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Abstract

The aim of this study was to examine the reciprocal associations between sleep (duration and quality) and aggressive behavior in toddlers. The sample consisted of 82 children (43 boys and 39 girls) and their parents who completed two assessments, when children were 2 and 3 years old. At both time points, children wore an actigraph for three consecutive days to assess their sleep patterns, and both their parents reported on their child's aggressive behavior. The results indicated negative associations between sleep quality at age 2 and both parents' evaluations of aggressive behavior at age 3; in contrast, the relations between aggression at age 2 and sleep (duration or quality) at age 3 were small and non-significant. In line with studies of older children and adolescents, these results suggest that sleep difficulties are more likely to favor the emergence of aggressive behavior among young children than the converse.

Keywords: child sleep, aggression, actigraphy, toddlers

Sleep and aggressive behavior among toddlers: Investigating directionality of associations

Empirical research suggests that sleep is of paramount importance for children's healthy development (El-Sheikh & Sadeh, 2015). For example, sleep difficulties have been shown to relate to children's school adjustment difficulties (Bates, Viken, Alexander, Beyers, & Stockton, 2002), impaired cognitive development (Bernier, Beauchamp, Bouvette-Turcot, Carlson, & Carrier, 2013), and emotional (Gregory et al., 2005) as well as biological dysregulation (Raïkkönen et al., 2010). Unfortunately, sleep-related problems are frequent: they represent parents' chief developmental complaint (Mindell, Sadeh, Wiegand, How, & Goh, 2010) and the main reason for which they consult health professionals (Bayer, Hiscock, Hampton, & Wake, 2007).

When children do not sleep enough (duration) or do not sleep well (quality), they often show signs of aggression. In fact, aggressive behavior and related externalizing manifestations (irritability, inattention, impulse control deficits) are the most frequently reported symptoms among children with inadequate sleep (Dahl, 1996). Theories have been formulated to explain this relation between sleep and aggressive behavior. For example, Clinkinbeard, Simi, Evans, and Anderson (2010) suggested that poor sleep leads to irritability, which in turn increases the likelihood that a child will respond to aversive situations (e.g., peer provocation) in an aggressive manner. Weissbluth (1989) proposed that a child's lack of sleep is a stressor that increases the secretion of stress hormones such as cortisol (Ward, Gay, Anders, Alkon, Anders, & Lee, 2008), which in turn interferes with behavioral management and regulation. In fact, the prefrontal cortex, largely implicated in behavioral regulation, is particularly sensitive to the homeostatic processes underlying sleep, as shown with both behavioral (for reviews see Dahl, 1996; Harrison & Horne, 1998; Jones & Harrison, 2001) and electrophysiological assessments (Cajochen, Foy,

& Dijk, 1999; Cajochen, Knoblauch, Krauchi, Renz, & Wirz-Justice, 2001). Furthermore, it is

believed that sleep difficulties promote not only the emergence but also the maintenance of

aggressive behavior because fatigue resulting from sleep difficulties may accentuate problematic

behavior that is already present (Ireland & Culpin, 2006).

In line with these suggestions, the link between lower sleep quality, shorter sleep duration

and the presence of aggressive behavior among children is well-established empirically (see

Bagley & El-Sheikh, 2013 for review). A lingering question, however, pertains to the direction

of this association. Indeed, most research (although often using cross-sectional designs) has

considered a potential role of sleep difficulties in the development and maintenance of

aggressive behavior (e.g., Aronen, Paavonen, Fjallberg, Soininen, & Torronen, 2000; Bélanger,

Bernier, Simard, Desrosiers, & Carrier, 2015; El-Sheikh, Bub, Kelly, & Buckhalt, 2013;

Hiscock, Canterford, Ukoumunne, & Wake, 2007; Paavonen, Porkka-Heiskanen, & Lahikainen,

2009). However, the direction of this association has been debated, with some authors proposing

that aggression might perhaps predate and cause sleep difficulties. For instance, Bates, Viken,

Alexander, Beyers, and Stockton (2002) note that children exhibiting more negative behavior,

such as aggression, may show bedtime resistance that could then lead to difficulty falling asleep

and hence to shorter sleep duration. Furthermore, Posthumus, Böcker, Raaijmakers, Van

Engeland and Matthys (2009) observed that children who exhibit more aggressive behavior have

lower skin conductance levels, a marker that is also associated with subjective reports of

sleep/wake problems in school-aged children (El-Sheikh & Arsiwalla, 2010).

Despite this, very few studies to our knowledge have tried to disentangle the direction of

the association between sleep and aggression in samples of typically-developing children.

Gregory and O'Connor (2002) found that parent-reported sleep problems among 4-year-old

children predicted higher parent-reported aggression at age 15, whereas there was no evidence that early aggression predicted subsequent sleep problems. In a study with adolescents using three time points over a 3-year period, Meijer, Reitz, Deković, van den Wittenboer, and Stoel (2010) found evidence for reciprocal associations between higher youth-reported aggressive behavior and lower youth-reported sleep quality and duration, with, however, much stronger predictive relations from sleep to aggression than the converse. In a rare longitudinal study using multiple informants, Kelly and El-Sheikh (2014) observed that reduced sleep duration and worse sleep quality assessed objectively by actigraphy at age 10 predicted an increase in parent-reported externalizing symptoms between ages 10 and 13. The reciprocal relations were less convincing, and found only with subjective measures: externalizing symptoms at age 8 predicted an increase in child-reported sleep problems between ages 8 and 10. Taken together, these three studies mostly support a directional association from sleep to subsequent aggression, while also tentatively suggesting the presence of (likely smaller) effects of aggression on later sleep difficulties. Overall, most published studies with otherwise normally-developing youth have supposed an impact of poor sleep on aggressive behavior, but very few have tried to unravel the direction of this association, and only one has done so while avoiding single-reporter data.

Furthermore, although the links between sleep and aggression appear as early as the preschool years (Bélanger et al., 2015), no study to date has examined reciprocal associations between sleep and aggression in very young children. This may be an important oversight, given that early childhood is a particularly salient period for the display of aggressive behavior (Achenbach & Rescorla, 2000; Côté, Vaillancourt, LeBlanc, Nagin, & Tremblay, 2006; NICHD Early Child Care Research Network, 2004). Several characteristics of early childhood may explain young children's greater propensity to aggression compared to school-age children.

Tremblay (2000) argues that toddlers commonly use physical aggression to settle disputes with peers or to express anger, whereas with the development of emotion regulation skills and the emergence of alternative strategies to deal with conflict, physical aggression becomes relatively rare among school-aged children. Brownell and Hazen (1999) further propose that toddlers may use aggression to initiate playful interaction, a tendency that is gradually replaced by more mature social-communicative skills. In fact, it has been observed that expressive language was negatively associated with the presence of aggressive behavior among toddlers (Dionne, Tremblay, Boivin, Laplante, & Pérusse, 2003). Overall, toddlers are especially prone to aggression and may sometimes resort to aggressive behavior in order to express discomfort due, for instance, to insufficient or poor-quality sleep. Given also that sleep itself changes markedly during toddlerhood (Acebo et al., 2005), the lack of research on sleep and aggression in toddlers represents a significant gap in the developmental literature.

Accordingly, the present study examined reciprocal associations between aggressive behavior and sleep in toddlers, using an objective sleep measure and both parents' reports of children's aggressive behavior. Both sleep and aggression were assessed twice, when children were 2 (T1) and 3 years-old (T2). Given evidence that sleep duration and sleep quality relate differently to child outcomes (e.g., Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010), it is now recommended to consider these two aspects of sleep separately (e.g., Bagley & El-Sheikh, 2013; El-Sheikh & Buckhalt, 2015). Accordingly, we examined indices of both sleep duration and sleep quality (in the current case, efficiency, which represents the percentage of time spent asleep between sleep onset and offset). Based on research with older children and adolescents, it was anticipated that shorter sleep duration and lower sleep quality at T1 would relate positively to aggressive behavior at T2, and to an increase in aggressive behavior between T1 and T2. Given

the mixed evidence for a role of aggression in the development of sleep difficulties presented

above, no predictions were made concerning the converse associations.

Methodology

Participants

Eighty-two children (43 boys and 39 girls) and their parents participated in this study.

Families were recruited from birth lists generated by the Ministry of Health and Social Services.

These lists consisted of families randomly selected by the Ministry among those who had

reported a birth in the previous six months in five neighborhoods (chosen by the research team

for their socio-economic diversity) of the city of Montreal, Canada. Families received a letter

describing the project and were then contacted by phone; 39% of contacted families agreed to

participate. Criteria for participation were full-term pregnancy and the absence of any known

physical or mental disability in the child. Different aspects of parent-child relationships and child

functioning were assessed during home visits that took place when children were 12 and 15

months old. This report focuses on two subsequent visits in which child sleep was assessed; these

visits took place when children were 2 (T1; $M = 24.92$ months, $SD = 0.94$) and 3 years-old (T2;

$M = 36.68$ months, $SD = 0.74$). Yearly family income varied from less $20,000 to more than

$100,000. When their children were born, mothers were aged between 20 and 44 years old ($M =$

31.9, $SD = 4.5$), and fathers between 21 and 47 years old ($M = 33.9$, $SD = 5.0$). Most mothers

(73%) and fathers (67%) had a college-level education. Most children (93%) were White

Caucasian and had older siblings (60%).

Among these 82 families, 70 mothers and 54 fathers provided assessments of child

aggression (described below) at T1, and 62 mothers and 51 fathers did so at T2. At T2, valid

sleep data were available for 63 children. The sources of missing sleep data for the other 19

children were: family left the study because they moved away or no longer had enough time (n =

3); child refused the actigraph (n = 6); actigraph worn but sleep diary not completed by mother

(n = 4); and actigraph worn but data had to be discarded due to the identification of potential

artefacts in the actogram or based on the diary (n = 6). Families with complete data did not differ

from others on socio-demographic or initial aggression or sleep scores (all *p*s > .13). Missing

data were handled with multiple imputation (Jelicic, Phelps, & Lener, 2009). Hence, participants

with missing data were included in analyses (yielding a sample size of 82) by estimating the

missing values through multiple imputation (10 imputations). To reduce bias and maximize the

precision of imputed data, missing values were imputed from all other data available (Enders,

2010). All subsequent analyses were performed on each of the imputed data sets, and results

were then averaged.

Procedure

At both T1 and T2, a research assistant visited the families in their homes and gave the

parents an actigraph (described below), instructing them to place it on the child's ankle or wrist

for three consecutive days during which their child had a fairly usual sleep routine. To cross-

check actigraphy data and identify potential artefacts, mothers were also instructed to complete a

diary of their child's sleep during the same three days. Because most children attended daycare,

it was impossible for mothers to observe napping times on weekdays; therefore, only nighttime

sleep is considered here. Research assistants also left two copies of the aggression subscale of the

Child Behavior Checklist,1.5-5 year version (CBCL; Achenbach & Rescorla, 2000), asking the

mother and father to complete it independently and to return it by mail with provided pre-paid

envelopes. The parents signed a consent form that informed them on the nature and risks of

participating, and they received financial compensation along with a toy for the child after each assessment.

Instruments

Child aggression. At T1 and T2, mothers and fathers were asked to complete the 19-item aggression subscale of the CBCL to evaluate the presence of aggressive behavior in their child (e.g., *defiant, easily frustrated, doesn't seem to feel guilty after misbehaving, punishment doesn't change his/her behavior*). The CBCL is a very well-validated and widely-used questionnaire. As reported by Achenbach and Rescorla (2000), the aggressive behavior subscale shows very good internal consistency ($\alpha = .84$) and test-retest reliability ($r = .87$). In the current study, internal consistency for aggression scores was also high for both mothers, at T1 ($\alpha = .82$) and T2 ($\alpha = .86$), and fathers, at T1 ($\alpha = .83$) and T2 ($\alpha = .83$).

Child sleep. Also at T1 and T2, children wore an actigraph monitor (Mini-Mitter® Actiwatch Actigraph, Respironics) for three consecutive nights to measure their sleep quality and duration. The 72-hour period was chosen with the aim of reducing family burden, and based on prior actigraphy research with same-age children (e.g., Ward, Gay, Anders, Alkon, & Lee, 2008). An actigraph is a small wireless watch-like device that allows for continuous recording of body movements in the natural environment. An accelerometer detects wrist or ankle activity, subsequently transformed into sleep or wake states by standard scoring algorithms. Numerous reports have shown actigraphy to provide valid assessment of sleep in young children (e.g., Acebo et al., 1999; Sung, Adamson, & Horne, 2009). However, actigraphy tends to overestimate night awakenings because of young children's increased motor activity during sleep (Meltzer, Montgomery-Downs, Insana, & Walsh, 2012). Consequently, actigraphic data were analyzed with the manufacturer's high sensitivity algorithm (more appropriate for young children's motor

activity). A secondary "smoothing" algorithm, developed specifically to address the problem of overestimation of night waking, was then applied to the nighttime data. This algorithm allows for excellent concordance with videosomnography (Sitnick, Goodlin-Jones, & Anders, 2008) and home-based polysomnography (PSG; Bélanger, Bernier, Paquet, Simard, & Carrier, 2013).

About two thirds of children wore the actigraph on the ankle. Location of the monitor does not influence data among 2-5 year-old children: this model of actigraph shows good to high agreement (77% to 98% across variables) with PSG for this age group, regardless of location (Bélanger et al., 2013).

Two indicators of sleep, chosen for their demonstrated correspondence to PSG estimates when using this model of actigraph with same-age children (Bélanger et al., 2013), were derived and averaged across the three assessment days: nighttime sleep duration (total number of minutes between sleep onset and offset that were scored as sleep) and sleep efficiency, which is an index of sleep quality (sleep minutes at night / (sleep minutes at night + wake minutes at night) * 100). Estimates of sleep duration and efficiency showed moderate stability from night to night (rs between .47 and .60) and were thus averaged into composite indices of sleep duration at 2 years ($\alpha = .75$) and 3 years ($\alpha = .81$) and sleep efficiency at 2 years ($\alpha = .71$) and 3 years ($\alpha = .73$). On an exploratory basis, we also considered whether bed time and wake time were related to aggression scores. Given that neither was significantly associated with child aggression at either 2 or 3 years of age, as reported by mothers or fathers (p values ranging from .12 to .66), these two variables were not considered further.

Analytic strategy

After examining descriptive statistics, we investigated the extent to which sleep and aggression scores were related to potentially confounding variables (to select covariates). With a

descriptive purpose, we then examined stability in sleep and aggression scores between T1 and

T2, inter-parental agreement on child aggression, and concurrent associations between sleep and

aggression. The main analyses consisted of two steps. We first ran bivariate correlations between

sleep at T1 and aggression at T2, and conversely, between aggression at T1 and sleep at T2. In a

second step, we used regression analyses to examine whether T1-sleep predicted changes in

aggressive behavior between T1 and T2, and vice-versa.

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Results

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Preliminary analyses

Table 1 presents the descriptive statistics for the main study variables. All variables

presented satisfactory variability, comparable to that observed in previous studies (e.g., Côté et

al., 2006; Goodlin-Jones, Tang, Liu, & Anders, 2009; Ward, Gay, Anders, Alkon, & Lee, 2008).

We next examined whether sleep and aggression scores were related to child age and sex as well

as maternal and paternal age, maternal and paternal education, and family income. Child sex

showed three marginal relations with study variables: girls had longer sleep duration at T1 ($p =$

.054) and greater sleep efficiency at T2 ($p = .053$), whereas boys showed marginally more

aggression, however only as reported by their fathers at T1 ($p = .053$). Children of older mothers

had marginally shorter sleep duration at T1 ($p = .078$). Although these relations were only

marginally significant, we controlled for child sex and maternal age in the main analyses, in

order to run stringent analyses. Paternal and child age, maternal education, paternal education,

and family income were unrelated to aggression or sleep (all ps $\geq .137$) and thus not considered

further.

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<table 1 about here>

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Table 2 presents the bivariate correlations among all sleep and aggression variables. Sleep duration and efficiency were highly correlated at both T1 ($r = .71, p < .001$) and T2 ($r = .58, p < .001$). Maternal and paternal reports of child aggressive behavior were also positively correlated at T1 ($r = .31, p = .009$) and at T2 ($r = .22, p = .038$). With respect to stability between T1 and T2, maternal ($r = .40, p < .001$) and paternal ($r = .49, p < .001$) reports of child aggressive behavior were moderately stable. In contrast, sleep duration ($r = .15, p = .090$) and efficiency ($r = .11, p = .162$) were not stable between the ages of 2 and 3 years. Finally, both parents' reports of child aggression were related to concurrent sleep duration and quality (rs between -.16 and -.25, ps < .08).

<table 2 about here>

Main analyses

Zero-order correlations were computed next to examine the associations between sleep at T1 and parental evaluations of aggressive behavior at T2. These correlations are also presented in Table 2. Results indicated that children with lower sleep efficiency at age 2 showed more aggressive behavior at age 3 as estimated by both their parents ($r = -.30, p = .007$ and $r = -.35, p < .001$ respectively for maternal and paternal reports). Moreover, lower sleep duration at 2 years was associated with more aggressive behavior at 3 years, however, only as estimated by mothers ($r = -.21, p = .049$). The relation to paternal reports was in the same direction but non-significant. We then examined the opposite relation between initial aggression and subsequent sleep. Parental evaluations of child aggression at T1 were unrelated to sleep efficiency at T2, for mothers ($r = -.05, p = .751$) and fathers ($r = .08, p = .622$). Likewise, sleep duration at T2 was unrelated to mothers' ($r = -.07, p = .820$) or fathers' ($r = .02, p = .901$) earlier reports of child aggressive behavior.

These results are consistent with the notion that sleep difficulties are predictive of subsequent aggressive behavior more so than the converse. To further investigate this, we used hierarchical regressions to examine whether sleep could predict changes in aggressive behavior, and vice-versa. Given the strong associations noted above between sleep duration and efficiency, they were considered in separate models.

<table 3 about here>

Table 3 illustrates that after controlling for child sex, maternal age, and age-2 levels of aggression, age-2 sleep duration (β = -.22, p = .059) and efficiency (β = -.28, p = .051) marginally predicted less aggression at 3 years as evaluated by fathers. Although estimates were in the same direction with maternal reports of children's aggressive behavior, results were not significant (sleep duration: β = -.17, p = .098; sleep efficiency: β = -.19, p = .114).

A second series of regression equations was used to investigate the contribution of age-2 aggression to the prediction of changes in sleep between age 2 and age 3 (results not displayed in a table). Results were inconclusive: age-2 aggression, whether evaluated by mothers or fathers, did not predict age-3 sleep above and beyond child sex, maternal age, and initial levels of sleep duration or efficiency (highest β = .08, *ns*).

Discussion

A great deal of research has shown reliable associations between inadequate sleep, for instance short sleep duration and low efficiency, and the presence of aggressive behavior in adolescents and school-age children. These results are often generalized to younger children even though this population is quite different, for instance because the preschool age witnesses pronounced and rapid developments in sleep patterns that stabilize in later years (Iglowstein, Jenni, Molinari, & Largo, 2003) and is marked by the presence of relatively high levels of

aggression that tend to decrease after children enter school (Côté et al., 2006; NICHD Early

Child Care Research Network, 2004). Importantly, the direction of the association between sleep

and aggression is unclear. Most studies assume an effect of poor sleep on aggression, but very

few studies have systematically tackled this question with much-needed longitudinal designs to

strengthen inferences about directionality, or with multiple informants to overcome shared

method variance problems. Aiming to tackle these gaps, this study used a longitudinal design to

examine the bidirectional associations between sleep (evaluated objectively) and parent-reported

aggressive behavior in toddlers.

The findings suggested a relation between lower sleep quality (operationalized here by

sleep efficiency) and subsequent aggressive behavior, with somewhat comparable but weaker

findings with sleep duration. Specifically, results suggested that children with lower sleep quality

at age 2 showed significantly more aggressive behavior as evaluated by both parents at age 3,

despite relatively modest convergence between maternal and paternal reports ($r = .22$, $p = .038$).

Concerning shorter sleep duration at 2 years, it was linked to more aggressive behavior estimated

by mothers but not fathers at age 3 (note however that although it was non-significant, the

relation to father reports was somewhat comparable in size to the relation involving maternal

reports). The fact that results appeared to be slightly more reliable with sleep efficiency

tentatively suggests that sleep quality may be more robustly associated with subsequent

aggressive behavior among toddlers than sleep duration. However, studies conducted with

school-aged children have found significant relations between sleep duration, evaluated

objectively, and externalizing behavior problems (Aronen et al., 2000; Kelly & El-Sheikh, 2014).

Developmental considerations might perhaps be at play. There is a great deal of individual

variability in the amount of sleep that younger children need to be rested, with some children

requiring fewer hours of sleep to feel equally rested as other children who sleep more (Jenni, Molinari, Caflisch, & Largo, 2007). Some toddlers may thus exhibit aggressive behavior because their sleep duration, although comparable to that of their peers, is insufficient for their individual needs, which would obscure average associations between sleep duration and aggression. This said, it is important to keep in mind that although results with sleep efficiency appeared to be more reliable, they were not much stronger in magnitude than those involving sleep duration. The estimates pertaining to sleep duration may well have been found statistically significant as well in a better powered study.

Results were less clear when considering the predictive relations between sleep and subsequent increases in aggressive behavior. Poorer sleep quality and reduced sleep duration at age 2 predicted a marginal increase in aggressive behavior between ages 2 and 3, however only as perceived by fathers. Given, though, that father-reported aggression showed substantial stability ($r = .49$, $p < .001$), the fact that both sleep duration and quality at age 2 could predict a marginally significant portion of the variance in age-3 aggression not accounted for by earlier aggression may be non-negligible. Nonetheless, evidence for a predictive role of sleep in increases in aggression was modest, and thus requires further scrutiny with larger samples.

In contrast, very little evidence was found for the reverse association, namely a predictive role of child aggression in subsequent sleep difficulties. Both correlational and regression analyses yielded not only non-significant but in fact near-zero relations between initial aggression and subsequent sleep. This is broadly in line with previous studies with older children and adolescents, which found modest (Meijer et al., 2010), inconsistent (Kelly & El-Sheikh, 2014), or non-significant relations (Gregory & O'Connor, 2002) between early aggression and subsequent sleep, even when assessed by a single reporter (Gregory & O'Connor, 2002; Meijer

et al., 2010). Hence, the current results extend to the preschool period the conclusion proposed

by Bagley and El-Sheikh (2013), namely that the association between poor sleep and the

development of aggressive behavior appears to be more significant than the reverse association.

Certain limitations of this study must be noted. The sample size was relatively modest,

and the related diminished statistical power may be implicated in some of the marginally

significant results that we found (e.g., those involving age-2 sleep and increases in father-

reported aggressive behavior). The sample's composition (mostly college-educated and

Caucasian parents) also suggests that findings may not replicate in samples characterized by

greater economic, biological, or psychosocial risk. Importantly, the longitudinal but correlational

design does not allow for causal inference, and limits this study to the investigation of

associations between sleep and aggression. Another issue is that actigraphy data were available

for three days only. While this is not unusual when working with young children (Gnidovec,

Neubauer, & Zidar, 2002; Harrison, 2004; Sazonov, Sazonova, Schuckers, Neuman, & CHIME

Study Group, 2004; Scher, Hall, Zaidman-Zait, & Weinberg, 2010; So, Buckley, Adamson, &

Horne, 2005; Ward, Gay, Anders, Alkon, & Lee, 2008), it is deemed preferable to use at least

five days (Acebo et al., 1999). Finally, because children attended daycare we did not consider

naps, which might play a protective role against the display of aggressive behavior (Hall, Scher,

Zaidman-Zait, Espezel, Warnock, 2011). Nonetheless, this study is the first, to our knowledge, to

suggest that the relation of sleep to subsequent aggressive behavior in toddlers is more reliable

than the converse relation, and thus adds to the theoretical case for a role of sleep difficulties in

the development of aggression, starting early in life.

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Table 1.

Descriptive statistics for study variables

	Minimum	Maximum	Mean	SD
Sleep variables				
Efficiency T1 (%)	67.03	98.82	89.09	8.65
Duration T1 (minutes)	389.25	666.50	559.72	70.85
Efficiency T2 (%)	70.93	100.00	93.56	6.52
Duration T2 (minutes)	466.00	660.66	549.50	46.62
Aggression variables				
Agg-Mother T1	0.00	17.00	8.03	4.55
Agg-Father T1	0.00	16.00	7.77	4.82
Agg-Mother T2	0.00	19.00	8.23	5.57
Agg-Father T2	0.00	19.00	7.30	4.76

Note. Agg-Mother = mother-reported child aggressive behavior; Agg-Father = father-reported child aggressive behavior. SD =standard deviation.

Table 2.

Bivariate correlations among all sleep and aggression variables

	Agg-Mother T1	Agg-Father T1	Efficiency T1	Duration T1	Agg-Mother T2	Agg-Father T2	Efficiency T2	Duration T2
Agg-Mother T1	---	.31**	-.21*	-.24*	.40***	.21*	-.05	-.07
Agg-Father T1		---	-.20*	-.25*	.17^t	.49***	.08	.02
Efficiency T1			---	.71***	-.30**	-.35***	.11	.20*
Duration T1				---	-.21*	-.15	.08	.15^t
Agg-Mother T2					---	.22*	-.17^t	-.16^t
Agg-Father T2						---	-.22*	-.19^t
Efficiency T2							---	.58***
Duration T2								---

Note. Duration = sleep duration; efficiency = sleep efficiency; Agg-Mother = mother-reported child aggressive behavior; Agg-Father = father-reported child aggressive behavior

^{t} $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

Table 3.

Hierarchical regression analyses predicting change in aggressive behavior between T1 and T2 from sleep at T1

	R^2	ΔR^2	F Change	β
Agg-M T2				
1. Agg-M T1	.16		5.53***	.40***
Child sex				-.06
M age				.05
2. Duration T1	.23	.07	2.68	-.15
Agg-M T2				
1. Agg-M T1	.16		5.53***	.40***
Child sex				-.06
M age				.05
2. Efficiency T1	.20	.04	1.43	-.10
Agg-F T2				
1. Agg-F T1	.24		9.51***	.49***
Child sex				-.03
M age				-.06
2. Duration T1	.32	.09	3.42^t	-.19^t
Agg-F T2				
1. Agg-F T1	.24		9.51***	.49***
Child sex				-.03
M age				-.06
2. Efficiency T1	.33	.09	3.78^t	-.21^t

Note. Duration = sleep duration; efficiency = sleep efficiency; Agg-M = mother-reported child aggressive behavior; M age = maternal age; Agg-F = father-reported child aggressive behavior

$^t p < .10$; *** $p < .001$