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Investigating the association between sleep parameters and the weight status of children: night sleep duration matters☆,☆☆

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ABSTRACT

Objectives: To examine the associations between sleep parameters and weight status in a large sample of preschool children.
Design: Cross-sectional survey data from the Effective Early Educational Experiences for children (E4Kids) study were analyzed.
Participants: 1111 children aged 3 to 6 years from Queensland and Victoria, Australia.
Measurements: General linear modeling, with adjustment for significant control variables, assessed the impact of night sleep duration, total sleep duration, napping frequency, sleep timing (onset, offset and midpoint), and severity of sleep problems on standardized body mass index (BMI *z* score). General linear modeling was conducted for the total sample and then separately by sex.
Results: For the total sample, there was a significant association between short sleep duration (≤10 hours) and increased BMI *z* score. No other sleep parameters were associated with BMI *z* score in this sample. Analyses by sex revealed that, among girls, there were no associations between any sleep parameter and BMI *z* score. However, among boys, short night sleep duration and napping frequency were both significantly associated with weight status even after adjustment for controls.
Conclusion: Night sleep duration is a consistent independent predictor of body mass in young children. These results identify a complex relationship between sleep and body mass that implicates sex. Potential mechanisms that might explain sex differences warrant further investigation.

Pediatric obesity is a significant public health concern with negative psychosocial and health sequelae in childhood and across the life course.[1,2] Globally, it is estimated that 42 million children under the age of 5 are classified as overweight or obese.[3] In Australia, 23% of children aged between 2 and 4 years are classified as overweight or obese, with slight increases in prevalence observed through to adolescence.[4] To date, intervention strategies have been directed to the immediate problem of energy intake and energy expenditure (eg, Get Up & Grow [Australia], Hip-Hop to Health [USA], MAGIC [UK] campaigns); however, the problem remains significant. For this reason, attention has turned to identifying other modifiable mechanisms implicated in weight status. Sleep has emerged as a significant candidate for investigation.

Meta-analyses have identified an association between shortened sleep duration and increased risk of obesity in children.[5,6] However, not all studies have found an association between sleep duration and weight status in young children (e.g. Hiscock et al., 2011).[7] Furthermore, recent research suggests that alternative sleep parameters, including sleep midpoint and timing of sleep onset or offset, potentially exert a greater influence on weight status than duration alone.[8–12] For example, Olds et al (2011) report that children and adolescents classified as "late bed–late rise" had decreased physical activity and greater weight status compared with those classified as

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"early bed–early rise" despite these groups having similar sleep durations. Similarly, in a study of "late" vs "normal" sleepers, later sleep midpoint was associated with higher weight status, although sleep duration did not differ.[11] In longitudinal analysis of younger children (aged 4-5 years), both shorter night sleep duration and later sleep onset at age 4 were associated with increased body mass between 4 and 5 years of age.[9] This may be indicative of early dysregulation of circadian timing, resulting in metabolic hormone disruption (eg, leptin and ghrelin) leading to increased body mass.[13]

Considering the independent effects of a multiplicity of sleep parameters on the weight status of young children may provide greater understanding of the mechanisms at play. Therefore, the aim of this study was to investigate associations between multiple sleep parameters (daytime napping, night-time sleep duration, sleep timing, and sleep problems) and weight status in a large sample of Australian children aged 3 to 6 years (N=1111). We hypothesized that sleep parameters indicative of poorer sleep would be associated with increased body mass. Furthermore, because of recent research indicating significant sex differences associated with shortened sleep duration[14] and subsequent increased BMI *z* score,[15] we conducted exploratory analyses stratified by sex.

Method

Participants

The children were participants in the Effective Early Educational Experiences for Children (E4Kids) Study, a 5-year Australian longitudinal study of the developmental impact of early childhood education and care (ECEC) services. The sample and design of the study have been detailed elsewhere.[16] Briefly, children and families were recruited in 2010 from childcare services across 4 locations in 2 states: Queensland—Brisbane (metropolitan) and Mt Isa (remote), Victoria—Melbourne (metropolitan) and Shepparton (rural). Stratified random sampling was used to capture the range of licensed service types (long day care, kindergarten, and family day care) and ensure representation of both high and low socioeconomic status (SES). Recruitment was focused on children aged between 3 and 5 years of age, with any child within identified ECEC rooms invited to participate. Written informed consent was provided by main caregivers and children gave verbal consent. Ethical approval was provided by both The University of Melbourne and Queensland University of Technology Human Research Ethics Committees. A total of 2488 children were recruited in 2010 from 140 services. These data are from the second year (2011) of the study, when height and weight were collected for 1945 children (78.2%). Parents of 1288 children completed the sleep items. Complete data were available for a total of 1112 children.

Analyses were conducted to investigate if there were any significant differences between parents who did and did not complete the main caregiver sleep items in 2011. Parents who did not complete the items were significantly younger ($M = 30.56$ [.23]) than parents who completed ($M = 32.20$ [.14]) the survey (t (1,129.56) $= -6.11$, $P < .001$). Furthermore, parents who completed the survey had significantly higher relative advantage on SES ($M = 1031.54$ [2.1]) than parents who did not complete ($M = 1000.96$ [2.16]) the survey (t (1281) $= -10.13$, $P < .001$). No other significant differences were found between parents who completed or did not complete the study in 2011.

Weight status

Height and weight were measured by trained fieldworkers to WHO standards[17] within the child's ECEC service. Children were dressed in light clothing and without shoes and were measured using calibrated stadiometers (SECA Leicester Portable Height Measure) and floor scales (HD-316, Wedderburn Scales; Tanita Corporation, Tokyo, Japan). Children were measured twice; if measurements differed (weight >0.1 kg; height >0.5 cm), a third measurement was taken by the researcher with the mean of these measurements used to calculate BMI. The WHO's Anthro (version 3.2.2) and AnthroPlus (for children over 5.1 years) programs were then used to transform raw anthropometric data into sex- and age-specific *z* scores. To ensure comparability, weight status was reported using international cut-points.[18,19] Biologically implausible values were identified using the WHO guidelines, with 1 child identified and subsequently removed.

Sleep parameters

The main caregiver reported their child's typical night sleep: (1) "On a typical night, when does the study child usually go to sleep?"—responses were indicated by a time between "before 5 PM" through to "midnight or after midnight" presented in half-hour increments; (2) "On a typical morning, when does the study child usually wake up?"—respondents indicated a time between "before 4 AM" through to "after 10 AM" presented in half-hour increments. The main caregiver also reported on their child's napping frequency and duration: (1) "Does the study child ever nap (sleep during the

Table 1
Definition of the sleep parameters assessed in this study

Sleep parameter	Description	Variable type
Sleep onset	Typical time that sleep commences.	Continuous
Sleep offset	Typical time that sleep ends.	Continuous
Night sleep duration	Calculated using the duration of time between typical sleep onset and offset. Night-time sleep duration was then categorized into long (>10 h) and short sleepers (≤10 h) consistent with previous research and also with the National Sleep Foundations–recommended 10 h of sleep for children in preschool age range.[20]	Categorical (2 levels)
Total sleep duration	Calculated by summing napping duration per week with night-time sleep duration. Nap duration per week[21] was calculated by multiplying nap duration by days napped per week which was then divided by 7 d.	Continuous
Sleep midpoint	Calculated as a proxy for circadian timing[22] using the midpoint of the time between sleep onset and offset, then transformed using a median split into late sleep midpoint (>1:15 AM) and early sleep midpoint (≤1:15 AM); this is consistent with previous research.[11]	Categorical (2 levels)
Napping frequency	As a significant number (848; 76.7%) of children had ceased napping, the distribution of napping duration per week was extremely skewed. Therefore, children were classified into 4 napping frequency groups: non-nappers, incidental nappers (<1/wk), transitioning nappers (1-3 d/wk), consistent nappers (4-7 d/wk).	Categorical (4 levels)
Sleep problems	The responses on the 2 sleep problem questions were dichotomized into "no problem/mild' vs "moderate/severe."	Categorical (2 levels)

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