics of the catchment areas from which the sample was recruited.\textsuperscript{31} By 6th grade, 1077 children were still enrolled in the study,\textsuperscript{30} and 806 of them had anthropometric data in 6th grade. Much of the missing anthropometric data were accounted for by families’ moving to other communities, which prevented them from attending the laboratory visits where the measurements were taken but allowed continued participation in questionnaires and telephone interviews. Children with missing anthropometric or sleep-duration data at 6th grade were excluded from the analysis, which resulted in a final sample size of 785 children (58% of the original cohort). This study was approved by the institutional review boards of all participating institutions.

**Measurement of Sleep**

Data regarding sleep duration and sleep problems were obtained by maternal report on the Children’s Sleep Habits Questionnaire (CSHQ)\textsuperscript{16} in 3rd and 6th grades, when children were on average 9.02 (SD: 0.31) and 11.61 (SD: 0.15) years of age, respectively. The CSHQ is a validated parent questionnaire regarding the child’s sleep duration and problems, modified for use in the NICHD-SECCYD to consist of 28 items.\textsuperscript{37} Sleep duration was based on maternal response to the question, “How much sleep does your child get each day (including naps)?” Mothers reported sleep characteristics on the remaining 27 items (Appendix) using a 3-point scale: 1 = usually, 2 = sometimes, and 3 = rarely). Four summary scores were computed by the NICHD-SECCYD as the average of their contributing question items: bedtime problems, night waking problems, morning waking problems, and daytime sleepiness (Cronbach $\alpha = .60$, .64, .74, and .65, respectively). We created a general sleep problems score by taking the mean of the 4 subscores. The possible range was therefore 1 to 3, with higher scores indicating more sleep problems.

**Measurement of Overweight**

Height and weight were measured during laboratory visits in 3rd and 6th grades by trained research assistants using a protocol standardized at all 10 sites.\textsuperscript{38} BMI was calculated and child overweight defined dichotomously as a BMI of $\geq 95$th percentile for age and gender based on National Center for Health Statistics norms.\textsuperscript{39} BMI z score at 3rd grade was also calculated using these norms.

**Covariates**

Gender was included as a covariate given the association of male gender with shorter sleep duration and increased overweight prevalence.\textsuperscript{11,30} Race (categorized as white versus nonwhite) was included as a covariate because of the association of minority race/ethnicity with increased childhood overweight prevalence,\textsuperscript{22,23} and sleep problems.\textsuperscript{18-21} Race was categorized in this manner because of the small number of children of each race/ethnicity besides white in this cohort. SES, indexed as years of maternal education, was included because of the association of lower SES with increased overweight prevalence,\textsuperscript{41} shorter sleep duration, and more sleep problems.\textsuperscript{21} Maternal education is correlated with income-to-needs ratio (family income relative to the poverty line, accounting for family size) in this data set (Spearman rank correlation $= 0.59$, $P < .001$). Maternal education was used as the primary index of SES given that it provided a larger sample size.

For determination of whether an identified relationship between shorter sleep duration and overweight simply reflected an underlying lack of structure or suboptimal parenting, 3 additional covariates were considered. The CHAOS Scale\textsuperscript{42} is a 15-item validated questionnaire that is completed by mothers in 3rd grade to assess the degree of environmental chaos in the home. Items are responded to as “true” (1 point) or “false” (2 points), thus resulting in a possible range of 15 to 30, with higher scores indicating more chaos in the home. The quality of the home environment in 3rd grade was measured by the Mid-Childhood Home Observation for Measurement of the Environment (HOME), one of the most widely used indices of the quality and quantity of stimulation and support available to a child in the home.\textsuperscript{43} Information is obtained during a home visit via observation and interview. It is composed of 55 items, each of which is scored in a binary manner (yes/no), with scores therefore ranging from 0 to 55 and higher scores indicating higher quality home environments. The HOME has consistently been correlated with cognitive, language, achievement, and socioemotional outcomes.\textsuperscript{44} For assessment of parental discipline strategies, mothers completed a questionnaire that was adapted from Greenberger’s Raising Children Checklist\textsuperscript{45,46} when the child was in 3rd grade. We included the lax control subscale, which consists of the sum of responses to 9 items. Response choices ranged from 1 to 4 (“definitely no” to “definitely yes”), and subscale scores therefore ranged from 9 to 36, with higher values indicating more lax parenting (Cronbach $\alpha = .73$).

Child behavior problems were assessed in 3rd grade via the Child Behavior Checklist (CBCL), a 99-item rating scale that is the most widely used assessment of behavioral problems in children.\textsuperscript{47} Scores are presented as T scores, which have a mean of 50 and an SD of 10. A cutoff of 60 is frequently used to denote clinically signif-
icant behavioral problems. We specifically tested the internalizing and externalizing subscale scores as covariates, given that sleep disturbance is a defining feature of affective disorders and the reported association of behavior problems and affective disorders with overweight in children.

Evaluation of Missing Data
We compared the sample with complete data for overweight status and sleep duration at 6th grade (n = 785) with the sample without complete data for these 2 variables. Children without complete data had mothers with fewer years of education (mean [SD]: 14.0 [2.6] vs 14.4 [2.4]; P = .02). There was no difference in gender (P = .16) or race/ethnicity (P = .61).

Statistical Analyses
Analyses were conducted with SAS 9.1 (SAS Institute, Cary, NC). The primary outcome of interest was overweight status (yes versus no) in 6th grade. We first performed unadjusted bivariate analyses (t test for continuous variables and χ² for categorical variables) comparing each of our main effect sleep measures as well as each of our covariates (gender, race, maternal education, CHAOS score, HOME total score, lax-parenting subscale score, and CBCL internalizing and externalizing subscale scores) by the child’s overweight status in 6th grade. We also evaluated the relationship between each of these covariates and mother-reported sleep duration and problems at 6th grade using t tests and correlation coefficients.

Adjusted Concurrent Relationship: Sleep Duration and Overweight at 6th Grade
A multiple logistic regression was used to test the independent relationship of sleep duration with overweight status concurrently at 6th grade, controlling for gender, race, and maternal education. The model was repeated to test the following covariates individually in the model one by one: mother-reported bedtime at 6th grade, mother-reported wake time at 6th grade, mother-reported sleep problems at 6th grade, CHAOS score at 3rd grade, HOME total score at 3rd grade, lax-parenting subscale score at 3rd grade, and CBCL internalizing and externalizing subscale scores at 3rd grade.

Longitudinal Relationship: Sleep Duration Between 3rd and 6th Grades and Overweight at 6th Grade
To test the longitudinal relationship of sleep duration in 3rd and 6th grades with overweight status at 6th grade, we created a model that included the main predictors of sleep duration in 3rd grade and change in sleep duration between 3rd and 6th grades. Covariates included gender, race, and maternal education. The child’s BMI z score in 3rd grade was also included as a covariate to assess whether the relationship between sleep duration from 3rd to 6th grade and overweight at 6th grade was present independent of the child’s weight status at the beginning of this time frame. The presence of a relationship while controlling for the child’s weight status at the beginning of the period would provide evidence supporting a causal relationship between short sleep duration and increased likelihood of future overweight. We also tested the quadratic and cubic polynomial terms for the “change in sleep duration” variable and “change in sleep duration” in tertiles (tertile 1: a decline in sleep duration ≥1.6 hours [9.2%]; tertile 2: change in sleep duration between −1.5 and 0.3 hours [78.3%]; and tertile 3: an increase in sleep duration >0.3 hours [12.3%]).

RESULTS
Characteristics of the sample in 6th grade are provided in Table 1. Fifty percent of the children were male, 81% were white, and 18% (n = 139 of 785) were overweight. Mothers reported that children slept on average 9.0 hours per night. Overweight children in 6th grade were more likely to be male; to be of minority race/ethnicity; and to have lower quality home environments, more internalizing behaviors, and mothers with lower education. Overweight children were reported to have shorter sleep duration in 6th grade than nonoverweight children.

Relationships between each of the covariates and mother-reported sleep duration and problems at 6th grade are presented in Table 2. Boys were reported to sleep fewer hours, whereas girls were reported to have more sleep problems. Children of minority race/ethnicity were reported to have both shorter sleep duration and more sleep problems. There was a marginal but significant correlation between a higher CHAOS score and both shorter sleep duration and more sleep problems. Higher HOME scores were marginally but significantly associated with fewer sleep problems. Higher lax-parenting subscores were marginally but significantly associated with shorter sleep duration, and higher CBCL internalizing and externalizing subscale scores both were
marginally but significantly associated with shorter sleep duration and more sleep problems.

### Adjusted Concurrent Relationship: Sleep Duration and Overweight at 6th Grade

Greater sleep duration was associated with a reduced concurrent likelihood of overweight in 6th grade adjusted for gender, race, and maternal education (Table 3). The inclusion of bedtime significantly reduced the association between sleep duration and overweight risk (OR: 0.86; 95% CI: 0.69–1.07; \( P = .18 \)). The inclusion of neither wake time nor general sleep problems score reduced the association between sleep duration and overweight risk. The inclusion of the CHAOS score, the HOME total score, the lax-parenting subscale score, or the CBCL internalizing or externalizing subscale scores did not alter the relationship between sleep duration and overweight risk. The CHAOS score, HOME total score, lax-parenting subscale score, and CBCL externalizing subscale score were also not independently associated with overweight in 6th grade in these models. The CBCL internalizing subscale score was, however, indepen-

### Table 1: Characteristics of Sample According to Overweight Status at 6th Grade \( (N = 785) \)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overweight ( (n = 139) )</th>
<th>Not Overweight ( (n = 646) )</th>
<th>Total ( (n = 785) )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>11.61 (0.14)</td>
<td>11.62 (0.15)</td>
<td>11.61 (0.15)</td>
<td>.77</td>
</tr>
<tr>
<td>Gender, ( n ) (%)</td>
<td></td>
<td></td>
<td></td>
<td>.004</td>
</tr>
<tr>
<td>Male</td>
<td>85 (61.2)</td>
<td>308 (47.7)</td>
<td>393 (50.0)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>54 (38.8)</td>
<td>338 (52.3)</td>
<td>392 (50.0)</td>
<td></td>
</tr>
<tr>
<td>Race/ethnicity, ( n ) (%)</td>
<td></td>
<td></td>
<td></td>
<td>.016</td>
</tr>
<tr>
<td>White</td>
<td>99 (71.2)</td>
<td>536 (83.0)</td>
<td>635 (80.9)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>40 (28.8)</td>
<td>110 (17.0)</td>
<td>150 (19.1)</td>
<td></td>
</tr>
<tr>
<td>Maternal education, mean (SD), y</td>
<td>13.6 (2.2)</td>
<td>14.5 (2.4)</td>
<td>14.4 (2.4)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>CHAOS score</td>
<td>19.0 (5.5)</td>
<td>19.0 (5.1)</td>
<td>19.0 (5.2)</td>
<td>94</td>
</tr>
<tr>
<td>Mid-childhood HOME total score</td>
<td>45.1 (5.9)</td>
<td>46.7 (6.4)</td>
<td>46.4 (6.3)</td>
<td>.01</td>
</tr>
<tr>
<td>Lax-parenting subscale score</td>
<td>14.9 (3.2)</td>
<td>14.8 (3.3)</td>
<td>14.8 (3.3)</td>
<td>.94</td>
</tr>
<tr>
<td>CBCL internalizing subscale score, mean (SD)</td>
<td>50.6 (10.4)</td>
<td>48.0 (9.8)</td>
<td>48.4 (10.0)</td>
<td>.01</td>
</tr>
<tr>
<td>CBCL externalizing subscale score, mean (SD)</td>
<td>49.0 (9.7)</td>
<td>47.1 (9.9)</td>
<td>47.4 (9.9)</td>
<td>.06</td>
</tr>
<tr>
<td>Sleep duration, mean (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep duration in 3rd grade, h</td>
<td>9.45 (0.82)</td>
<td>9.57 (0.78)</td>
<td>9.55 (0.79)</td>
<td>.12</td>
</tr>
<tr>
<td>Sleep duration in 6th grade, h</td>
<td>8.78 (0.93)</td>
<td>9.02 (0.88)</td>
<td>8.97 (0.89)</td>
<td>.005</td>
</tr>
<tr>
<td>Bedtime on school days in 6th grade, h:min</td>
<td>21:32 (37.2)</td>
<td>21:25 (38.4)</td>
<td>21:26 (38.4)</td>
<td>.04</td>
</tr>
<tr>
<td>Waking time on school days in 6th grade, h:min</td>
<td>6:44 (36.6)</td>
<td>6:44 (31.8)</td>
<td>6:44 (32.4)</td>
<td>.86</td>
</tr>
<tr>
<td>Change in sleep duration between 3rd and 6th grades, h</td>
<td>-0.66 (1.03)</td>
<td>-0.55 (0.87)</td>
<td>-0.57 (0.90)</td>
<td>.27</td>
</tr>
<tr>
<td>Sleep problems, mean (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedtime problems score</td>
<td>1.32 (0.39)</td>
<td>1.25 (0.32)</td>
<td>1.26 (0.34)</td>
<td>.08</td>
</tr>
<tr>
<td>Daytime sleepiness score</td>
<td>1.17 (0.33)</td>
<td>1.12 (0.24)</td>
<td>1.13 (0.26)</td>
<td>.08</td>
</tr>
<tr>
<td>Night waking problem score</td>
<td>1.18 (0.32)</td>
<td>1.13 (0.29)</td>
<td>1.14 (0.29)</td>
<td>.11</td>
</tr>
<tr>
<td>Morning waking problem score</td>
<td>1.75 (0.50)</td>
<td>1.71 (0.46)</td>
<td>1.72 (0.46)</td>
<td>.37</td>
</tr>
<tr>
<td>General sleep problems score</td>
<td>1.35 (0.26)</td>
<td>1.31 (0.22)</td>
<td>1.32 (0.23)</td>
<td>.06</td>
</tr>
</tbody>
</table>

### Table 2: Relationship of Sleep Duration and Sleep Problems in 6th Grade With Covariates \( (N = 785) \)

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Sleep Duration</th>
<th>General Sleep Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Pearson's Correlation</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>8.91 (0.89)</td>
<td>—</td>
</tr>
<tr>
<td>Female</td>
<td>9.04 (0.90)</td>
<td>—</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td>.004</td>
</tr>
<tr>
<td>White</td>
<td>9.01 (0.82)</td>
<td>—</td>
</tr>
<tr>
<td>Other</td>
<td>8.79 (1.14)</td>
<td>—</td>
</tr>
<tr>
<td>Maternal education</td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>CHAOS score</td>
<td>—</td>
<td>—0.11</td>
</tr>
<tr>
<td>Mid-childhood HOME total score</td>
<td>—</td>
<td>.07</td>
</tr>
<tr>
<td>Lax-parenting subscale score</td>
<td>—</td>
<td>—0.10</td>
</tr>
<tr>
<td>CBCL internalizing subscale score</td>
<td>—</td>
<td>—0.11</td>
</tr>
<tr>
<td>CBCL externalizing subscale score</td>
<td>—</td>
<td>—0.11</td>
</tr>
</tbody>
</table>

— indicates that the data are not applicable.
Longitudinal Relationship: Sleep Duration Between 3rd and 6th Grades and Overweight at 6th Grade

The model evaluating the longitudinal relationship of sleep duration between 3rd and 6th grades and overweight at 6th grade is shown in Table 4. Longer sleep duration in 3rd grade was associated with a reduced likelihood of overweight in 6th grade. The relationship was present independent of gender, race, maternal education, change in sleep duration between 3rd and 6th grades, and the child’s weight status in 3rd grade. Neither the quadratic nor the cubic polynomial term for change in sleep duration was significant in the model. Analysis of the effect of change in sleep duration by tertiles indicated an independent increased likelihood of overweight in 6th grade for children in tertile 1 (greatest decline in sleep duration) compared with tertile 2 (OR: 3.48; 95% CI: 1.09–11.12; P = .04). An increase in sleep duration (tertile 3 compared with tertile 2) was not significantly independently associated with overweight (OR: 0.75; 95% CI: 0.25–2.30; P = .62).

DISCUSSION

This study found that shorter sleep duration in 6th grade was independently associated with increased concurrent risk for overweight. In addition, shorter sleep duration in 3rd grade was associated with increased likelihood of future overweight in 6th grade, independent of the child’s weight status in 3rd grade. For every additional 1 hour of sleep in 6th grade, the child was ~20% less likely (95% CI: 2%–35%) to be overweight in 6th grade. For every additional 1 hour of sleep in 3rd grade, the child was ~40% less likely (95% CI: 1%–64%) to be overweight in 6th grade. The protective effect of longer sleep duration was mediated by sleep onset rather than wake times.

To our knowledge, this study is the first to examine the association between short sleep duration and overweight risk in a relatively large US cohort. Previous studies that investigated the association between short sleep duration and overweight risk were limited by either a relatively small sample size or ethnic and socio-economic homogeneity, making it difficult to ascertain whether the findings were easily broadly extrapolated. Our findings indicate that shorter sleep duration is associated with overweight risk in US children regardless of gender, race, or maternal education.

Children with sleeping disorders exhibit increased hyperactivity, inattention, conduct disorders, and aggression. Although in this study, externalizing behaviors alone did not seem to mediate the relationship between short sleep duration and increased overweight risk, it is possible that other factors that were not measured and that may mediate such a pathway are involved. Parents may use food to pacify sleep-deprived, irritable, and behaviorally dysregulated children. These children may also request food more often and eat beyond satiety; therefore, the effect of the sleep-deprived child’s behavior on weight may vary on the basis of parenting style. The same parents who report less control over their child’s intake may also be less strict about (or unable to control) their child’s bedtime. We had hypothesized that the relationship between short sleep duration and overweight risk may therefore have been confounded by parenting behaviors, but our data did not support this hypothesis. It is possible that family climate, including the degree of interparental or parent–child conflict, acts as a confounder, and our measure of parenting did not

**TABLE 3**

Concurrent Sleep Duration and Overweight in 6th Grade (N = 785)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep duration, h</td>
<td>0.80 (0.65–0.98)</td>
</tr>
<tr>
<td>Maternal education, y</td>
<td>0.87 (0.80–0.94)</td>
</tr>
<tr>
<td>Gender (female vs male)</td>
<td>0.60 (0.41–0.87)</td>
</tr>
<tr>
<td>Race (other vs white)</td>
<td>1.58 (1.02–2.46)</td>
</tr>
</tbody>
</table>

*P < .05.
*P < .01.

**TABLE 4**

Sleep Duration Between 3rd and 6th Grades and Overweight in 6th Grade (N = 706)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep duration in 3rd grade</td>
<td>0.60 (0.36–0.99)</td>
</tr>
<tr>
<td>Change in sleep duration</td>
<td>0.68 (0.44–1.06)</td>
</tr>
<tr>
<td>Gender (female vs male)</td>
<td>0.82 (0.40–1.71)</td>
</tr>
<tr>
<td>Race (other vs white)</td>
<td>1.42 (0.54–3.73)</td>
</tr>
<tr>
<td>Maternal education</td>
<td>0.84 (0.72–0.99)</td>
</tr>
<tr>
<td>BMI z score at 3rd grade</td>
<td>127.4 (480.0–337.8)</td>
</tr>
</tbody>
</table>

*P < .05.
*P < .001.
assess these factors. We had also hypothesized, using the same line of reasoning, that children with more internalizing behavior problems may both have disrupted sleep and be more likely to be overweight, but the data also did not support a confounding role of internalizing behavior problems in the relationship between sleep duration and overweight risk. In short, if sleep problems and behavior problems devolve from the same underlying genetically or environmentally determined physiologic base, then our findings suggest that this common underlying mechanism is not the same mechanism that links sleep duration to overweight.

In short, the temporal relationship indicated in this study, as well as the absence of confounding by a variety of covariates, supports hypotheses set forth by others previously regarding a biological link between sleep duration and obesity risk. The proposed physiologic mechanisms have involved changes in levels of circulating leptin and ghrelin, both of which have been implicated in the regulation of appetite. Short sleep duration has also been shown to alter carbohydrate metabolism and lead to impaired glucose tolerance, which may also affect weight status. Apart from the direct influence of sleep on these parameters, there are significant endogenous circadian rhythms that affect circulating leptin, glucose, and insulin levels. The release of leptin, which reduces appetite, seems to be regulated by the circadian pacemaker, as well as increased by sleep. Reduced sleep duration has been linked with reduced leptin secretion during a 24-hour period. When sleep phase is shifted (with shift work being the most extreme example), perturbations in the stability of leptin levels would theoretically be the result, with potentially significant impacts on appetite regulation. The potential effect of delayed sleep onset on leptin secretion in children is an important area for future research.

Longer sleep duration has also been associated with a greater amount of exercise, although the direction of the association remains entirely unclear. It is possible that greater sleep duration leads to a higher likelihood that the child will be more physically active, which leads to a lower risk for overweight. Alternatively, more physical activity may both increase sleep and reduce weight gain. Notably, several previous studies of adults that tested physical activity as a covariate did not find it to be a significant contributor to the relationship between sleep and obesity risk. Ultimately, additional research is required to characterize better the physiologic components that contribute to the association between short sleep duration and overweight risk and to shed light on the preferential role of bedtime as opposed to wake time in driving the association.

In contrast to the findings regarding sleep duration, this study did not detect an association between the mother’s report of the child’s having sleep problems and likelihood of overweight in 6th grade. To the best of our knowledge, this is the first study to examine this relationship in a large sample of US children. Our findings are in agreement with studies of adults and adolescents that also did not detect an association.

There were several limitations to our study. The version of the CSHQ used in this study was modified from its original version for which psychometric data were available. The ability to compare results of the CSHQ in this study with results of other studies using the original version is therefore somewhat limited. Objective measures of sleep problems such as polysomnography were not performed, and no questions were asked about snoring or breathing difficulties that might suggest undiagnosed obstructive sleep apnea, which is known to be associated with overweight status in children. These questions deserve additional research. Parental weight status was also not available in this data set, and it is possible that this may have acted as a confounder.

Decreased sleep quantity and poor sleep quality have been associated with increased aggression, conduct disorders, impaired working memory, and poorer academic performance in children and young adolescents. It is important to note that no study to date, including this one, has established a causal relationship between sleep deprivation and increased obesity risk. Observational studies such as these can establish only that an association exists; therefore, interpreting causality should be done with caution. Nonetheless, this study suggests that an increased risk for overweight is yet another potential consequence of short sleep duration, providing an additional reason to ensure that children are receiving adequate sleep, primarily through enforcing an age-appropriate bedtime.

Despite these associations and the increasing prevalence of long-term sleep deprivation in children, the 2004 Sleep in American Poll found that only 38% of

### TABLE 5 General Sleep Problems Score at 3rd and 6th Grades and Overweight at 6th Grade

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sleep Problems at 3rd Grade and Overweight at 6th Grade (n = 761)</th>
<th>Sleep Problems and Overweight at 6th Grade (n = 781)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General sleep problems score</td>
<td>1.59 (0.71–3.59)</td>
<td>2.01 (0.96–4.21)</td>
</tr>
<tr>
<td>Gender (female vs male)</td>
<td>0.53 (0.36–0.78)*</td>
<td>0.57 (0.39–0.83)*</td>
</tr>
<tr>
<td>Race (other vs white)</td>
<td>1.73 (1.11–2.71)*</td>
<td>1.52 (0.98–2.35)</td>
</tr>
<tr>
<td>Maternal education, y</td>
<td>0.87 (0.80–0.95)*</td>
<td>0.87 (0.81–0.95)*</td>
</tr>
</tbody>
</table>

* * *
parents with school-aged children reported that their child’s doctor asked about sleep habits. The many apparent associations between adequate sleep and optimal functioning of the child in multiple domains, including overweight status, support the importance of including a discussion of an appropriate bedtime during visits with pediatric providers. From a policy perspective, our findings also provide additional support for policies that propose later school start times. The very early school start times for US adolescents have raised concerns in the pediatric community because of their apparent adverse impact on sleep duration and, consequently, children’s general academic and behavioral functioning.63–65 The results of this study suggest that a reduced prevalence of overweight may also be a positive outcome of such policies.

APPENDIX: SLEEP PROBLEMS QUESTIONS ON CSHQ

1. My child goes to bed at the same time each night.
2. My child falls asleep within 20 minutes after going to bed.
3. My child falls asleep in own bed.
4. My child needs me or another parent in the room to fall asleep.
5. My child is afraid of sleeping alone.
6. Getting my child to bed at night is a problem.
7. My child sleeps too little.
8. My child sleeps too much.
9. My child sleeps in someone else’s bed during the night (parent, brother, sister, etc).
10. My child complains about problems sleeping.
11. My child awakens during the night screaming, sweating, and inconsolable.
12. My child awakens alarmed by a frightening dream.
13. My child awakes once during the night.
14. My child awakes more than once during the night.
15. How much of a problem are sleep wakings for you?
16. If your child wakes during the night, how much time does the night waking usually last?
17. My child wakes up in a negative mood.
18. My child has difficulty getting out of bed in the morning.
19. My child takes a long time to become alert in the morning.
20. My child wakes up very early in the morning.
21. Getting my child up in the morning is a problem.
22. My child naps during the day.
23. My child suddenly falls asleep in the middle of watching television, readings in a car, or other daily activities.
24. My child seems tired during the day.
25. Daytime sleepiness is a problem for my child.

ACKNOWLEDGMENTS

This study was supported by American Heart Association Fellow-to-Faculty Transition Award 0275040N and American Heart Association Midwest Affiliate Grant-in-Aid 0455563Z (to Dr Lumeng).

We thank Kyung Rhee, MD, Emily Fredericks, PhD, and Ron Chervin, MD, for thoughtful review of earlier versions of this manuscript.

REFERENCES


Downloaded from www.pediatrics.org by on August 19, 2009
adolescents: shorter sleep, poorer sleep quality, sleepiness, and sleep-disordered breathing. *J Pediatr Psychol.* 2006;104:1–11


47. Achenbach TM, Edelbrock CS. *Manual for the Child Behavior Checklist and Revised Child Behavior Profile.* Burlington, VT: University of Vermont, Department of Psychology; 1983


56. Patel SR, Malhotra A, White DP, Gottlieb DJ, Hu FB. Associa-

THE VALUE OF CASE REPORTS

“Case reports are well known to be the lowest and most useless form of evidence. Various commentators on evidence-based medicine have been known to snort derisively when they are mentioned as ‘potential papers,’ and they are dying out of most major journals. However, what is ‘well known’ is not necessarily true. Consider, for example, the diagnostic value of a raised CRP. There are some, limited instances where case reports and well observed series can obviate the need for randomized trials. Pediatricians can turn to the value of empirical antibiotics in febrile neutropenia, inhaled salbutamol in acute asthma or the classical appearance of a child with Down syndrome. These instances have something in common—they are all examples of ‘all or none’ (or ‘almost all and nearly none’) effects. Before a treatment, everyone dies. After a treatment, some don’t. It can be statistically calculated when an interesting observation becomes profound enough to be truth ( Glasziou et al and e-responses). This technique compares the rate of something happening before an intervention, and the rate afterwards. If the success rate is about ten times (or more) greater with than without the intervention, then it’s probably a real effect. However, there are far more times when a single case doesn’t prove anything than occasions when it does, but don’t let anyone tell you the case report is useless.”

*Arch Dis Child* 2007;92:817–824

Noted by JFL
Shorter Sleep Duration Is Associated With Increased Risk for Being Overweight at Ages 9 to 12 Years
Julie C. Lumeng, Deepak Somashekar, Danielle Appugliese, Niko Kaciroti, Robert F. Corwyn and Robert H. Bradley
Pediatrics 2007;120;1020-1029
DOI: 10.1542/peds.2006-3295

Updated Information & Services
including high-resolution figures, can be found at:
http://www.pediatrics.org/cgi/content/full/120/5/1020

References
This article cites 57 articles, 19 of which you can access for free at:
http://www.pediatrics.org/cgi/content/full/120/5/1020#BIBL

Citations
This article has been cited by 4 HighWire-hosted articles:
http://www.pediatrics.org/cgi/content/full/120/5/1020#otherarticles

Subspecialty Collections
This article, along with others on similar topics, appears in the following collection(s):
Nutrition & Metabolism
http://www.pediatrics.org/cgi/collection/nutrition_and_metabolism

Permissions & Licensing
Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at:
http://www.pediatrics.org/misc/Permissions.shtml

Reprints
Information about ordering reprints can be found online:
http://www.pediatrics.org/misc/reprints.shtml