The Stability of Sleep Patterns in Children 3 to 7 Years of Age

Rachael W. Taylor, PhD[1], Sheila M. Williams, DSc[2], Victoria L. Farmer, MSc[1], and Barry J. Taylor, MBChB, FRACP[3]

Objective To determine the reliability and stability of sleep (duration and quality) over time in young children using repeated accelerometer estimates of sleep.

Study design One hundred ninety-four children wore Actical accelerometers for 5-day periods (24-hour monitoring) at 3, 4, 5, 5.5, 6.5, and 7 years of age. Sleep variables of interest (duration, onset, offset, latency, efficiency, and wake after sleep onset) were estimated using the Sadeh algorithm within a commercial data reduction program (ActiLife). Children were divided into various groups according to sleep stability, and demographic and behavioral differences were compared across groups by ANOVA.

Results All measures of sleep quantity and quality required 4-7 days of accelerometry to obtain acceptable reliability estimates, except morning wake time (2-4 days), and sleep latency (11-21 days). Average year-to-year correlations were only moderate for most measures (r = 0.41-0.51), but considerably higher than those observed for sleep latency, efficiency, and wake after onset (r = 0.15-0.24). Only 29 children were classified as sleep-stable over the 4 years. These children were less likely to be from ethnic minority groups (P = .017) and had higher levels of day-time physical activity (P = .032).

Conclusions Sleep patterns in children are not particularly stable, showing considerable variation both within a week and across the years. Few children exhibit stable sleep patterns over time, yet characterization of these children might provide further information regarding how sleep benefits health. *(J Pediatr 2015;166:697-702)*.

Poor sleep, whether in terms of duration or quality has been related to multiple aspects of child health including emotional and behavioral difficulties,[1] school performance,[2] family functioning,[3] and obesity.[4] Sleep has most commonly been measured using a variety of questionnaires, only some of which meet evidence-based assessment criteria.[5] Actigraphy (accelerometers) offers a simple approach for researchers to obtain multiple nights of data for a relatively low respondent burden, at least in healthy children.[6]

Despite marked interest in the contribution of sleep duration to health,[7] few prospective studies have examined the stability of sleep duration during childhood. Anders et al[8] demonstrated that sleep duration measured using actigraphy declined over a 6-month period, with marked variation within individuals. Data from the Zurich Longitudinal study investigated stability from the age of 1-10 years, demonstrating low short-term stability, with sleep duration varying from year-to-year. Over a longer time period, however, sleep duration was moderately stable with most children remaining in the same SD channel.[9] However, as this study assessed "usual" sleep duration by asking parents to record typical sleep and wake times to the nearest 30 minutes, only a crude estimate of time asleep was obtained at each age. Determining whether demographic or behavioral variables differ between children with more and less stable sleep patterns could provide clues about developing a more stable sleep pattern. To date, no studies appear to have examined what factors might be associated with a stable sleep pattern in children.

Our Family Lifestyle, Activity, Movement and Eating study collected multiple day accelerometry data from a large cohort of young children over a 4-year period, allowing us to examine the stability of sleep patterns in young children. The aims of our study were: (1) to assess the reliability of several measures of sleep quantity (sleep duration) and sleep quality including sleep latency (time taken to go to sleep after going to bed), wake after sleep onset, and sleep efficiency (accounts for waking after sleep onset) in young children; (2) to estimate how well each of these measures track from 3-7 years of age; (3) to determine whether estimates of sleep duration are stable in children over this 4-year period; and (4) to examine whether differences in demographics and physical activity exist between children with varying sleep stability.

Methods

The Family Lifestyle, Activity, Movement and Eating project was a longitudinal observational study designed to examine factors in early childhood, which may contribute to the development of overweight and obesity. We aimed to recruit a total of 240 participants, enabling examination of up to 24 variables of interest

BMI	Body mass index
MVPA	Moderate-to-vigorous physical activity

From the Departments of [1]Medicine, [2]Preventive and Social Medicine, and [3]Women's and Children's Health, University of Otago, Dunedin, New Zealand

Funded by the University of Otago, the Child Health Research Foundation, and the Dean's Bequest–AAW Jones Trust. The authors declare no conflicts of interest.

http://dx.doi.org/10.1016/j.jpeds.2014.11.014

(10 participants per variable). Children were recruited just before their third birthday from a cohort (n = 872) born at the only maternity hospital servicing the city of Dunedin, New Zealand (Queen Mary Maternity) between July 2001 and January 2002. Exclusion criteria including prematurity (<37 completed weeks gestation), multiple births, major congenital abnormalities, severe postnatal illness (n = 75), no longer living in Dunedin (n = 348), or not likely to be resident locally for the next 2 years (n = 11). A further 25 families were unable to be contacted. After exclusions, 413 children were eligible, of which 244 (44% girls) agreed to participate (59% response rate). The children were predominantly European (83%), with 10.8% identifying as Maori, 3.7% as Pacific Islanders, and 2.5% as other ethnicities, reflecting the wider Otago population. Participants did not differ from nonparticipants in terms of sex, gestation, or birth weight, but were more likely to be European and from homes with lower levels of household deprivation. Nonparticipating mothers were also 1-2 years younger (data not shown). The study received ethical approval from the Lower South Regional Ethics Committee (Reference OTA/04/03/023), and signed informed consent was obtained from the parents or guardians of each participating child.

Children were seen every 6 months at University research clinics between ages 3 and 7 years as close as possible to their birthdays, although not all measures were obtained at all time points. Measures of the main outcome variable (sleep) were obtained at 3, 4, 5, 5.5, 6.5, and 7 years. Weight was measured in duplicate wearing light clothing and with shoes removed, by electronic scales (Mettler-Toledo, Victoria, Australia) to the nearest 0.1 kg. Height was measured in duplicate to the nearest 0.1 cm using an electronic wall-mounted stadiometer (Heightronic; QuickMedical, Northbend, Washington). Body mass index (BMI) was derived (kg/m^2) and BMI *z*-scores were calculated using US reference data.[10]

Sleep was measured using Mini-Mitter (Bend, Oregon) omnidirectional Actical accelerometers attached by belts to the waist, set at 15-second epochs. Parents were instructed to keep the monitors on the children at all times for at least 5 consecutive days, including 2 weekend days. Parents also completed an activity log describing when the children went to bed, went to sleep, and woke up each day of measurement. A sleep algorithm (Sadeh) contained within a commercial data reduction program (ActiLife 6; Actigraph, Pensacola, Florida) was used to analyze the data. The algorithm produces the following variables: (1) sleep onset time (bed time); (2) sleep end time (wake time); (3) sleep latency, the difference between the sleep onset time from the accelerometer and the bedtime indicated in the parent diary; (4) sleep efficiency, the percentage of time in bed spent asleep; and (5) wake after sleep onset, the amount of wake time within the total sleep period. In general terms, this algorithm determines a subject's sleep state by examining the activity counts over an 11-minute sliding window. Probability analysis is used to define each minute of recorded activity (using an 11-minute sliding window) as either a sleep or wake epoch by weighting the activity scores of the surrounding minutes. If the probability is zero or greater, the specific epoch is scored as sleep; otherwise it is scored as wake. After selecting sleep end and sleep offset each minute of sleep data is analyzed this way, including night awakenings.[11]

Moderate-to-vigorous physical activity (MVPA) was also measured by accelerometry during awake time only. Individual level filters were created in MeterPlus (Santech, Inc, San Diego, California), a commercial data reduction program, to remove all sleep time for each individual day for each child. Time spent in MVPA was estimated using the cut-points of Evenson et al.[12] Maternal BMI was measured, and questionnaires on maternal smoking in pregnancy, maternal education, and child ethnicity were collected at baseline.

Individual days from children were only included in the dataset if they had a corresponding parental report for sleep and wake times. This meant that children were included even if we only had a single day of measurement.

Statistical Analyses

All analyses were undertaken using Stata Release 12 (StataCorp, College Station, Texas). Missing data were assuming to be missing at random. A mixed model with a random effect for participant was used to estimate the reliability of each measure at each age. The Spearman Brown formula was used to estimate the number of replications that would be required for the average of the measurements to have a reliability of 0.7 (aim 1). Pearson correlations assessed the year-to-year tracking between sleep measures of interest (aim 2).

To assess the stability of sleep (aim 3), a mixed model was fitted to the average of sleep duration for each age. The model included fixed effects for sex, age and age squared, and random effects for participant, age and age squared. The mixed model accounted for the correlations among the repeated measures, and age and age squared terms allowed for a nonlinear association.[13] The residuals or the difference between average sleep predicted from the fixed part of the model and the observed average sleep at each age were used to define 4 groups. The groups were based on the within-person average size of the residuals in the first place. In 1 group, the high average sleep group, the averages of the residuals were greater than 30 minutes, whereas in the low average sleep group they were less than 30 minutes. The remaining group was divided into 2 on the basis of the within-person SD of the residuals, with the SDs in the consistent medium sleep group being less than 15 minutes. Differences in sleep stability groups were examined using one-way ANOVA or Fisher exact test as appropriate, with Bonferroni post-hoc tests where appropriate (aim 4).

Results

Table I (available at www.jpeds.com) presents the number of children who were included in analyses at each age based on having complete parental sleep reports (bed time and wake time). In the main analysis, these were well completed with 80%-88% of eligible children included in analyses at each