Consistent use of bedtime parenting strategies mediates the effects of sleep education on child sleep: secondary findings from an early-life randomized controlled trial ☆

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ABSTRACT

Objective: Using data from a randomized controlled trial, this study investigated whether parent's consistent use of recommended bedtime strategies with infants was a mediating mechanism for improved child sleep.

Methods: Expectant mothers were allocated to 4 groups: usual care (Control); additional support regarding Food, (physical) Activity, and Breastfeeding (FAB); advice on infant sleep through 1 group educational session during the antenatal period and 1 home visit when the child was 3 weeks of age (Sleep), or both FAB and Sleep interventions (Combination). An index relating to parent's consistent use of strategies to encourage infant sleep self-settling was developed from data collected when infants were 4 and 6 months of age. Child sleep self-control was measured at 3.5 years of age through a behavior rating scale. Child overnight sleep duration was measured using accelerometers at 1, 2, 3.5, and 5 years of age. Analyses examined whether any association between intervention group and child sleep self-control or sleep duration was mediated by consistent use of bedtime strategies at 4 and 6 months.

Results: Compared to Controls, Sleep group parents had significantly higher odds of using more intervention strategies consistently (1.63; 95% confidence interval [CI] 1.14-2.33), as did Combination group parents (1.45; 95% CI 1.01-2.07). Consistent strategy use was significantly associated with a decrease in child bedtime behavioral difficulties (0.97; 95% CI 0.95-0.98) and increased sleep duration (0.152; SE = 0.017). Sleep group assignment reduced child sleep self-control difficulties and improved sleep duration indirectly via parent's consistent use of bedtime strategies.

Discussion: Consistent use of appropriate bedtime strategies in infancy is an important factor that influences child sleep self-control in later development.

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Introduction

Sleep difficulties, including trouble with sleep initiation and prolonged night-waking, are experienced by 20%-36% of infants and children[1–4] and are among the most common complaints presented to pediatricians.[5] Sleep problems are also associated with a range of difficulties in later development, including anxiety, aggression, and overactivity/impulsivity.[6] Randomized controlled trials (RCTs) have demonstrated that educating or training parents about how to manage infants at bedtime and night-waking with minimal involvement may reduce problematic bedtime behavior and improve sleep,[7–11] presumably because this provides infants with the opportunity to learn to fall asleep on their own.[12,13] Outcome effects have been reported even when the interventions are relatively brief, involving just 2 to 3 consultations.[9]

Despite these promising results, several issues need clarification.[12,14] Few empirical studies have investigated what aspects of these interventions are crucial for infant/child sleep

outcomes.[12] One approach to addressing this is to test potential mediation effects.[15] A possible mediating factor linking sleep education and training interventions to child sleep may be parental consistency in implementing intervention strategies.[16] Research has demonstrated that emphasizing the importance of a regular bedtime routine to parents can have benefits for infant sleep (eg, reduced sleep onset latency) over several weeks.[13] However, it is unclear if the number of different bedtime parenting strategies implemented consistently during early infant development mediates the effects that a parenting-based intervention might have on child sleep self-control at a later age.

Because bedtime parenting behavior is a plausible mediating mechanism between intervention group assignment and child sleep, it is also of interest to examine whether there are factors that moderate the effect of intervention on bedtime parenting behavior. Although not previously examined specifically in relation to bedtime parenting strategies, previous research examining parenting interventions targeting other child behavior problems suggests that potential moderators of an intervention pertain to parent and family characteristics, including maternal depression, socioeconomic status, maternal age, and maternal education.[12,17—21]

We undertook the Prevention of Overweight in Infancy (POI) RCT to determine how a sleep intervention (that educated parents about appropriate ways to manage an infant's sleep with minimal interference) and a food, activity, and breastfeeding intervention affected infant growth, both separately and in combination, compared to only receiving usual care.[22] As part of this RCT, we also collected information on parenting practices and child sleep. Previous results from the POI study have indicated that the sleep intervention had an effect on some (but not all) measures of child sleep and parenting behavior.[22,23]

The aim of the current study was to conduct secondary analyses of data collected during the POI study to investigate bedtime strategy use in relation to child sleep at later ages. It was hypothesized that caregivers assigned to groups that received education on strategies for child sleep would, on average, consistently implement more of these strategies relative to those not assigned to these groups and that this effect would translate to children exhibiting fewer difficulties with sleep self-control (assessed at 3.5 years of age) and having longer overnight sleep duration (assessed with actigraphy when children were 1, 2, 3.5, and 5 years of age). In other words, consistent use of these strategies would at least partially mediate any intervention effects on later sleep. Second, we wished to explore potential moderators of any association between intervention group and consistent use of sleep strategies.

Methods

Participants

Detailed information on the POI study and its primary outcomes have been published elsewhere.[22,24,25] Briefly, this 4-arm RCT examined whether additional education and support on sleep (Sleep group); Food, (physical) Activity, and Breastfeeding, (FAB group); or both (Combination group) affected weight gain from birth to 5 years of age compared to usual care (Control group).[22,24,25] Parents who had booked into the single maternity hospital serving Dunedin, New Zealand, between May 2009 and November 2010 were invited to participate. Participants were excluded before birth if the family lived outside the city, the family was planning to move away from the city in the next 2 years, the mother was booked into the maternity center after 34 weeks' gestation, or the family was unable to communicate in English or Te Reo Māori (language of the indigenous ethnic group of New Zealand). After birth, participants were excluded if infants were delivered before 36.5 weeks' gestation or were

identified as having a congenital abnormality likely to affect feeding or growth. Of 1458 eligible families invited to participate, 847 (58%) agreed, of which 802 met eligibility criteria. Informed written consent was obtained from parents before participation at each assessment period. Ethical approval to conduct this study was granted by the New Zealand Lower South Regional Ethics Committee (Project Key: LRS/08/12/063).

Intervention groups

Parents assigned to the Sleep intervention had 2 contacts with a trained nurse: a group education session during the antenatal period and a 1-hour home visit when the infant was around 3 weeks of age. Information was provided on normal sleep and evidence-based strategies that encourage children to develop healthy sleep habits. An emphasis was placed upon (a) putting the infant down to sleep when tired but still awake, (b) allowing the infant to fall asleep on their own (eg, without touching or feeding them), (c) providing a consistent environment for the infant to sleep in, and (d) minimizing parents sleeping with their infants on the same surface (see Appendix 1-2 of[23] for details of sleep intervention). Parents assigned to the FAB group received 3 contacts at which they were provided with education and support on breast feeding (antenatal, 1 week, and 4 months postpartum) by an international board-certified lactation consultant. At 3 months postpartum, families attended a session delivered by an established sporting organization designed to encourage physical activity from an early age. The combination group received the same education and support provided to both the Sleep and FAB groups. All groups, including the control group, received standard maternity and Well Child care that is provided within New Zealand.

Measures

Bedtime parenting strategies

An index measuring the number of bedtime strategies consistently implemented by parents (hereafter referred to as *bedtime parenting strategies*) was derived from mothers' responses to 4 questionnaire items (3 rated on a 7-point scale with 1 = "Never" and 7 = "Always"; 1 rated on a 6-point scale with 1 = "Usual sleeping place" and 6 = "Never") administered at *both* the 4- and 6-month assessment periods (see Table A1). To reflect the consistency with which parents used a particular strategy, responses for each particular item across the 4- and 6-month assessment periods were dichotomized based on the following a priori criteria: a practice was coded as "consistently used" if mothers endorsed one of the two highest ratings for that practice at *both* time points. Otherwise, a practice was coded as "not consistently used." For example, if for the item "frequency baby is put to bed awake when tired" was endorsed with a rating of 7 at 4 months but 5 at 6 months, these responses were coded as not consistently used at both ages. If, on the other hand, it was rated 7 at one time point and 6 at the other, the practice was coded as consistently used at both ages. This approach was used in favor of means (or medians) which would not necessarily capture consistent use. Thus, for each child, there were 4 dichotomous variables pertaining to the 4 questionnaire items indicating whether or not their parent consistently implemented a particular bedtime parenting strategy across both the 4- and 6-month assessments. Given confirmatory factor analysis (CFA) indicated that items coded in this way represented a unidimensional construct and that the internal reliability coefficient of these 4 items was 0.72 (details in Appendix A), these items were summed together into a single index which was investigated as a potential mediator between the intervention and sleep self-control. A score on this index could be 1 of 5 values (0, 1, 2, 3, or 4). A 1-unit increase on this scale reflects a parent using 1 more of the 4 bedtime strategies consistently across both

the 4- and 6-month assessment periods. Hence, this index reflects the degree of later adherence with the intervention recommendations for bedtime parenting strategies.

Child sleep self-control

Child sleep self-control was assessed at the 3.5-year assessment using maternal ratings of 7 items pertaining to the extent a child has difficulty with bedtime resistance, sleep initiation, and nighttime wakings. As with the items relating to Bedtime Parenting Strategies, these items were also created specifically for the POI study. Each item (Table B1) was rated by parents on a 6-point scale (1 = "Never," 2 = "Occasionally," 3 = "1-2 times per week," 4= "3-4 times per week," 5 = "5-6 times per week," 6 = "every night"). CFA indicated that items reflected a unidimensional construct, and the internal reliability coefficient for a scale created from the sum of all 7 items was 0.73 (details in Appendix B). The maximum possible score on this index was 42 and the minimum possible score was 7, with higher scores reflecting relatively greater difficulty with child sleep self-control.

Overnight sleep duration

Children's overnight sleep duration was measured using accelerometers (Actical, Mini-Mitter, Bend, OR) worn over their right hip (which gives similar sleep time estimates to those obtained when accelerometers are worn on a wrist[26]) for 5-7 nights during assessment periods at 1, 2, 3.5, and 5 years of age. Data were recorded in 15-second epochs. These data were processed using an automated MATLAB (MathWorks, Natick, MA) script that implemented a count-scaled algorithm denoting sleep and wake states to epochs using an empirically derived threshold and weighting formula.[27] Descriptions of this algorithm's computational details, rationale, and validity have been published elsewhere.[27,28] Briefly, this algorithm performs a search method on scaled activity count data specific to each assessment period for each individual. After being initiated using prespecified "time flags" (approximately half an hour before average bedtime and wake times at each assessment period as determined for our data using sleep diaries[27]), the program searches 3 hours forward and 3 hours backward from the selected time flag to detect sleep onset and offset for each participant file. If sleep onset or offset is not identified within these time frames, the file is reprocessed using observer-identified time flags. Waking is defined as the last of 15 continuous minutes of sleep followed by 5 minutes of awake and sleep as the start of 15 continuous minutes of sleep preceded by 5 minutes of awake. The scoring definition for wake after sleep onset was 5 consecutive minutes scored as awake during a sleep interval. Previous research examining the validity of this method against polysomnography found that it achieved 86% overall agreement for epoch-to-epoch sleep/wake time estimates for both children (unpublished pilot data from a sample of 25 participants) and infants,[28] comparable (if not slightly higher) to agreement obtained by other often-implemented algorithms.[28] *Overnight sleep duration* was defined as the time between sleep onset and offset, minus awakenings. Sleep duration calculated in this way has been shown to have good agreement with parental diary data for these young age groups.[28]

Maternal depression at baseline

Maternal depression symptoms were measured at baseline, before group assignment, using the Edinburgh Postnatal Depression Scale (EPDS). The EPDS is a reliable and well-validated scale for measuring maternal depression both pre- and postpartum.[29,30] It consists of 10 items (eg, "I have been so unhappy that I have been crying") that are self-rated on a 4-point scale ("0," "1," "2," or "3"). The sum of these items yields a total score with a possible maximum of 30 and possible

minimum of 0, with higher scores reflecting greater severity of reported depression symptoms.

Baseline demographics

Demographic information was obtained at baseline (late pregnancy) from questionnaires and hospital records and included maternal age, maternal education, maternal parity, maternal and child ethnicity, household deprivation level (derived from household address and calculated with reference to the New Zealand Deprivation Index,[31] which assigns geographical meshblock regions a decile-based score ranging from 1, indicating low deprivation, to 10, highest deprivation), and child sex.

Statistical methods

For each intervention group, we present descriptive statistics for baseline demographic variables, the bedtime parenting strategies index (percentages per integer level), child sleep self-control difficulties, and child sleep duration. Questionnaire data relevant to the current study were obtained from 86.1%-89.6% of participants at the 4- and 6-month assessments and 75.0% at the 3.5-year assessment. Accelerometry data for sleep duration were available for 71.6% of participants for at least 1 assessment period.

The main statistical analyses were conducted with regression and structural equation models using the *stats* (version 3.4.2),[32] *ordinal* (version 2018.4-19),[33] and *lavaan* (version 0.6-2.1254)[34] packages within the *R* (version 3.4.2) statistical software environment.[32] Ordinal logistic regression was used to model Bedtime Parenting Strategies. Predictors for this model were intervention group, baseline maternal depression, maternal age, child sex, maternal education, household deprivation level, and maternal parity (the last 2 being RCT stratification variables). A general linear model was used to model child sleep self-control following log-transformation to improve model residual normality. As well as including the same predictors as the first model, this model also included Bedtime Parenting Strategies. Overnight sleep duration was modeled using a trait-state latent variable model. This model partials variance in overnight sleep duration into a factor pertaining to individual differences that are stable over every assessment period (trait factor) and factors pertaining to individual differences specific to each assessment period (state factors), above and beyond trait level differences. In all analyses, 2-sided $P < .05$ was considered statistically significant. In the case of multicategorical variables, pairwise comparisons were only performed following a significant Wald test.

Mediation effects were estimated using a *product-of-coefficients* approach following procedures outlined by Mackinnon.[35] As such, indirect effects were only examined if there was evidence for (*a*) an effect of intervention group on Bedtime Parenting Strategies *and* (*b*) an effect of Bedtime Parenting Strategies on child Sleep self-control at 3.5 years or overnight sleep duration. Based on a standard definition,[36] we report if mediation effects are *complete* (in instances when effects for intervention group on child sleep measures are nonsignificant [with $P \geq .05$] after adjusting for Bedtime Parenting Strategies) or *partial* (in instances when effects for intervention group on child sleep measures are significant at the $P < .05$ level after adjusting for Bedtime Parenting Strategies), and we quantify the mediation effect to assist with interpretation. Moderation effects on Bedtime Parenting Strategies were examined in turn by including the relevant interaction terms in the ordinal logistic model.

To address noninformative missing data, all main analyses using ordinal logistic regression or general linear models were conducted using multiple imputation (for further details, see online supplement section). Latent variable models were estimated using full information maximum likelihood with robust maximum likelihood.

Results

Sample descriptives

Descriptive statistics by intervention group are presented in Table 1. Compared to New Zealand national estimates, a greater percentage of the study sample was of NZ European ethnicity, mothers were slightly older, and fewer families came from households with high levels of deprivation.[37] A higher percentage of parents in the Sleep and Combination groups used all 4 strategies consistently (13.9% and 16.6%, respectively) compared to those in the control and FAB groups (9.0% and 9.5%, respectively).

Effect of intervention on Bedtime Parenting Strategies

Significant predictors of Bedtime Parenting Strategies (presented in Table 2) were intervention group, maternal depression, and maternal age. Compared to the control group, the odds of using more sleep strategies were 63% greater for parents assigned to the Sleep group (cumulative odds ratio [OR] = 1.63, 95% confidence interval [CI] 1.14-2.33, $P < .01$) and 45% higher for those assigned to the Combination (cumulative OR = 1.45, 95% CI 1.01-2.07, $P < .05$). Parents assigned to the FAB group did not significantly differ from the Control group in terms of number of consistently implemented Bedtime Parenting Strategies. Each 5-year decrease in maternal age was associated with a 15% increase in the odds of using more strategies, whereas a 1-unit increase in maternal depression was associated with a 4% reduction in the odds of using more Bedtime Parenting Strategies.

Predictors of child sleep self-control difficulties

As presented in Table 3, significant predictors of child sleep self-control were the number of consistently implemented

Table 2
Testing predictors of Bedtime Parenting Strategies: cumulative ORs and P value statistics for the ordinal logistic regression model

Model parameters	P value[a]	Cumulative OR (95% CI)[b]
Intervention group (Control group is referent)	**0.010**	
FAB		1.01 (0.71-1.44)
Sleep		**1.63 (1.14-2.33)**[**]
Combination		**1.45 (1.01-2.07)**[*]
EPDS (per point)	**0.037**	**0.96 (0.93-1.00)**[*]
Maternal education (nonuniversity is referent)		
University	0.808	0.99 (0.74-1.31)
Maternal age (per 5 y)	**0.016**	**0.85 (0.74-0.97)**[*]
Child Sex (female is referent)		
Male	0.854	0.99 (0.77-1.28)
Deprivation Index (score range 1-3 is referent)	0.074	
4-7		0.72 (0.54-0.96)
8-10		0.90 (0.62-1.29)
Maternal parity (no previous children is referent)		
Had previous children	0.686	0.96 (0.80-1.16)

[a] P values are from analysis of deviance test. These values indicate if a predictor has a significant effect upon the outcome variable (after controlling for all other predictor effects entered in the model).

[b] Cumulative OR is the cumulative odds ratio and is interpreted as the relative odds of scoring higher on the index of Bedtime Parenting Strategies associated with a particular outcome. All numbers are reported rounded to 2 decimal places.

[*] Indicates statistically significant difference from reference group or slope at $P < .05$.

[**] Indicates statistically significant difference from reference group or slope at $P < .01$.

Bedtime Parenting Strategies ($P < .001$), intervention group ($P = .036$), and maternal depression symptom severity ($P = .037$). A 1-unit increase in Bedtime Parenting Strategies predicted a significant reduction in child sleep self-control difficulties of approximately 3%. Compared to the control group, children of parents

Table 1
Descriptive statistics by group for selected baseline characteristics

Baseline characteristic	Control n = 209	FAB n = 205	Sleep n = 192	Combination n = 196
Child sex (% male)	46.9%	52.2%	57.3%	49.0%
Child ethnicity				
European	77.5%	78.4%	76.6%	79.6%
Māori	11.5%	9.3%	7.3%	9.2%
Pacific	0.5%	2.5%	4.7%	2.6%
Asian	4.8%	5.9%	7.8%	5.6%
MELAA	1.9%	1.0%	1.0%	1.5%
Other	3.8%	2.9%	2.6%	1.5%
Maternal EPDS; median (IQR)	7.0 (5.5)	7.0 (7.0)	7.0 (6.0)	6.0 (6.0)
Maternal education (% university degree or higher)	59.2%	66.3%	58.3%	59.5%
Maternal age in years; mean (SD)	31.5 (5.0)	32.1 (5.3)	31.6(5.2)	31.0 (5.4)
Maternal parity (% with no previous children)	47.4%	46.8%	46.9%	49.5%
Household deprivation level				
1-3 (low)	36%	36.5%	33.9%	34.7%
4-7 (medium)	45.1%	42.4%	43.8%	45.1%
8-10 (high)	18.9%	23.1%	22.3%	20.2%
Bedtime Parenting Strategies (% parents who consistently implemented 0, 1, 2, 3, or 4 strategies)				
0	17.5%	23.1%	16.6%	21.7%
1	27.7%	24.8%	15.2%	14.9%
2	21.5%	15.4%	19.2%	19.2%
3	24.3%	27.2%	35.1%	28.5%
4	9.0%	9.5%	13.9%	16.6%
Sleep self-control,[a] mean (SD)[b]	12.9 (1.4)	12.9 (1.3)	12.1 (1.3)	12.2 (1.3)
Overnight sleep duration (h), mean (SD)				
1 y	10.33 (1.12)	10.46 (1.06)	10.49 (0.78)	10.27 (0.97)
2 y	10.32 (0.96)	10.46 (0.85)	10.43 (0.85)	10.18 (0.19)
3.5 y	10.55 (0.71)	10.59 (0.82)	10.67 (0.83)	10.61 (0.63)
5 y	10.55 (0.68)	10.50 (0.67)	10.51 (0.69)	10.54 (0.71)

Data are presented as percentages for categorical variables, means, and standard deviations (SD) for normally distributed continuous variables, and medians and interquartile range (IQR) for non-normally distributed continuous variables. MELAA, Middle Eastern, Latin American, or African; EPDS, to the Edinburgh Postnatal Depression Scale (0-30, higher score reflects greater symptom severity).

[a] Higher indicates relatively greater difficulties with Sleep Self-Control.

[b] Descriptive statistics are for the geometric mean and SD of Sleep Self-Control.

Table 3
Testing predictors of child sleep self-control: effect estimates and *P* value statistics for general linear regression model

Model parameter	*P* value[a]	Ratio of geometric means (95% CI)[b]
Bedtime Parenting Strategies	**<.001**	**0.97 (0.95-0.98)**[***]
Intervention group (control group is referent)	**.036**	
FAB		1.00 (0.95-1.06)
Sleep		**0.94 (0.89-1.00)**[*,**]
Combination		0.95 (0.90-1.00)
EPDS (per point)	**.037**	**1.01 (1.00-1.01)**[*]
Maternal education (nonuniversity is referent)		
University	.395	1.02 (0.97-1.05)
Maternal age (per 5 y)	.796	1.00 (0.98-1.03)
Child sex (female is referent)		
Male	.776	1.00 (0.96-1.03)
Deprivation index (score range 1-3 is referent)	.828	
4-7		0.99 (0.95-1.03)
8-10		0.98 (0.93-1.04)
Maternal parity (no previous children is referent)		
Had previous children	.566	0.99 (0.96-1.02)

[a] *P* values are from Wald test. These values indicate if a predictor has a significant effect upon the log-transformed measure of child sleep self-control (after controlling for all other predictor effects entered in the model).
[b] Ratio of geometric means is the exponential of the general linear model estimate for the log-transformed measure of child sleep self-control. All numbers are reported rounded to 2 decimal places.
[*] Indicates statistically significant difference from reference group or slope at $P < .05$.
[**] Indicates statistically significant difference from reference group or slope at $P < .01$.
[***] Indicates statistically significant difference from reference group or slope at $P < .001$.

assigned to the Sleep group, on average, reported significantly lower (by approximately 6%) difficulties with sleep self-control. In contrast, children of parents assigned to either the Combination or FAB groups did not differ significantly from the Control group on sleep self-control. For maternal depression, a 1-unit increase on the EPDS score predicted a small but significant 1% increase in child sleep self-control difficulties.

Because the regression models indicated that (*a*) there was a significant effect for parents assigned to the Sleep and Combo groups to consistently use more Bedtime Parenting Strategies compared to parents of the control group and (*b*) Bedtime Parenting Strategies predicted a relative decline in the severity of child sleep self-control difficulties, we examined if Bedtime Parenting Strategies mediated effects of sleep intervention group on child sleep self-control. For the Sleep group, there was a statistically significant effect indicating *partial* mediation ($\beta = -0.017$, 95% CI -0.032 to -0.002, $P = .023$); assigning parents to receive the sleep education intervention reduced children's difficulties with sleep self-control at 3.5 years in part because of effects on the parenting behaviors accounted for by the Bedtime Parenting Strategies variable. For the Combination group, there was a statistically significant effect indicating *complete* mediation ($\beta = -0.013$, 95% CI -0.023 to -0.002, $P = .017$); assigning parents to receive the sleep education intervention was not associated with children's difficulties with sleep self-control at 3.5 years after adjusting for the effects on the parenting behaviors accounted for by the Bedtime Parenting Strategies variable. These effects are illustrated in Fig. 1A and B, respectively.
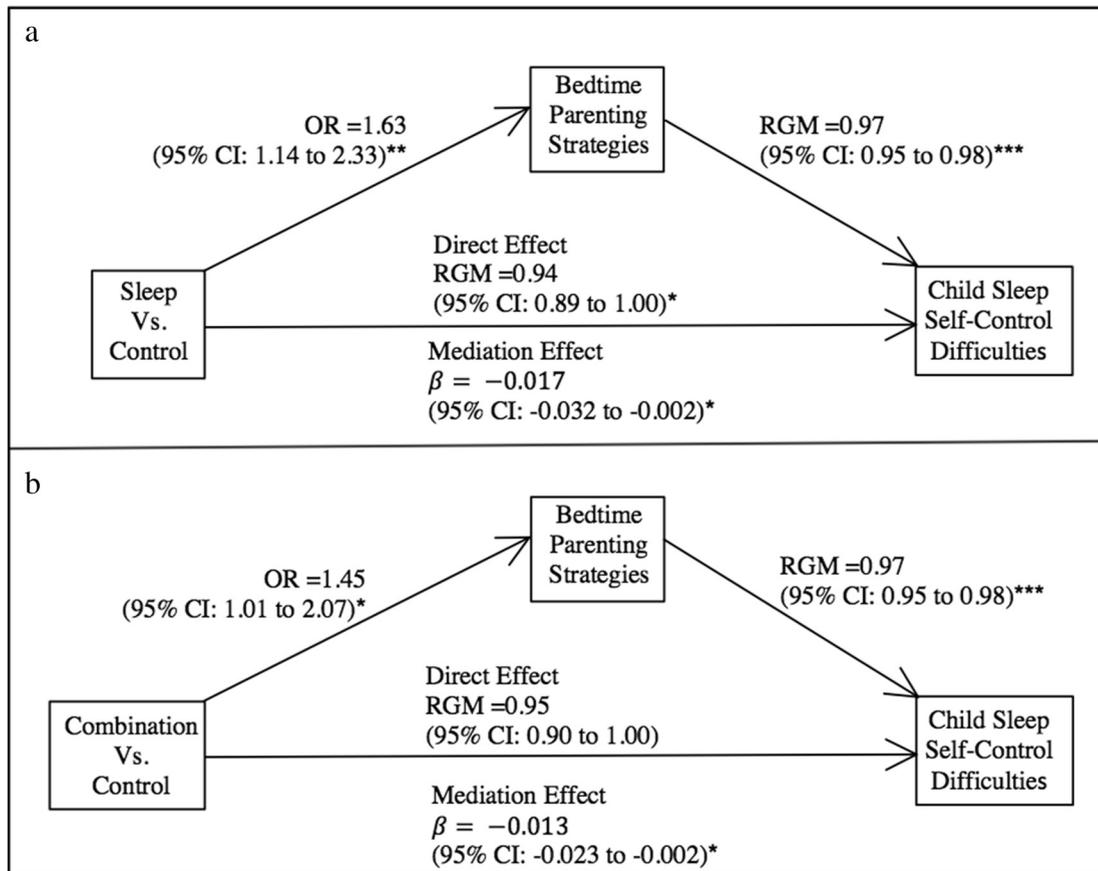

Fig. 1. Path diagrams illustrating mediation effects of Bedtime Parenting Strategies. OR = odds ratio, and is the exponential of an ordinal logistic regression estimate (presented in Table 2). RGM = ratio of geometric means, and is the exponential of linear regression estimate of a log-transformed dependent variable (presented in Table 3). β = the mediation effect computed using the *product-of-coefficients* method from nonexponentiated estimates from ordinal logistic and linear regression models. * Indicates statistically significant difference from reference group at $P < .05$. ** Indicates statistically significant difference from reference group at $P < .01$. *** Indicates statistically significant difference from reference group at $P < .001$.

Besides intervention group, it is notable that consistent use of Bedtime Parenting Strategies was also predicted by maternal depression and age. Thus, it is plausible that either of these 2 variables may also influence child sleep self-control via effects on Bedtime Parenting Strategies. Although the mediation effect for maternal age on child sleep self-control via Bedtime Parenting Strategies was significant ($\beta = 0.0011$, 95% CI 0.0001-0.002, $P = .037$), the mediation effect of maternal depression symptom was not ($\beta = 0.0012$, 95% CI -0.0001 to 0.003, $P = .06$).

Predictors of overnight sleep duration

Preliminary latent variable models did not indicate any significant weak or strong effects for the longitudinal measurement invariance of overnight sleep duration (Appendix C for details), satisfying the assumption that latent variables of overnight sleep duration represented the same construct on the same scale at all assessment periods. Intraclass correlation coefficients (Shrout and Fleiss version *1,k* [38]) indicated that the degree of consistency for a measure that is a composite of overnight sleep duration at each assessment period was 0.75 when children were 1 year old, 0.77 when 2 years old, 0.69 when 3.5 years old, and 0.68 when 5 years old; these values are generally viewed as being acceptable.[39]

Overnight sleep duration was modeled using a latent trait-state model that represents the total variance in observed overnight sleep duration by a trait factor, reflecting individual differences that are stable over time, and 4 state factors, each reflecting individual differences specific to each assessment period. The trait-state measurement model for overnight sleep duration fitted the data well (mean square error of approximation [RMSEA] = .000, 90% CI .000-.013; standardized root mean square residual [SRMR] = .071, comparative fit index [CFI] = 1.00). A total of 11.8% of the variance in overnight sleep duration was stable over time. The average state coefficient indicates that 23.1% of the true variance in sleep duration was unstable between each assessment period. The remaining 65.1% of variance in sleep duration variance not accounted for by the latent factors is attributed to both systematic effects unaccounted for by the latent factors and measurement error.[40]

The latent trait-state model was expanded to a path analysis model (RMSEA = .007, 90%CI .000-.015; SRMR = .057, CFI = 1.00) that included estimation of regression coefficients (presented in Table 4 and illustrated in Fig. 2) for predictors of trait and state sleep duration as well as predictors of Bedtime Parenting Strategies. Significant predictors of Bedtime Parenting Strategies were intervention group ($P = .022$), maternal depression ($P = .030$), and maternal age ($P = .029$). Compared to the control group, parents assigned to the Sleep intervention group on average used 0.38 ($P < .01$) more bedtime strategies consistently. For maternal depression, each point increase was on average associated with using 0.026 fewer Bedtime Parenting Strategies. A 1-year increase in maternal age was associated with a 0.023 decrease in Bedtime Parenting Strategies.

With regard to overnight sleep duration, most significant predictors were associated with the trait level factor representing individual differences in sleep duration that are stable over time. Notably, a 1-unit increase in the number of Bedtime Parenting Strategies was associated with a 0.152 ($P < .001$) standard deviation increase in trait overnight sleep duration. In addition, significantly shorter trait sleep duration was associated with the child being male (0.268 of a standard deviation shorter, $P = .008$) or household deprivation level, with those within the highest deprivation level range being 0.433 standard deviation shorter relative to the lowest deprivation level range ($P < .01$). As seen in Table 4, the only significant predictor of overnight sleep duration at the state level (ie, individual differences in overnight sleep duration specific to each assessment occasion) was maternal parity; having a previous child was associated with longer sleep duration at 2 years.

Testing mediation effects for the path analysis model indicated that Bedtime Parenting Strategies did appear to mediate the effect of Sleep group assignment on trait sleep duration ($\beta = 0.024$, 95% CI 0.002-0.046, $P = .035$). However, there was a lack of evidence that Bedtime Parenting Strategies mediated the effects of maternal age ($\beta = -0.001$, 95% CI -0.003 to 0.001, $P = .059$) or maternal depression ($\beta = -0.002$, 95% CI -0.004 to 0.0001, $P = .067$) on child trait sleep duration.

Moderation effects for Bedtime Parenting Strategies

Intervention group by moderator interaction effects indicated that the effect of intervention group on the number of Bedtime Parenting Strategies consistently implemented did not depend upon any of the potential preintervention moderators examined, which included severity of maternal depression symptoms ($P = .198$), level of maternal education ($P = .980$), maternal age ($P = .789$), child's sex ($P = .373$), household deprivation level ($P = .890$), and maternal parity ($P = .537$). Given these nonsignificant results, no further analyses on moderation were performed.

Discussion

We have shown that, compared to usual care, parents assigned to a brief intervention, beginning in the antenatal period, that provided education (up to 3 weeks postnatally) concerning strategies for managing infant bedtime focused on allowing infants the opportunity to self-settle implemented more of these strategies consistently across follow-up assessments (4 and 6 months of age). Moreover, implementing more strategies consistently was associated with children having lower sleep self-control difficulties at 3.5 years of age and longer trait level overnight sleep duration from 1 to 5 years of age. Notably, bedtime parenting strategies consistently implemented acted as a mediating mechanism between the intervention and child sleep self-control at 3.5 years, or child trait sleep duration from 1 to 5 years of age. Taken together, these results suggest that assigning parents to a sleep intervention indirectly improves child sleep via affecting the number of bedtime parenting strategies implemented consistently.

This study builds upon previous RCTs examining effects of parent education on child sleep.[41,42] By collecting data at multiple time points, this study demonstrated that a brief educational intervention was able to affect the number of infant bedtime strategies *consistently* implemented by parents when infants were 4-6 months of age. Although previous studies have examined if parent education or training interventions have an effect on parents' implementation of bedtime strategies,[43] to the best of our knowledge, no previous studies have examined an index that pertains to the number of strategies that parents implement consistently over more than 1 time point. Examining such a measure of parenting is important given that consistency in parenting is emphasized in clinical guidelines for the behavioral management of children's difficulties with self-directed settling to sleep.[16]

The study also afforded the possibility of testing mediation effects in the context of child development up to 5 years of age. Despite previous RCTs measuring both parenting behavior and child sleep outcomes,[8,9,13] none have examined how parenting behavior might act as a mediating mechanism linking the provision of an intervention to measures of child sleep. For the present study, results indicated that a parenting-based intervention indirectly affected child sleep via the number of strategies that parents consistently implemented. Strengthening plausibility of this interpretation, findings were consistent in that bedtime parenting strategy use mediated sleep intervention effects upon both parent reported child sleep behavior and child sleep duration measured using accelerometry.

Table 4
Regression coefficients for path model predicting child sleep duration

Predictors	Outcome variables											
	Bedtime Parenting Practices		Trait sleep duration		Sleep duration at 1 y		Sleep duration at 2 y		Sleep duration at 3.5 y		Sleep duration at 5 y	
	P value	β (95% CI)	P value	β[a] (95% CI)	P value	β[a] (95% CI)	P value	β[a] (95% CI)	P value	β[a] (95% CI)	P value	β[a] (95% CI)
Bedtime Parenting Strategies	—	—	<.001	**0.152 (0.118-0.185)**	.142	0.053 (−0.006 to 0.112)	.326	0.042 (−0.023 to 0.107)	.764	−0.012 (−0.063 to 0.039)	.801	−0.011 (−0.056 to 0.034)
Intervention group (control group is referent)	**.022**		.235		.353		.092		.397		.989	
FAB		0.011 (−0.244 to 0.266)		0.173 (0.059-0.287)		0.042 (−0.189 to 0.273)		0.138 (−0.072 to 0.348)		−0.041 (−0.229 to 0.147)		−0.078 (−0.231 to 0.075)
Sleep		**0.383 (0.103-0.663)****		0.207 (0.099-0.315)		0.071 (−0.145 to 0.287)		−0.023 (−0.246 to 0.200)		0.170 (−0.032 to 0.372)		−0.119 (−0.268 to 0.030)
Combination		0.241 (−0.039 to 0.521)		−0.128 (−0.246 to −0.010)		−0.075 (−0.302 to 0.152)		−0.194 (−0.435 to 0.047)		0.186 (0.025-0.347)		0.072 (−0.087 to 0.231)
EPDS (per point)	**.030**	**−0.026 (−0.050 to −0.003)***	.934	0.001 (−0.009 to 0.011)	.374	−0.010 (−0.028 to 0.008)	.077	0.023 (0.003-0.043)	.452	−0.010 (−0.026 to 0.006)	.713	−0.005 (−0.019 to 0.009)
Maternal education (nonuniversity is referent)	.998	0.000 (−0.222 to 0.222)	.214	0.138 (0.050-0.226)	.760	−0.032 (−0.199 to 0.1346)	.849	−0.023 (−0.201 to 0.155)	.767	0.033 (−0.106 to 0.172)	.218	0.144 (−0.011 to 0.269)
Maternal age (per year)	**.029**	**−0.023 (−0.045 to −0.001)***	.537	−0.008 (−0.018 to 0.002)	.241	0.012 (−0.006 to 0.030)	.738	0.004 (−0.014 to 0.022)	.275	−0.013 (−0.027 to 0.007)	.215	−0.015 (−0.029 to −0.001)
Child sex (female is referent)	.894	0.014 (−0.188 to 0.216)	**.008**	**−0.268 (−0.348 to −0.188)****	.271	−0.101 (−0.248 to 0.046)	.895	−0.013 (−0.166 to 0.140)	.684	−0.042 (−0.169 to 0.085)	.847	0.019 (−0.089 to 0.127)
Deprivation index (score range 1-3 is referent)	**.031**[b]		**.009**		.075		.298		**.013**[b]		.429	
4-7		−0.316 (−0.541 to −0.091)		−0.053 (−0.184 to 0.078)		−0.244 (−0.413 to −0.075)		0.202 (0.026 to 0.378)		−0.067 (−0.200 to 0.066)	.270	0.124 (0.004-0.244)
8-10		−0.154 (−0.450 to 0.142)		**−0.433 (−0.564 to −0.302)****		−0.128 (−0.346 to 0.090)		0.119 (−0.097 to 0.335)		−0.324 (−0.546 to −0.103)	.591	0.081 (−0.080 to 0.242)
Maternal parity (no previous children is referent)	.344	−0.102 (−0.312 to 0.108)	.082	0.182 (0.098-0.266)	.086	−0.168 (−0.325 to −0.011)	**.025**	**0.254 (0.085 to 0.423)***	.740	0.036 (−0.079 to 0.151)	.959	−0.005 (−0.117 to 0.107)

[a] Indicates partially standardized coefficient and is interpreted as the portion of a standard deviation of change in the latent variable associated with a 1-unit change in the predictor.
[b] Significant effects for omnibus test but not for pairwise group comparisons.
* Indicates statistically significant difference from reference group or slope at $P < .05$.
** Indicates statistically significant difference from reference group or slope at $P < .01$.
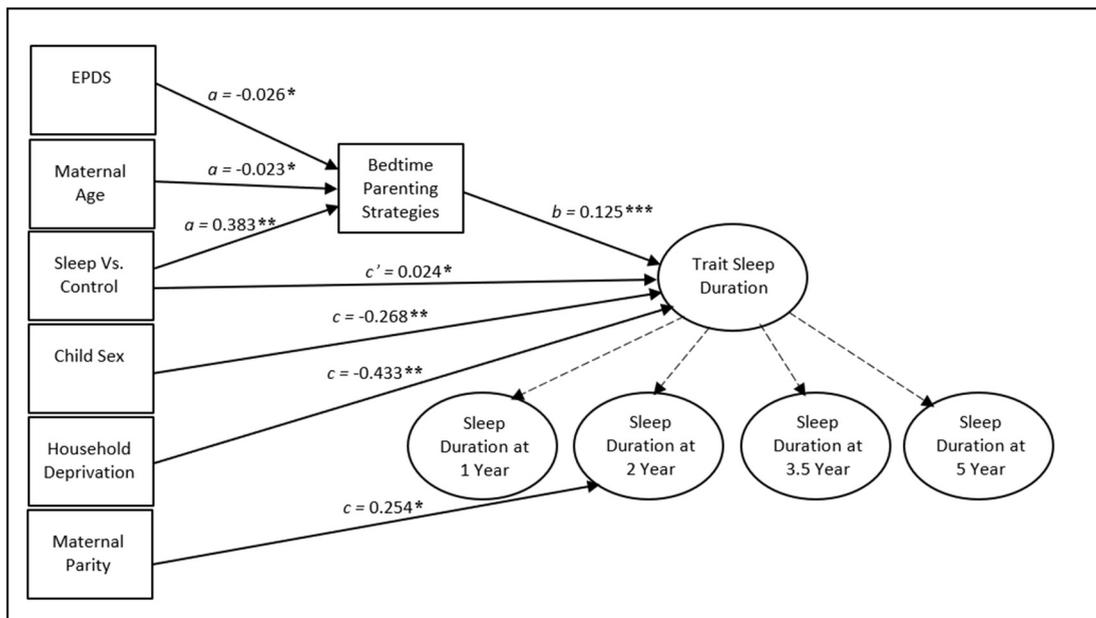
Fig. 2. Mediation model predicting trait and state overnight sleep duration. Circles represent state and trait latent variables for overnight sleep duration (latent variable indicators not depicted). Dashed lines represent latent variable loadings. Boxes represent observed variables. Solid lines and corresponding numbers represent estimated regression coefficients. Only significant effects are depicted. a = regression coefficients predicting the mediator. b = regression coefficient for mediator predicting outcomes. c = regression coefficients for direct effects on outcome. c' = regression coefficients for mediation effects on outcome. * Indicates statistically significant difference from reference group at $P < .05$. ** Indicates statistically significant difference from reference group at $P < .01$. *** Indicates statistically significant difference from reference group at $P < .001$.

Interestingly, some predictors were not consistently associated with sleep self-control and overnight sleep duration. Although maternal depression and age had significant effects on child sleep self-control, they were not significant predictors of child overnight sleep duration. In the case of maternal depression, these differing results may be accounted for by shared method variance deriving from the fact that measures of depression and child sleep self-control were obtained using self-report ratings from the same individual. Another possibility for maternal depression and age predicting child sleep self-control but not overnight sleep duration may relate to sleep self-control and overnight sleep duration, although correlated, also relate to different constructs.[44] The measure of child sleep self-control used in this study consisted of items with similar face validity as those used in other parent-rating measures of child sleep[45,46] and relate to children's ability to settle oneself to sleep. Sleep duration, measured using accelerometry, was modeled as a latent construct representing individual differences in sleep duration at trait and state levels. Although untangling these possibilities are a topic for further research, findings from the current study nevertheless highlight the importance of examining child sleep using both objective and subjective measures.

This study also examined whether the influence of intervention on bedtime parenting strategies was moderated by baseline covariates (including maternal depression, maternal age and education, and level of family deprivation). None of these variables appeared to moderate the Sleep and Combination intervention effects on the number of consistently implemented bedtime parenting strategies. Testing for these moderation effects was important given previous empirical investigations demonstrating that these variables can moderate the effects of other interventions focused on parent education and training.[17–21]

An additional finding of interest concerns the factor structure of sleep duration across 1-5 years of age. In particular, the latent trait-state model indicated that only around 11.8% of total variance in overnight sleep duration was attributable to trait influences stable over time, whereas 23.1% of the total variance was accounted for by unique

effects for each assessment period. Although most sleep studies that use accelerometry examine individual differences in sleep as an average across nights and hence are unable to partition variance in this fashion, this finding is not entirely unprecedented. Notably, a cohort study examining a sample of 194 children assessed at 3, 4, 5, 5.5, 6.5, and 7 years of age also found considerable variation, both across 24-hour cycles within weekly assessment periods and across the years, for accelerometry-derived sleep measures.[47]

Strengths of this study are that it examined how a parenting intervention influences bedtime parenting strategies and child sleep using a relatively large community sample, the longitudinal design, and having both parent report and accelerometer measures of overnight sleep duration. However, the study is not without limitations that should be addressed in further research. One is that accelerometry, although a valid approach for estimating overnight sleep duration, is less suited to estimating other measures of sleep (eg, sleep efficiency) that can be measured using polysomnography.[28,45,48] Another is that, to reduce the potential for overburdening participants, not all measures were administered consistently at all time points, which prevented a more detailed examination of associations between parenting and child sleep both concurrently and prospectively across time. Studies specifically focused on sleep could at least in part resolve this challenge. Also, generalizability of our findings is potentially limited by the overrepresentation of those of European ethnicity and low household deprivation level in our sample compared with national estimates.

Conclusions

This study provides empirical support that parenting interventions targeting child sleep behavior could be improved by emphasizing the importance of implementing evidence-based bedtime strategies consistently. This information is important also for researchers planning sleep interventions to consider building strategies to enhance consistent use of the bedtime practices taught.

Acknowledgments

Appendix A. Psychometric properties of items relating Bedtime Parenting Strategies

We used CFA to evaluate if items relating to consistency of bedtime parenting strategies reflected a single latent factor. The CFA analysis was conducted in R with the Latent Variable Analysis (lavaan) package.[34] Because items were ordinal and dichotomous, the analysis used multivariate probit analysis with diagonally weighted least squares.[49] We follow the common practice of reporting multiple fit indices, namely, the RMSEA, the SRMR, and the CFI.[50] A CFA model is deemed to fit the available data if the RMSEA is below .08, the SRMR is below .08, and the CFI is above .95.

Of the 802 participants in the study, 657 had complete data to compute all 4 dichotomous variables indicating if a bedtime parenting strategy was consistently implemented or not. Fit indices for the single factor CFA using data from these 657 participants suggested that a unidimensional model was an adequate fit of the data (RMSEA = .034, SRMR = .030, CFI = .999). Standardized factor loadings for this model are presented in Table A1.

Table A1

Confirmatory factor analysis statistics for variables indicating consistency of bedtime parenting practices

Item wording	Factor loading	Factor loading standard error	Residual variance
Frequency baby is put to bed awake when tired[a]	.990	.034	.021
Frequency baby falls asleep without holding or touching[a]	.914	.033	.165
How often can baby sleep in usual sleeping place during the day?[a]	.286	.052	.918
What is infant's access to main carer's bed in the last 2 wk?[b]	.558	.050	.689

[a] Rated on a 7-point Likert-type item (1 = "Never", 4 = "Sometimes," 7 = "Always"); parents asked to rate with reference to previous 2 weeks.
[b] Rated on a 6-point Likert-type item (1 = "Usual sleeping place," 2 = "Usually stays night," 3 = "Sometimes stays more than 5 hours," 4 = "Sometimes stays less than 5 hours," 5 = "Always put back to own bed," and 6 = "Never").

Reliability of a scale created by taking the sum of all 4 items was examined following the approach recommended by Kelly and Pornprasertmanit.[51] This approach recommends calculating what has been termed *categorical coefficient* ω. Similar to (the often used) coefficient α, categorical coefficient ω is interpreted as the proportion of true score variance to total variance (sum of error variance and true score variance). Categorical coefficient ω is estimated from a CFA conducted with tetrachoric or polychoric correlations and has several advantages over α. In particular, simulation studies suggest categorical coefficient ω is a more accurate estimate of reliability when scale items are ordinal.[51] For the current study, the categorical ω coefficient estimated for the 4 dichotomous items indicating consistency of bedtime parenting practices was .72.

Appendix B. Psychometric properties of items relating to child sleep self-control

CFA was also used to examine if the 7 items selected to measure child sleep self-control reflected a unidimensional construct. Similar to the previous CFA examining bedtime parenting strategies, the CFA examining child sleep self-control items was also conducted in R with the lavaan package. Of the 802 participants in the study, 602 had data for the 7 items relating to child sleep self-settling. Fit indices for the model with all 7 items indicated that it was an inadequate fit (RMSEA = .181, SRMR = .117, CFI = .877). Examination of modification indices indicated that model fit could be improved by allowing for residual correlation between the *Upset* and *Resist* items. Fit indices for a second CFA that allowed for this residual correlation to be freely estimated suggested an improved but still inadequate fit (RMSEA = .135, SRMR = .100, CFI = .936). Examination of modification indices for this second model indicated that model fit could be improved by allowing for residual correlations between the items *Own Bed* and *All Night*. A third CFA that allowed for residual correlation between *Own Bed* and *All Night* to be freely estimated showed an adequate fit across all fit indices (RMSEA = .063, SRMR = .053 CFI = .987). The item factor loadings, standard error, and residual variances of this model are presented in Table B1. Given the indication of correlated residual errors, reliability was estimated using the ω coefficient.[52] The ω coefficient for all 7 items was .73. These results suggest that a composite scale of all 7 items represents a single construct, albeit with some pairs of items more closely associated with each other than with other items.

Table B1

Confirmatory factor analysis statistics for single factor model of 7 items indicating child sleep self-control

Item wording	Factor loading	Factor loading standard error	Residual variance
Does your child fall asleep in their own bed each night?[a]	.175	.062	.969
Does your child sleep in their own bed all night?[a]	.246	.054	.940
Does your child appear tired during the day (other than at their usual nap time)?	.194	.046	.962
Do you feel your child has difficulty falling asleep?	.798	.028	.363
Do you feel the time it takes for your child to fall asleep is a problem for you?	.909	.025	.167
How often does your child resist or refuse bedtime (ie, cries, screams, makes excuses)?	.574	.035	.671
How often is your child upset about bedtime?	.556	.036	.691

CFA allowed for item residual covariance to be freely estimated for the item pairs *Resist* and *Upset* (.389), and *Own bed* and *All night* (.460).
All items were rated on a 6-point scale (1 = "Never," 2 = "Occasionally," 3 = "1-2 times per week," 4= "3-4 times per week," 5 = "5-6 times per week," and 6 = "every night"); parents asked to rate with reference to previous 2 weeks.
[a] Indicates item was reverse scored.

Appendix C. Details for latent variable measurement invariance analysis for child sleep duration

Nested CFAs tested assumptions of longitudinal measurement invariance relating to the order of nights that sleep was measured using actigraphy. The first, *configurable invariance*, CFA model was

specified reflecting the assumption that the latent factor of sleep duration has the same pattern of observed variable loadings at each assessment period. The second, *weak invariance,* model was specified with an additional constraint reflecting the assumption that observed variable loadings for each of the respective 5 nights are equal at each assessment period (eg, loading for night 1 is equivalent across assessment periods). The third, *strong invariance,* model was specified with the additional constraint that observed variable intercepts are equal at each assessment period (eg, intercept for night 1 is equivalent across assessment periods).

Table C1
Fit statistics for nested confirmatory factor analysis models testing measurement invariance of child sleep duration actigraphy

Model	Model fit statistics				χ^2 likelihood ratio test P values for nested model comparisons
	CFI	SRMR	RMSEA (95% CI)	χ^2 (df)	
Configual	1.00	.052	.000 (.000-.016)	158.68 (164)	—
Weak	1.00	.067	.000 (.000-.015)	169.09 (176)	Weak vs configual: $P = .619$
Strong	1.00	.069	.000 (.000-.014)	178.47 (188)	Strong vs weak: $P = .673$

Fit indices indicated that all models (configurable, weak, and strong invariance) fitted the observed data well. χ^2 likelihood ratio tests comparing the fit of nested models (weak vs configual and strong vs weak) were not significant. Hence, there is no evidence indicating that the order of nights that sleep was measured affected latent variable intercept and loadings for each assessment period differently. Comparisons of additional nested models indicated no significant autoregressive effects between state factors, suggesting that the over-time covariation between state factors did not depend upon the time interval between them.

Appendix D. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleh.2019.03.002.

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