Sleep Duration Predicts Cardiometabolic Risk in Obese Adolescents

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Objective To examine the independent contributions of objectively measured sleep duration and fragmentation on cardiometabolic risk accumulation in free-living obese adolescents.

Study design Characteristics of metabolic syndrome (waist circumference, mean arterial pressure, fasting high-density lipoprotein cholesterol, triglycerides, glucose) were measured in obese adolescents and standardized residuals (z-scores) were summed (inverse high-density lipoprotein cholesterol) to create a continuous cardiometabolic risk score (cMetScore), adjusted for age, sex, and race. Sleep and physical activity were objectively measured in habitual, free-living conditions for 7 days (SenseWear Pro3, BodyMedia, Pittsburgh, Pennsylvania; n = 37; 54% female, ages 11-17 years). Associations between sleep duration and cMetScore were assessed via multiple linear regression.

Results Body mass index, total sleep time, and sleep session length were each correlated with cMetScore ($P < .05$ all). Total sleep time was inversely and independently associated with cMetScore ($r = -0.535$, $P = .001$) and was the best independent predictor of metabolic risk.

Conclusions Sleep duration inversely predicts cardiometabolic risk in obese adolescents, even when we controlled for various measures of physical activity, anthropometry, and adiposity. Further research should investigate the biological mechanism of this relationship and the potential treatment effect of sleep intervention in decreasing cardiometabolic risk in this population. *(J Pediatr 2014;164:1085-90)*.

More than 30% of US adolescents are overweight, and more than 15% are obese,[1] placing them at increased cardiometabolic risk. Compared with normal-weight peers, overweight adolescents (12-19 years) exhibit greater risk of cardiovascular disease,[2] and obese youth (5-15 years) have increased glucose, blood pressure, insulin, and lipids as well as increased left ventricular mass.[3] Metabolic syndrome has been diagnosed in 25%-50% of obese pediatrics.[4-6] Each half-unit increase in body mass index (BMI) z-score is associated with increased metabolic syndrome risk in overweight adolescents.[6] Childhood BMI tracks into adulthood,[7] as do cardiovascular[8-13] and cardiometabolic[14] risk. Fortunately, obese adolescents who become nonobese by adulthood experience similar cardiometabolic risk as those who were never obese,[15] suggesting that the treatment of obesity during youth can indeed improve lifelong health.

Due to multiple factors,[16-22] most adolescents do not obtain adequate sleep.[23] Short sleep duration has been associated with cardiometabolic risk and type 2 diabetes mellitus in adults.[24,25] In pediatric patients, short sleep duration has been associated with greater BMI[26-35] and risk for being overweight,[36] although the strength of these relationships often is stronger in children than in older adolescents.[37,38] Sleep duration may be associated with insulin resistance[35] and increased waist circumference in youth[39,40] but has not been consistently associated with metabolic risk or insulin resistance in adolescents.[27,41] In a recent study, overweight youth exhibited greater cardiovascular risk than normal-weight peers, but meeting step count and sleep duration recommendations did not mitigate these differences.[42] Thus, the relationship between sleep duration and cardiometabolic risk in obese adolescents remains uncertain.

An objective field measurement of sleep duration via a SenseWear armband (SWA; BodyMedia, Pittsburgh, Pennsylvania) offers a minimally invasive assessment of habitual sleep that can be easily incorporated into many settings. The purpose of this study was to determine the independent association between objectively measured habitual sleep duration and cardiometabolic risk in obese adolescents. We hypothesized that both decreased sleep duration and increased sleep fragmentation would be associated with cardiometabolic risk in this population, independent of body mass and composition.

Methods

Obese (BMI ≥95th percentile) adolescents (11-17 years) were recruited from a family-based, multidisciplinary weight-loss program (Michigan Pediatric Outpa-

BMI	Body mass index
cMetScore	Cardiometabolic risk score
HDL-C	High-density lipoprotein cholesterol
MET	Metabolic equivalent
PA	Physical activity
SWA	SenseWear armband

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tient Weight Evaluation & Reduction program[43]) at the University of Michigan. Baseline assessments were included in the present study. This study was approved by the University of Michigan Institutional Review Board (HUM00028810).

Standing height (to 0.5 cm) and body mass (to 0.1 kg) were measured using a wall-mounted stadiometer ("Stow-a-weigh"; Scale-Tronix, White Plains, New York). BMI was calculated as weight (kg) divided by height (m) squared ($kg \bullet m^{-2}$). Body composition was measured via air-displacement plethysmography per the manufacturer's directions and accounted for measured lung volume (Bod Pod; COSMED Inc, Rome, Italy). Waist circumference was measured at the natural waist.[44] Seated blood pressure was measured manually. Blood was collected from the patient via an antecubital vein after an overnight (12-hour) fast. Serum was analyzed for high-density lipoprotein cholesterol (HDL-C; enzymatic colormetric assay), triglycerides (enzymatic colormetric assay), and glucose (hexokinase, nicotinamide adenine dinucleotide end point) by the Clinical Chemistry Laboratories in the Department of Pathology at the University of Michigan (accredited by the College of American Pathologists). Mean arterial pressure was calculated as diastolic blood pressure plus one-third pulse pressure.[45]

Each participant was fitted on the upper arm with physical activity (PA) monitor (SWA, SenseWear Pro3 or the newer model "mini"; BodyMedia) and instructed to wear it continuously for 7 days, except during activities in water. The SWA uses a tri-axial activity monitor, combined with sensors that measure galvanic skin response, near-body ambient temperature, skin temperature, and heat flux. The information collected via SWA permits the measurement of objective PA and sleep in habitual conditions, as well as assessment of activity intensity (ie, metabolic equivalents [METs]) and differentiation between inactivity and sleep. A MET is a measure of the intensity of PA expressed as a multiple of resting metabolic rate. A greater MET indicates greater energy cost. These monitors have been validated for use in pediatrics for both PA[46-48] and sleep.[49] A minimum of 22 hours of data capture per day were required for inclusion in analysis. This value was chosen as determined by estimates of nonwear time due to personal grooming (ie, bath, shower) and required charge-time. Two consecutive days of monitoring were required to capture overnight sleep. PA was assessed during a 24-hour period between midnight and midnight, and sleep was assessed during a 24-hour period between noon and noon. Because sleep patterns and duration generally differ between weekday and weekends, only participants with at least 3 weekdays and 2 weekend days meeting inclusion criteria were included in analyses. Five days of data were required to match current recommendations for free-living sleep assessments in pediatrics.[50]

Time in PA was calculated as the sum of all time spent in moderate or vigorous PA (≥3 METs). Both total duration (time) and average intensity (METs) were included in the regression model.

Total sleep time and the sessions that composed sleep were assessed. SWA returned minute-by-minute data for the entire time it was worn (ie, 1440 lines of data/day when worn for 24 hours). Sleep session was defined as at least 15 continuous minutes of sleep and sleep fragmentation as at least 15 minutes of wakefulness. This value was chosen as determined by expected typical wakefulness after sleep onset.[51] If a participant awoke for less than 15 minutes, this was not considered a break in sleep, and the sleep cycle was deemed continuous. Total sleep time within a 24-hour period was measured and could include short periods (<15 minutes) of being "awake" as noted by SWA. Weekly sums were created: 5× weekday average + 2× weekend average. Weekly average = weekly sum/7.

Metabolic characteristics (waist circumference, mean arterial pressure, fasting HDL-C, triglycerides, glucose)[52] were individually regressed onto age, sex, and race to create a standardized residual (z-score) for each characteristic. These residuals were then summed (inverse HDL-C) to create a continuous cardiometabolic risk score (cMetScore).[53] Because a high HDL-C is indicative of decreased risk, the inverse of HDL-C was included in this summation.

Statistical Analyses

Thirty-seven participants were included in analysis (**Figure 1**; available at www.jpeds.com). Baseline characteristics were assessed via ANOVA. Sex-specific differences were tested via *t* test. Pearson bivariate correlation coefficient was used to assess the relationships of cMetScore and primary outcomes. Independent associations between sleep duration and cMetScore were assessed with multiple linear regression. In each model, cMetScore was entered as the continuous dependent variable, and the adolescents' sleep, PA duration, and intensities (METs) were entered as independent predictors, along with potential covariates (ie, BMI). Multicollinearity of explanatory factors was assessed via variance inflation factor. Statistics were completed via SPSS versions 18.0 and 20.0 (IBM, Armonk, New York). Statistical significance was defined as $P < .05$.

Results

Participants (17 male, 20 female) were 11-17 years of age, were from varying racial backgrounds, and were obese per age- and sex-specific standards (≥95th BMI percentile; **Figure 1** and **Table I**). Other than BMI percentile, subject characteristics did not differ by sex (**Table I**). One-third of participants met the minimum recommendation of being physically active at least 60 minutes/day.[54] Participants slept approximately 7 hours per night, separated into 2 sleep sessions (**Table I**), which is less than the National Sleep Foundation recommendation for 10-17 year olds (8.5-9.25 hours/night).[55] Five participants (14%) met the minimum guideline and slept at least 8.5 hours per night (≥8.5 and ≤9 hours/night, n = 3; > 9 hours/night, n = 2). The length and number of sleep sessions were inversely correlated ($r = -0.804$, $P < .001$), and the length of sleep sessions and total weekly sleep were positively correlated ($r = 0.722$, $P < .001$), revealing that less sleep fragmentation was indicative of greater volume of sleep over time.