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Original Article

Sleep duration and growth outcomes across the first two years of life in the GUSTO study

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ABSTRACT

Background and Aim: Short sleep duration is thought to be a factor contributing to increased body mass index (BMI) in both school-age children and adults. Our aim was to determine whether sleep duration associates with growth outcomes during the first two years of life.
Study design: Participants included 899 children enrolled in the Growing Up in Singapore Towards healthy Outcomes (GUSTO) birth cohort study. Anthropometric data (weight and body length) and parental reports of sleep duration were collected at 3, 6, 9, 12, 18, and 24 months of age. A mixed-model analysis was used to evaluate the longitudinal association of BMI and body length with sleep duration. In subgroup analyses, effects of ethnicity (Chinese, Indian, and Malay) and short sleep at three months of age (≤12 h per day) were examined on subsequent growth measures.
Results: In the overall cohort, sleep duration was significantly associated with body length ($\beta = 0.028$, 95% confidence interval [CI] 0.002–0.053, $p = 0.033$), but not BMI, after adjustment for potential confounding factors. Only in Malay children, shorter sleep was associated with a higher BMI ($\beta = -0.042$, 95% CI –0.071 to –0.012, $p = 0.005$) and shorter body length ($\beta = 0.079$, 95% CI 0.030–0.128, $p = 0.002$). In addition, shorter sleep was associated with a higher BMI and shorter body length in children who slept ≤12 h per day at three months of age.
Conclusion: The association between sleep duration and growth outcomes begins in infancy. The small but significant relationship between sleep and growth anthropometric measures in early life might be amplified in later childhood.

Abbreviations: BISQ, Brief Infant Sleep Questionnaire; BMI, body mass index; GUSTO, Growing Up in Singapore Towards healthy Outcomes.

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1. Introduction

Over the past few decades, the rate of childhood obesity has increased substantially. Today, about one-third of children worldwide are either overweight or obese [1]. In parallel with the global obesity epidemic, there has been a gradual decline in sleep duration over the past several decades that includes children in Asia, Europe, and the United States [2]. Numerous studies have demonstrated an inverse correlation between sleep duration and adiposity or obesity risk in children and adults [3–10]. Possible mechanisms include decreased leptin and increased ghrelin associated with sleep deprivation [11], leading to increased caloric intake and reduced energy expenditure, both of which contribute to obesity. In addition, sleep is thought to be essential for growth during child development. As pulsatile release of human growth hormone occurs during slow-wave sleep [12], it is possible that chronic exposure to short sleep during childhood affects growth (body length), although this hypothesis has yet to be systematically tested.

The relationship between sleep duration and growth outcomes has been primarily investigated in school-age children and not in younger age groups [3,6,7,9,10,13]. In addition, earlier studies were performed in populations that are predominantly Caucasian, even though epidemiologic evidence indicates that sleep duration in children is shorter in East Asian countries [14–16]. Similarly, in Singapore it has been reported that 2-year-old children sleep about 2 h less per day relative to Swiss children of the same age [17,18], but the impact on growth outcomes has not been explored. This study, therefore investigated the relationship between sleep duration and growth in Singaporean children during the first two years of life. Here, we tested the hypothesis that shorter sleep duration is associated with a higher body mass index (BMI) and shorter body length across early development.

2. Methods

2.1. Study design and population

This study was conducted as part of the Growing Up in Singapore Towards healthy Outcomes (GUSTO) birth cohort study, which aims to identify perinatal and early-life factors that affect growth and metabolic health of children raised in Singapore. The GUSTO study methodology has been described in detail elsewhere [19]. Pregnant women aged ≥18 years were recruited in their first trimester from KK Women's and Children's Hospital and the National University Hospital, the two major public hospitals with obstetric services in Singapore. Only women with a homogeneous parental ethnic background who were Chinese, Malay, or Indian were eligible for the study. Women were excluded if they were on chemotherapy, taking psychotropic drugs, or if they had preexisting diabetes mellitus. A total of 1247 women with singleton pregnancy were recruited, with children born between 30 November 2009 and 1 May 2011. Informed written consent was obtained from each participant on the day of study enrollment, and procedures were approved by the National Healthcare Group Institutional Review Board (IRB) and the SingHealth Centralized IRB. This study is registered under the Clinical Trials Identifier NCT01174875.

2.2. Sleep duration

The Brief Infant Sleep Questionnaire (BISQ) was used to assess infant sleep behavior at 3, 6, 9, 12, 18, and 24 months of age [20]. The BISQ was administered to the main caregiver of the child (mostly mothers) in English, Chinese, Tamil, or Malay language. Two items were selected from the questionnaire responses: (1) "How much time (on average) does your child spend in sleep during the NIGHT?" and (2) "How much time (on average) does your child spend in sleep (naps) during the DAY?" Both responses were reported in hours and minutes. The main exposure parameter in this study was total daily sleep duration, which was calculated as the sum of daytime sleep and nighttime sleep.

2.3. Growth measures

Growth measures were examined at time points corresponding to administration of the BISQ. Weight was measured to the nearest gram using a calibrated scale (SECA 334 weighing scale; SECA Corp., Hamburg, Germany). Recumbent body length was measured in duplicate to the nearest 0.1 cm from the top of the head to the soles of the feet using a measuring mat (SECA 210 mobile measuring mat; SECA Corp.). BMI was calculated as the weight in kilograms divided by squared body length in meters.

2.4. Covariates

Demographic parameters such as ethnicity, maternal education, and household income were collected at the beginning of the study. In addition, parental anthropometric measures were collected during pregnancy, and maternal height and BMI at 26 weeks of gestation were used in this analysis. Data concerning delivery and perinatal risk factors included sex of the child, gestational age, birth weight and length, pregnancy smoking status, and maternal gestational diabetes mellitus. Anthropometric measurements of newborns were completed within 24 h of birth. Breast-feeding status was documented at every visit during the study as exclusive, predominant, partial, or formula only, which followed the World Health Organization's definitions [21]. Considering that breast-feeding patterns changed over time, a weighted sum was used (weights: exclusive breast-feeding = 1, predominant breast-feeding = 0.75, partial breast-feeding = 0.5, and formula only = 0) for total breast-feeding duration which took into account the type of breast-feeding and its corresponding duration. Early lifestyle measures in children were also included as covariates such as total media use and outdoor physical activity at 24 months. Data on the number of daily hours spent on the computer and handheld devices or watching television were collected at 24 months of age for both weekdays and weekends, and a weighted average of total media use was calculated. The average number of hours per day spent playing/exercising outdoors was similarly calculated after taking into account weekday and weekend behavior.

2.5. Statistical analysis

We first examined maternal and offspring characteristics, as well as exposure and outcome variables, of the three main ethnic groups in Singapore (Chinese, Indian, and Malay). Mean comparisons among groups were performed using one-way analysis of variance (ANOVA). In order to account for the dependence among repeated measures across time points, as well as to maximize usage of longitudinal data, a mixed model without random effects was used to examine the relationship between BMI and sleep duration from three months to two years of age. Sleep duration and BMI values at 3, 6, 9, 12, 18, and 24 months were entered into the mixed model, together with covariates described in the previous section. A similar model was used to examine the longitudinal relationship between body length and sleep duration.

In subgroup analyses, the associations of BMI and body length with sleep duration within different ethnic groups were examined after adjusting for covariates. Similarly, children within subgroups with either shorter or longer sleep duration were also examined, with shorter sleep duration defined as ≤12 h per day at three months of age. This cutoff was chosen because it was the mean sleep duration at the 3-month time point. In addition, our