Sleep duration mediates the relationship between health behavior patterns and obesity

Jill L Kaar, PhD [a,*], Sarah J Schmiege, PhD [b], Maya Vadiveloo, PhD, RD [c], Stacey L Simon, PhD [d], Alison Tovar, PhD [c]

[a] Department of Pediatrics, Division of Pediatric Endocrinology, Children's Hospital Colorado and University of Colorado Anschutz Medical Campus, Aurora, Colorado
[b] Department of Biostatistics and Informatics, Colorado School of Public Health, University of Colorado Anschutz Medical Campus, Aurora, Colorado
[c] Department of Nutrition and Food Sciences, University of Rhode Island, Kingston, Rhode Island
[d] Department of Pediatrics, Division of Pulmonology, Children's Hospital Colorado and University of Colorado Anschutz Medical Campus, Aurora, Colorado

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ABSTRACT

Objective: To examine associations between health behavior patterns and childhood obesity, and the mediating effect of sleep duration.
Design: Population-based survey.
Participants: Secondary analysis of data from the Infant Feeding Practices Study (age 6 years, n = 1073).
Measurements: Mothers self-reported their child's health behaviors including physical activity (PA), screen time, sleep duration, and diet. Latent class analysis determined the child's patterns based on health behaviors. Sleep was examined as a mediator between the class membership variable and %BMI$_{p95}$.
Results: A 3-class model fit the data best, with classes labeled as "Poorest eaters" (low fruit/vegetable consumption, high fast food), "Healthy" (low screen time, highest fruit/vegetable consumption) and "Active, super-eaters, highest screen time" (highest PA and screen time, ate the most). "Poorest eaters" had an increased %BMI$_{p95}$ (β = 4.11, P = .006) relative to the "Healthy" class. The "Poorest eaters" and "Active, super-eaters, highest screen time" classes had shorter sleep duration (β = −0.51, P < .001; β = −0.38, P < .001; respectively) relative to the "Healthy" class. Independent of class membership, each additional hour of sleep was associated with a %BMI$_{p95}$ that was 2.93 U lower (P < .001).
Conclusions: Our results indicate that health behavior patterns mediated by sleep duration may influence a child's %BMI$_{p95}$. The bi-directionality of the relationship between health behaviors and sleep remains unclear. Our findings suggest the importance of a constellation of health behaviors on childhood obesity. Interventions should include a multitude of health behaviors and consider the possibility that improving diet and activity behaviors may facilitate improved sleep and lowered obesity risk among children.

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Introduction

Pediatric obesity continues to be a public health crisis with one in three children classified as overweight or obese.[1] Given that children with obesity are more likely to become adults with obesity and its related adverse consequences,[2] there is an urgent need to better understand the pathways by which modifiable health behaviors influence obesity risk, as well as potential mediators of this pathway, such as sleep duration. Sleep problems are among the most common parental complaints to pediatricians,[3] and preschool-age children are more likely to be diagnosed with a sleep disorder than any other age group.[4] Recent evidence suggests that insufficient sleep is associated with greater risk for obesity.[5] However, how sleep interacts with health behaviors to influence obesity risk obesity risk remains unclear. Insufficient sleep may negatively impact health behaviors (e.g., diet, physical activity, screen time) which in turn could lead to increased obesity risk. In a study of over 1,000 children aged 7 years, children who slept for longer durations were found to have a healthier diet and lower BMI z-score.[6] Similar findings in a cohort Canadian children found that parent reported longer sleep duration was associated with a better quality of diet as well as higher levels of physical activity.[7] Alternatively, it is possible that unhealthy behaviors could result in poorer sleep which in turn may influence obesity risk. The goal of this paper is to test the latter pathway to answer the question of whether sleep mediates the relationship between health behavior patterns and obesity risk in children. By better

* Corresponding author at: Children's Hospital Colorado, Section of Endocrinology, 13123 East 16th Avenue, Box 265, Aurora, CO 80045. Tel.: +1 720 777 3571.
E-mail address: Jill.Kaar@ucdenver.edu (J.L. Kaar).

understanding this potential pathway, effective interventions to prevent and treat obesity early in life can be designed.

Health behaviors such as diet and activity have shown bivariate associations with sleep duration. Certain dietary behaviors, for example habitual snacking throughout the day and high caffeine consumption, have been associated with shorter sleep duration; conversely certain fruits and dairy products have been associated with improved sleep.[8] Physical activity (PA), particularly moderate-vigorous PA, has been associated with improved sleep.[9] In contrast, screen time use has been consistently associated with shortened sleep duration.[10] Not only have health behaviors been associated with sleep duration, but sleep duration has been linked to obesity risk independent of these health behaviors.[11–13]

The underlying mechanism driving the sleep-obesity association, independent of diet and activity behaviors, appears to be through changes in metabolism. For example, in tightly controlled, laboratory-based sleep restriction studies among adults, shortened sleep duration had negative effects on hormones (i.e., leptin, glucose, insulin), which induced increases in weight.[14] Other adult studies also found significant decreases in body temperature following sleep restriction which could eventually lead to decreases in basal metabolic rate, thus impacting weight.[14] In pediatric populations, negative hormonal changes have occurred in individuals with circadian rhythm misalignment and sleep restriction (i.e., late bed times, early wake times).[15,16] However, whether insufficient sleep influences metabolism directly, or indirectly, through changes in diet and physical activity, is unknown, particularly in young children.

In understanding the pathway (Fig. 1) by which sleep influences the association between health behaviors and obesity, it is important to capture health behaviors as they pattern together. For example, although there are a number of studies exploring the unique contribution of sleep, diet, screen time and physical activity behaviors individually on obesity, it remains unclear how these health behaviors together impact risk for obesity. To date, an underlying assumption has been that obesity risk is the same for a given "dose" of an exposure.[17] For example, while high sugar-sweetened beverage intake may increase obesity risk controlling for confounders, it is plausible that very active children may be protected against the effects of energy-dense nutrient poor quality diets whereas children with poor sleep duration or quality may respond even more strongly to dietary risk factors. Thus it is critical to better understand how different health behavior clusters ultimately influence childhood obesity risk.

Health behaviors co-occur, and obese children most often report having two or more eating and activity risk behaviors.[18] It is possible that these health behaviors patterns may better predict obesity risk rather than focusing on single behaviors; unfortunately, few studies

have examined behavior patterns,[19–22] only two of these in childhood.[19,20] Furthermore, no studies to our knowledge have used these patterns in understanding the pathway by which sleep mediates the association between health behaviors and obesity. Therefore, the objective of this analysis is to examine the mediating effect of sleep duration in the relationship between health behavior patterns and childhood obesity. We hypothesize that the association between health behavior patterns and obesity risk is at least partially mediated by sleep duration in children.

Methods

Participants

This was a secondary analysis using the nationally-distributed Infant Feeding Practice Survey II (IFPS II) and Year 6 Follow—Up Study (Y6FU).[23,24] The IFPS II is a prospective, longitudinal cohort, funded by the Centers for Disease Control and Food and Drug Administration (CDC), that followed women in late pregnancy and their children through age 6 years. The sample for Y6FU was a subset of those who participated in IFPS II. Mother who completed at least the first postnatal questionnaire for IFPS II were contacted to participant in Y6FU (n = 2958 contacted). A total of 1542 mothers completed the mailed questionnaires.

Measurements

Mailed questionnaires were completed by mothers. The 1-month Harvard Children's Nutrition Food Frequency Questionnaire assessed the child's diet, and a study questionnaire queried their child's activity, screen time, and sleep behaviors.[24] These questionnaires were developed using previously published national surveys and pilot tested to ensure content validity as well as appropriate variation and range of responses. PA was assessed by asking "in a typical week, how many days is your 6-year-old physically active for a total of at least 60 minutes per day". Screen time was assessed by asking "on average, about how many hours per day does your 6-year-old play video games and watch TV programs or videos (do not count school or homework time)". Sleep was assessed with the question "Over the past month, how many hours did your 6-year-old usually sleep each night on weekdays". Mothers were also asked to measure and self-report their child's height and weight (Y6FU) when the children were 6 years old. These data were used to calculate the BMI as % of the 95th percentile ($\%BMI_{p95}$) using the CDC SAS program for growth charts.[25] Social-demographic data for the family was also self-reported by the mothers. Complete information regarding this study has been previously published.[23,24]

Statistical analysis

Our analysis plan consisted of three steps. First, we created dichotomous versions of our seven health behavior indicator variables using the Youden index. Next we carried out a latent class analysis (LCA) to identify health behavior patterns using these seven indicators. Lastly, we conducted a series of regression models to examine sleep duration as a mediator of the association of health behavior patterns and obesity.

The seven health behavior indicator variables were constructed using the Youden index. By utilizing a data driven approach, the Youden index calculates the amount of a given behavior that is associated with the outcome, obesity. The threshold for each variable was chosen as the value which maximized the J statistic (sensitivity + specificity – 1) from a linear regression with obesity (>$\%BMI_{p95}$) as outcome and the specified indicator variable. The following variables were constructed; high physical activity (>60 min/day, 5 d/wk), high
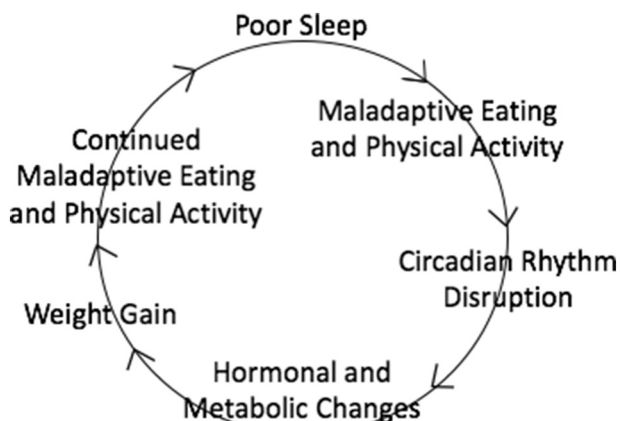

Fig. 1. Cyclic relationship of poor health behaviors worsening sleep.