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2015

## Relations Between Toddler Sleep Characteristics, Sleep Problems, and Temperament

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Molfese, Victoria J.; Rudasill, Kathleen Moritz; Prokasky, Amanda; Champagne, Carly; Holmes, Molly; Molfese, Dennis L.; and Bates, Jack, "Relations Between Toddler Sleep Characteristics, Sleep Problems, and Temperament" (2015). *Faculty Publications, Department of Child, Youth, and Family Studies*. 121.

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Published in final edited form as:

*Dev Neuropsychol.* 2015 ; 40(3): 138–154. doi:10.1080/87565641.2015.1028627.

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## Relations Between Toddler Sleep Characteristics, Sleep Problems, and Temperament

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### Abstract

Two sources of information (parent reported sleep diaries and actigraph records) were used to investigate how toddler sleep characteristics (bed time/sleep onset, wake time/sleep offset, total nighttime sleep and total sleep time) are related to sleep problems and temperament. There were 64 toddler participants in the study. Consistent with studies of older children, parent reports differed from actigraph based records. The findings that parent reported and actigraph recorded sleep characteristics varied as a function of parent report of toddler sleep problems and temperament add needed information on toddler sleep. Such information may contribute to improving parents' awareness of their child's sleep characteristics and correlates of problem sleep.

There is a growing understanding of the role of sleep in preschool children's development, particularly the impacts of sleep on children's behavior and school performance. For example, Hiscock, Canterford, Ukoumunne and Wake (2007) linked parents' reports of their 4- to 5-year-old children's sleep problems to health and behavior problems, as well as to problems in peer relations and social behaviors, and reports of hyperactivity/inattention. Bates, Viken, Alexander, Beyers, and Stockton (2002) found that 4- to 5-year-old children with disrupted sleep, based on parent daily sleep diaries documenting the variability in sleep

duration and bedtimes, had more teacher-reported adjustment problems in preschool. These findings are similar to those from other investigations of children ranging in age 4.5 to 16.5 years in which potentially more serious sleep problems, such as snoring or moderate or severe sleep-disordered breathing, were negatively associated with learning and behavior (Archbold, Giordani, Ruzicka, & Chervin, 2004; Blunden, Lushington, & Kennedy, 2001; O'Brien, et al, 2004; Sadeh, Gruber, & Raviv, 2003).

There are fewer studies of sleep in toddlers (aged 2.5 to 3.5 years of age) and, therefore, less information on the characteristics of toddler sleep, such as sleep onset latency (time between bedtime and sleep onset), wake time, total nighttime sleep and total sleep time (nighttime sleep plus nap). In the current study, we investigated toddler sleep using two common measures of sleep characteristics – parent reports of their toddler's sleep from daily sleep diaries and actigraph records. Beyond gathering basic data about toddler sleep, we were interested in agreement between parent reports and actigraph-recorded sleep. We also examined how toddler sleep characteristics based on actigraph records are related to parent perceptions of toddler sleep problems and toddler temperament. Jorgensen and Bilenberg (2009) examined parent reports of sleep problems of children five to 11 years of age with ADHD and from parents of typically developing children. For both groups, actigraph records did not verify parent reports of sleep problems. However, the authors speculated that children's behaviors related to sleep, such as bedtime struggles and variability in sleep patterns, contributed to, and may have exaggerated, parental perceptions of their children's sleep problems. We are interested in whether parental perceptions of sleep problems are related to actigraph recorded measures of sleep and to reactive behaviors of toddlers, which are temperamentally based.

## Toddler Sleep

The National Sleep Foundation (2014) estimates that toddlers 1- to 3-years-old should get 12 to 14 hours of sleep in a 24-hour period. However, it is not clear how much sleep typical toddlers are actually getting at night (nighttime sleep) or in a 24-hour period (total of nighttime and naptime sleep). Measures of toddlers' sleep are typically obtained from two sources: parent-reported sleep diaries and actigraph recordings. Parents use sleep diaries to record daily information across a specified period of time (typically from a few days to several weeks) about a child's bedtimes, morning wake times, and sleep disruptions (e.g., when the child was "out of bed"). Actigraphs are small, portable devices typically worn on the wrist for the same period of time as parent sleep diaries are recorded. Actigraphs resemble watches and provide information about a variety of different characteristics of sleep, including sleep onset (beginning of sleep) time and sleep off set (wake) time. Together, parent diaries and actigraphs can be used to obtain information on total nighttime sleep, and total sleep time (nighttime sleep plus nap) and appear to provide valid sleep data (Horne & Biggs, 2013). However, parent sleep diaries and actigraph sleep records are not always in agreement.

Nelson et al. (2014) reported average discrepancies of over 24 minutes between parent sleep diary entries of bedtime compared to actigraph-recorded sleep onset of children 4- to 9-year-old ( $M = 6.60$ ,  $SD = 1.18$ ). Similarly, Dayyat, Spruyt, Molfese and Gozal (2011) compared

parent sleep diary entries and actigraph data on 110 typically developing children 3 to 9 years of age ( $M = 6.6$  years,  $SD = 1.2$  years). They reported that parents overestimated their children's sleep duration by 26 minutes or more. Reasons for discrepancies are rooted in the different sources of information; diaries are based on parent report and are likely subject to guessing and estimation. Parents also may be unaware of when their children actually fall asleep and first wake in the morning. Further, children may engage in a variety of pre-sleep activities after being put to bed that delay actual sleep onset time. For example, some parents in the Dayyat, et al. (2011) study acknowledged that there could be discrepancies between when the child was put to bed and when the child fell asleep because the child was in his or her room playing, reading, watching T.V., or using electronic devices (e.g., game systems, tablets, and smart phones). It is unknown whether toddlers also might have these distractions; more information is needed about how parent reports of toddlers' bedtime and wake times are related to actigraph recordings. Comparing parent sleep diaries to objective actigraph records of sleep can provide this information. We investigated discrepancies between parent diary reports and actigraph records for four sleep characteristics – diary reports of bedtime compared to actigraph records of sleep onset, diary reports of wake time compared to actigraph records of sleep offset, total nighttime sleep (parent-reported bedtime to wake time compared to actigraph recorded sleep onset to offset) and total sleep time (total nighttime sleep plus parent-reported and actigraph recorded nap sleep). Based on previous findings of discrepancies between parent sleep diary reports and actigraph recordings in young children (Acebo et al., 2005; Dayyat et al., 2011; Nelson et al., 2014), we expected differences between parent reports and actigraph records for all four measures of sleep characteristics in toddlers.

## Sleep Problems

Measures of sleep are influenced by children's sleep behaviors, such as bedtime resistance, wake times in the morning and during the night, variability in timing of bedtime and wake time, and length of pre-sleep bedtime routines. Some sleep behaviors give rise to sleep problems. The *International Classification of Sleep Disorders, Revised* (ICSD, 2005, p. 18) describes sleep problems as arising from “the performance of daily living activities that are inconsistent with the maintenance of good quality sleep and full daytime alertness”. In this study, we refer to such behaviors as sleep problems. Sleep problems have been related to insufficient sleep time that may contribute to daytime sleepiness and non-optimal daytime performance (Molfese, Moritz Rudasill, & Molfese, 2013). In this study, we used a version of the Children's Sleep Habits Questionnaire (CSHQ; Owens, Spirito, & McGuinn, 2000) modified by the National Institutes of Child Health and Development Study of Early Childcare and Youth Development (NICHD ECCRN, 1993) to assess parents' perceptions of their toddlers' sleep problems and to examine the relations between parent perceptions of sleep problems and measures of sleep obtained from parent diaries and actigraph recordings. We expected that parent reports of more sleep problems would be reflected in parent reports and actigraph recorded poorer sleep characteristics.

## Temperament

Sleep also may be influenced by toddler temperament (Molfese, et al., 2013). Temperament is defined as biologically based individual differences (Rothbart & Bates, 2006) that inform one's affect, attention, and behavior (Rothbart, Ahadi, & Evans, 2000) in response to environmental stimuli. Temperament is conceptualized as a construct with two systems – one system is characterized by an individual's initial responses to stimuli in the environment (reactivity), and the other is a regulatory function that operates on reactivity (regulation) (Rothbart & Bates, 2006; Rothbart & Posner, 2005). Reactivity reflects the intensity and duration of an individual's response; a highly reactive child responds strongly and quickly, and has to work hard to regulate this response. When children are very young, the regulatory system is undeveloped, and reactivity can dominate a child's responses (Rothbart & Posner, 2005). For this reason, we are focusing on temperamental reactivity as a correlate of parent reported and actigraph recorded toddler sleep characteristics.

Reactive dimensions of temperament include fear, soothability, approach (i.e. positive anticipation) and activity level. These dimensions reflect the nature of the child's *initial response* to stimuli. Toddlers' temperamental reactivity may influence how sensitive they are to environmental factors or events that may disrupt their sleep, such as fear of the dark or environmental noise (Aron, 2012). Thus, a fearful child may be more likely to have sleep problems, and sleep problems may exacerbate the child's intense reactions and diminish the ability to regulate a fear response. Temperament-based differences in children's responses to environmental factors might have an influence on the variability in their sleep behaviors too, such that more variability in sleep onset, nighttime awakenings, nighttime sleep duration and napping might characterize children who are more reactive in temperament. Indeed, Bates, Viken, Staples, and Williams (2011) examined preschool children's temperamental resistance to control (indicative of high reactivity and low regulation) as a predictor of sleep disruption (including variability in sleep). They did not find a direct link between temperament and sleep disruption, but rather that more resistance to control exacerbated associations between sleep disruption and school adjustment. Given the conceptualization of temperament as biologically based (Rothbart & Bates, 2006), it seems logical for temperament to be related to sleep which also has a strong biological base as evidenced in research on sleep regulation and disorders (Raizen, Mason, & Pack, 2006). Whether this expectation holds true for toddler temperament and characteristics of sleep is explored in the present study.

Thus, in the present study, four research questions were addressed. First, what are the parent reported and actigraph recorded characteristics of sleep in toddlerhood? Second, to what extent do parent-reported and actigraph recorded measures of toddler sleep characteristics differ? Third, to what extent are parent reports of toddler sleep problems associated with their sleep characteristics as measured by parent-reported sleep diaries and actigraph recorded measures? Fourth, how are parent reports of reactive temperament related to parent reported and actigraph recorded sleep characteristics?

## Method

### Participants

The sample in the present study was part of a larger investigation examining the relations between measures of sleep, temperament, and self-regulation in toddlers 30- to 42- months-old and was approved by the Institutional Human Research Protection Committee.

English speaking families with typically developing toddlers (age 30-months) were recruited for participation. Recruitment was conducted in local preschool programs and day care sites, and through personal contacts, phone calls, and distribution of flyers describing the study and asking participants to refer potential participants to the study. Families with toddlers who fit within the age range, lived within a 1.5 hour drive of the research site, and expected to be available for the one year testing period of the study were eligible for participation. Data were gathered at three time points (when toddlers were 30-, 36-, and 42- months), but only data from the 30-month time point are reported here. The sample included 64 toddlers, aged 30- to 31-months ( $M = 30.14$  months,  $SD = .35$ ), of which 63% were male. The majority of toddlers was White, Non-Hispanic (81.3%), with the remaining African American (3.1%), Hispanic (4.7%) or other (10.9%). The ethnic breakdown of the sample reflected the broader demographics of the community from which it was drawn. Parent participants were primarily female (90.6%), married (84.4%), ranging in age from 25 to 44 years of age ( $M = 32.17$ ,  $SD = 4.33$ ) when the toddlers were 30-months-old. Parent education levels were college degree (81.3%), some college (12.5%) or high school diploma (1.6%). Three respondents did not report their education level. Family income was reported in blocks of \$5,000 and ranged from less than \$10,000 to more than \$125,000, with a mean of \$70,000 to \$75,000. Four respondents did not report family income.

### Measures

#### Sleep

**Actigraphy:** Toddlers' sleep was measured using actigraphy, which is a non-invasive method for tracking rest and activity periods. Actigraphy has been established as a valid and reliable method for measuring toddlers' sleep (Sadeh & Acebo, 2002; Sadaka, et al., 2014; Sadeh, Lavie, Scher, Tirosh, Epstein, 1991; Acebo, et al., 1999). The actigraph used was a MicroMini Motion Logger (Ambulatory Monitoring, Inc., Ardsley, New York), which is a small watch-like device that records motor activity via an accelerometer that monitors both speed and degree of motion in 1-minute epochs. The MicroMini Motion Logger user manual for revision 4.1 includes the following information: "zero crossing mode counts the number of times the accelerometer waveform crosses the predetermined sensitivity threshold of 20 during each epoch; therefore, it is a measure of frequency of movement (page 5)." Crossing Mode was used as the mode of data collection, with a wake sensitivity threshold of 20. The Act Millennium software, version 3.68.0.1 was used for initializing and downloading actigraph data, and the ActionW 2.7 software was used for data processing. The Sadeh, Alster, Urbach, and Lavie (1989) algorithms developed with a sample of 3 to 13 year olds were used for actigraph data scoring. These same algorithms also have been used with typically developing children aged 12 to 48 months and show high agreement between the

algorithm-based data scoring procedure and polysomnographic measures (Sadeh, et al., 1991).

Parents were instructed to have the toddler wear the actigraph enclosed in a sweatband on the non-dominant wrist; dominance was based on parental judgment. If the child resisted wearing the sweatband on the wrist, parents were instructed that the sweatband could be placed on the toddler's upper arm or leg. With the primary goal of obtaining actigraph data from toddlers across as long a period of days as possible, the choice of where the actigraph was worn was left to the parents. The actigraph was to be worn continuously throughout the day and night except when there was a risk of getting the device wet. When the device was taken off, parents were asked to indicate in the sleep diary when the actigraph was removed and why (e.g., "went to the pool from 1:00 pm to 3:00 pm"). The following variables were based on actigraph records: sleep onset time, sleep offset time, total sleep time and total nighttime sleep time. Consistent with the Meltzer, Montgomery-Downs, Insana, & Walsh (2012) suggested definitions, sleep onset is defined as the clock time for the first minutes of consecutive sleep as determined by the Sadeh algorithm following parent reported bedtime. Sleep offset time is defined as the clock time for the last minutes of sleep as determined by the Sadeh algorithm prior to parent reported wake time. In this study, total sleep is consistent with Meltzer et al.'s (2012) definition of a 24-hour sleep duration including nighttime sleep and daytime naps. Total nighttime sleep is specific to sleep at night and also consistent with Meltzer et al.'s definition. Sleep periods were identified in tandem with the parent reported sleep diaries (described in the next section), with parent reported bedtimes and wake times used to locate nighttime sleep periods in the actigraph records. Toddlers needed to have at least four nights of actigraph data to be included in analyses.

**Sleep diary:** Parents were asked to record in the diary the bedtime and wake time of their toddlers each day for two weeks, as well as to record any naps the child had during the same period and any times the actigraph device was taken off. Parents were asked to fill out the diary each day, rather than at the end of the two weeks, and to report sleep times as accurately as possible. Diaries were inspected at the lab visit (the midpoint of the two week testing phase) and parents were asked about their diary habits to increase accuracy of daily recordings. Families who enrolled their toddlers in daycare centers or in other out-of-home care used teacher/parent report to record naps that took place at the center. After the first week, diaries were reviewed with parents to ensure that directions were understood. In analyses we used parent reported bedtimes and wake times and we calculated parent reported total time in bed by summing the minutes between the bedtime and wake time.

**Sleep problems**—The Children's Sleep Habits Questionnaire (CSHQ: Owens, Spirito, & McGuinn, 2000) was used to assess sleep problems. The full CSHQ is a 45-item parent report questionnaire. However, in the present study an abbreviated version was in use across study sites. The abbreviated CSHQ includes 18 items and is based on modifications reported by the NICHD Study of Early Child Care and Youth Development (National Institute of Child Health and Human Development, Early Child Care Research Network, 1993). The CSHQ items include questions about bedtime, sleep behaviors, waking during the night, and morning wake up. Parents referred to a 5-point Likert scale, with 0 = never, 1 = rarely, 2 =

sometimes, 3 = usually, and 4 = always, to report on items such as “Child goes to bed at the same time at night”, “Child sleeps about the same amount each day”, “Child wakes up once during the night”, and “Child wakes up by him/herself.” Total scores for CSHQ sleep problems were based on the sum of scores on the 18 items; possible scores ranged from 0 – 72 and higher scores indicate more sleep problems. The domains on the abbreviated version of the CSHQ used in this study are aligned with the sleep characteristics derived from the parent reports in the sleep diary and from the actigraph records. While psychometrics are not available for the abbreviated version of the CSHQ, they are reported by Owens et al. (2000) for a 33-item version. Scores are reported to have good internal consistency (.68 for a community sample, .78 for a clinical sample) and test-retest reliability ranging from .62 to .79.

**Temperament**—Temperament was measured by parent report on the Children’s Behavior Questionnaire - Short Form (CBQ; Putnam & Rothbart, 2006), a 94-item assessment of children’s temperament. Parents report on a 7-point Likert scale ranging from 1 = “extremely untrue of your child” to 7 = “extremely true of your child” on items such as “Is afraid of loud noises” and “Gets very enthusiastic about the things s/he does”. The questionnaire yields scores for 15 dimensions of temperament, and has shown internal consistency values ranging from .65 to .70 (Putnam & Rothbart, 2006). For the present study, we examined four dimensions of temperamental reactivity (fear, soothability, approach, and activity level).

## Procedures

After recruitment, a home visit was scheduled with families. At the home visit, families were informed about the study and its procedures and, if they consented to participate, the parent, usually the mother, was given a binder with a packet of questionnaires. Among the questionnaires were those used to gather data for the present study - a demographic form, the Children’s Behavior Questionnaire - Short Form (Putnam & Rothbart, 2006), the abbreviated version of the Children’s Sleep Habits Questionnaire (Owens, Spirito, & McGuinn, 2000), and the sleep diary forms. The toddler was asked to pick out his or her preferred color of wristband and the actigraph enclosed in the wristband was given to the toddler to wear. The parent was given instructions regarding the wearing and care of the actigraph and instructions for completing the questionnaires and sleep diary. One week later, the parent and toddler came to the lab to participate in lab tasks as part of the larger project. During the lab visit, the completed questionnaires were gathered, actigraph data were downloaded, and additional sleep diary forms were provided to the parent. Also during the lab visit, the researchers reviewed the procedures to be used with the actigraph and with the sleep diary records with the parent. The actigraph was given the toddler to wear for another week. One week later, a second home visit was scheduled during which the actigraph and sleep diary forms were collected and the family and toddler were provided with compensations for participating.

## Analyses

While all 64 participants had scores for the CBQ and for the CSHQ, not all toddlers had complete actigraph and sleep diary data. Four of the 64 participants did not have at least 4

nights of useable actigraph data due to problems with the actigraphs (i.e., two were due to technical failures, one was due to loss of the actigraph, and one was due to repeated removal of the actigraph during sleep periods leaving an insufficient amount of data to analyze). These four participants were excluded from analyses of actigraph-recorded sleep onset, sleep offset, total sleep, and total nighttime sleep. Eight participants did not have any actigraph-recorded naps, had two or fewer naps across the whole recording period, or had nap times with no corresponding nighttime sleep on the same day. These participants were excluded from analyses using actigraph-recorded total sleep (night time plus nap time) data. From examinations of the sleep diary data, two participants were excluded; one participant did not have useable sleep diary information, and one did not have any naptime data recorded in the sleep diary. The first participant was excluded from all analyses while the second was excluded from analyses of total sleep involving parent reported naps. Overall, the participants had a mean of 13.17 days ( $SD = 4.064$ , range 4 – 23) of actigraph data and a mean of 11.59 days ( $SD = 2.136$ , range 4 – 13) of parent sleep diary data.

## Results

Table 1 shows the descriptive statistics for the sleep characteristics obtained from the participants' sleep diary and actigraph records, for CHSQ scores, and for the four CBQ temperament dimensions. Parent sleep diary reports and actigraph records were compared to examine differences between sleep characteristics derived from each data source. Pair-wise  $t$  tests were significant for all comparisons. Actigraph recorded sleep onset was 38.40 minutes later than parent reported bedtime,  $t(58) = 11.97$ ,  $p < .001$ ; compared to actigraph records of sleep offset, parent reported toddler wake times,  $t(58) = -8.24$ ,  $p < .001$ , were 21.87 minutes later. There were also differences in total nighttime sleep (parent reported bedtime to wake time compared to actigraph recorded sleep onset to offset) and total sleep time (total nighttime sleep plus parent reported and actigraph recorded nap sleep). Total nighttime sleep based on parent report was 152.95 minutes longer ( $t(58) = -20.40$ ,  $p < .001$ ) and total sleep times were 180.12 minutes longer,  $t(49) = -18.31$ ,  $p < .001$  compared to actigraph records. In sum, parent sleep diary reports consistently and significantly overestimated toddlers' sleep compared to actigraph records.

We examined relations between the measure of parent reported toddler sleep problems using CSHQ scores and parent reported characteristics of sleep using the sleep diaries and using actigraph recordings. The purpose of these comparisons was to determine whether toddlers reported by parents as having more sleep problems differed from toddlers with fewer sleep problems on the sleep measures. Significant correlations were found between parent reports of toddler sleep problems and actigraph recordings of sleep onset ( $r = .29$ ) and between parent reports of toddler sleep problems and parent reported measures of bedtime ( $r = .26$ ), total night time sleep ( $r = -.31$ ), and total sleep ( $r = -.29$ ). See Table 2. Toddlers with fewer reported sleep problems had earlier actigraph recorded sleep onset and were reported by parents to have earlier bedtimes, more nighttime sleep and more total sleep.

To explore these relations further, a median split was used to divide the toddlers into two sleep problems groups using scores from the abbreviated version of the CSHQ used in this project. Toddlers with scores above the median (18.5) were compared using MANOVA to

toddlers with scores below the median. Significant group differences were found for the actigraph recordings of sleep onset ( $F_{1, 50} = 5.598, p = .022, R^2 = .101$ ), such that toddlers with more parent reported sleep problems had longer sleep onset periods compared to toddlers with fewer sleep problems. No significant group differences were found for actigraph recordings of sleep offset time ( $F_{1, 50} = 1.107, p = .298, R^2 = .022$ ), total nighttime sleep ( $F_{1, 50} = 1.135, p = .253, R^2 = .026$ ) and total sleep ( $F_{1, 50} = 2.032, p = .160, R^2 = .039$ ). For parent sleep diary reports, there were no significant group differences for wake time ( $F_{1, 60} = .002, p = .968, R^2 = .000$ ), but there were significant group differences for bedtime ( $F_{1, 60} = 8.760, p = .004, R^2 = .127$ ), total night time sleep ( $F_{1, 60} = 10.181, p = .002, R^2 = .145$ ) and total sleep ( $F_{1, 60} = 14.886, p < .01, R^2 = .199$ ). That is, toddlers scoring above the median in parent reported sleep problems had significantly later parent reported bedtimes, less nighttime sleep, and less total sleep time.

To examine the relationships between sleep problems and temperament, we regressed the total CSHQ sleep problems scores on the four dimensions of temperament (activity level, approach, fear, and soothability) from the parent reported CBQ. The overall model was significant ( $F_{4,59} = 5.147, p = .001, R^2 = .259$ ), with soothability and fear emerging as significant predictors ( $\beta = -.307, t = -2.66, p = .010$ , and  $\beta = .306, t = -2.56, p = .013$  respectively) of the total CSHQ sleep problems scores. That is, higher scores on soothability and lower scores on fear predicted fewer sleep problems.

Finally, we explored the relations between parents' reports of toddlers' temperament and sleep characteristics based on parent reports and actigraph recordings. First, sleep characteristics were regressed on scores from the four temperament dimensions: activity level, approach, fear and soothability. The results are in Table 3. Although the models with temperament predicting actigraph-recorded or parent reported sleep characteristics were not significant, two temperament traits were significantly associated with actigraph-recorded sleep characteristics. Activity level was significantly and negatively associated with actigraph-recorded nighttime sleep ( $t_{59} = -2.35, \beta = -.314, p = .022, R^2 = .130$ ), and soothability was significantly and positively associated with actigraph-recorded total sleep (night and nap time sleep;  $t_{50} = 2.08, \beta = .303, p = .044, R^2 = .120$ ). That is, toddlers with higher ratings for activity level had less actigraph recorded nighttime sleep, and toddlers with higher soothability ratings had more actigraph recorded total sleep (night and nap). There were no significant associations between temperament and parent reported sleep characteristics.

Second, variability in the parent reported and actigraph recorded sleep characteristics (based on standard deviations computed for each measure) was regressed on the four temperament dimensions. The results are in Table 4. The model for variability in actigraph recorded sleep onset was significant ( $F_{4,55} = 3.84, p = .008, R^2 = .22$ ), with fear emerging as a significant predictor of variability in sleep onset time, ( $\beta = .359, p = .006$ ). That is, higher scores on the fear scale were associated with more variability in actigraph recorded sleep onset. The models for variability in actigraph recorded sleep offset ( $F_{4,55} = 1.33, p = .27, R^2 = .088$ ), night time sleep ( $F_{4,55} = 1.15, p = .35, R^2 = .077$ ), and total sleep ( $F_{4,46} = 1.44, p = .24, R^2 = .111$ ) were not significant. For parent reported sleep characteristics, the model for variability in nighttime sleep ( $F_{4,58} = 3.64, p = .01, R^2 = .20$ ) was significant, with

soothability emerging as a significant predictor of parent reported nighttime sleep variability ( $\beta = -.340, p = .007$ ) such that higher soothability scores were associated with less variability in parent reported nighttime sleep. The models for parent reported variability in bedtime ( $F_{4,58} = .480, p = .75, R^2 = .032$ ), variability in wake time ( $F_{4,58} = 1.28, p = .29, R^2 = .081$ ), and variability in total sleep ( $F_{4,55} = .53, p = .72, R^2 = .037$ ) were not significant.

## Discussion

In this study of toddlers' sleep characteristics and associations with sleep problems and temperament, three main findings emerged. First, in line with research conducted with older children, we found that parents' sleep diary reports over-estimated the measures of toddler sleep in comparison with actigraph records for the four sleep characteristics (bed time/sleep onset, wake time/sleep offset, total nighttime sleep and total sleep time). Second, as expected, toddlers with more parent reported sleep problems differed in sleep characteristics based on both parents' sleep diary reports and actigraph recordings. The most consistent finding was the relation between parent reported sleep problems and parent reports of bedtime and actigraph records of sleep onset time. Third, toddlers' temperament was associated with some sleep characteristics and variability in sleep characteristics. Activity level was negatively associated with actigraph recorded nighttime sleep, soothability was positively linked to actigraph recorded total sleep and negatively linked to variability in parent reported nighttime sleep, and fear was positively related to variability in actigraph recorded sleep onset time. Each of these findings will be discussed below.

Our finding that parents overestimate their toddlers' sleep by over 38 minutes compared to actigraph records is slightly longer than reports of other researchers from studies of older children (Nelson et al., 2014; Dayyat et al., 2011; Warner, Molinari, Guyer & Jenni, 2008). That there are differences in bedtime reports and sleep onset times should not be surprising because parents are not typically asked when their child fell asleep, only when the child was put to bed. While in some studies parents were asked to estimate when their child fell asleep after being put to bed, these estimates are also highly variable in comparison with actigraph sleep onset measures, averaging 23 minutes (SD = 4.5; Dayyat et al., 2011) and  $\pm 32$  minutes (Warner et al., 2008). These discrepancies in parent reports compared to actigraph records are important because the bedtime/sleep onset and wake time/sleep offset characteristics influence other sleep characteristics of interest, namely total nighttime sleep and total sleep. Because the most common measure of sleep is duration of sleep, either as nighttime sleep or total sleep in a 24 hour period (e.g., National Sleep Foundation, 2014), it is important that accurate estimates of sleep are available so that parents and practitioners can have access to information on actual sleep times. A more complete understanding of sleep in toddlers would require that additional sleep diary information be requested from parents. For example, specific information regarding sleep onset would be helpful in increasing parents' understanding of their child's actual sleep times. Information on sleep onset could be obtained from parent sleep diaries if parents were asked to check on their child at set intervals after the child is put to bed. Because of the links between sleep duration and daytime behaviors (e.g., Touchette, et al., 2009), engaging parents in attending to their child's sleep onset time could provide them with more accurate sleep information.

We also found that toddlers with more parent reported sleep problems on the CSHQ differed from those toddlers with fewer parent reported sleep problems in having later sleep onset times according to actigraph records and later bedtimes, less nighttime sleep, and less total sleep, according to parent reports. Sleep problems that lead to sleep insufficiency are particularly problematic because of the known relations between sleep insufficiency and impacts on cognitive skills (Molfese, et al, 2013). Much of the research establishing these links has focused on preschool children, typically those older than 3 years of age. It is notable that in this study with 30-month-old toddlers the average total sleep problem score on the CHSQ (Owens, et al., 2000) was just over 19 points, which is less than 27% of the possible total score. Such low scores are consistent with other reports of toddler sleep problems, such as Bates and Hoyniak (personal communication, November, 2014) who found average CSHQ total scores of 21 for a sample of over 100 30-month-olds. However, even low levels of sleep problems can impact early learning and behavior (Molfese, Beswick, Molnar, Jacobi-Vessels & Gozal, 2007); efforts to decrease toddlers' sleep problems that interfere with sleep are needed.

We found that toddlers' temperamental activity level, soothability, and fear were associated with characteristics of their sleep. The relationships between sleep and these temperamental dimensions are likely bidirectional, with sleep influencing the expression of temperament, and temperament influencing sleep (Molfese, et al., 2013). In terms of parent reports of temperamental activity level, toddlers with higher ratings had less nighttime sleep based on actigraph recordings. This finding is commensurate with the conceptualization of activity level as the extent to which a child engages in gross motor movement throughout the day (Rothbart, et al., 2000). We found that toddlers who were reported by parents as having highly active temperaments also had less actigraph recorded nighttime sleep. The relation between temperamental activity level and actigraph recorded nighttime sleep and not parent reports of nighttime sleep may indicate that parents are not aware of their toddler's active nighttime sleep. It is important to note that actigraph recordings yield estimates of sleep based on changes in activity in a 24-hour period. To avoid confusing night waking with active sleep, the standard criterion of 5 minutes of continuous high activity as a basis for determining a wake period was employed. While other research has reported that children higher in activity level sleep less based on parent reports of sleep than their less temperamentally active peers (Weissbluth, 1984), more research is needed to follow up these findings with temperamentally active children. Findings regarding soothability are also congruent with the conceptualization of soothability as the ease and speed with which a toddler is comforted after becoming agitated or upset (Rothbart & Bates, 2006). As expected, toddlers with higher soothability had more actigraph recorded total sleep and less variability in parent reported nighttime sleep. This finding is consistent with other research linking sleep problems with negative emotionality, of which low soothability is a component (Scher, Hall, Zaidman-Zait, & Weinberg, 2010; Ward, Gay, Alkon, Anders, & Lee, 2008).

Fear was positively related to variability in actigraph recorded sleep bedtime. We expected toddlers' fear scores to be associated with their ability to fall and stay asleep during the night, given the conceptual and empirical links between fear and sleep. What is novel here is the positive relation between fear and *variability* in sleep onset based on actigraph records. Fear is a reactive temperament dimension, meaning that it is a toddler's manifestation of an

initial response to an environmental stimulus (Rothbart & Bates, 2006). A toddler with high fear will be easily frightened, but not always stay frightened. Thus, high fear could be related to variability in sleep onset because fear-inducing stimuli are inconsistent. For example, on a day when the toddler encounters a frightening stimulus (e.g., a scary Halloween mask), bedtime may be particularly difficult. However, on another day with no upsetting stimuli, bedtime may be uneventful.

### Limitations and future directions

Although this study addressed characteristics and correlates of sleep in a naturalistic, home setting using parent sleep diary reports and actigraphy records, which are identified as valid methods for measuring sleep characteristics (Horne & Biggs, 2013), several limitations to the study should be mentioned. First, sleep diary information, sleep problems, and temperament were assessed via parent report, and this may have inflated associations between these measures. However, there were also significant associations between actigraph recorded sleep characteristics and parent reported sleep problems and temperament, which lessen concerns due to mono-method bias. Second, our findings are based on one time point, when toddlers were approximately 30 months of age. Examinations of longitudinal associations between parent reported and actigraph recorded sleep characteristics, parent reported sleep problems and temperament will be instrumental in contributing to a clearer understanding of the development of sleep in toddlers. Third, while there are associations between sleep problems and sleep characteristics found in this study, more detailed information about types of sleep problems is needed to understand the developmental nature and potential seriousness of sleep problems. Sleep training is a common topic in infancy as parents struggle to adapt their infants' sleep habits to family routines. Parents of toddlers also can struggle with the changing sleep habits of their young children. A closer examination of sleep problem data reported by parents and by out of home care providers using questionnaires with items targeting a broader range of sleep problems is needed. In addition, research on strategies and routines used with bedtime and nap times may be useful for gaining a better understanding of what strategies work in different circumstances for toddlers with different temperaments. Fourth, in this study, the placement of the actigraph on the toddler's non-dominant arm was recommended, but parents could make changes in placement to increase their toddler's likelihood of wearing the actigraph. A consistent placement of the actigraph is a methodologically important component. However, in this study there is a trade off between consistent placement and data collection across a sufficient number of nights needed for analyses. We did not ask parents to record the placement of the actigraph in the daily sleep diary. This information should be recorded to add to our knowledge of how the placement of the actigraph on the body affects the accuracy of actigraphy. Finally, some of the controls possible for studies conducted in sleep laboratories are not possible in naturalistic settings, such as the home environment. For example, parents were asked to record sleep times as accurately as possible but home clocks were not synchronized with the actigraphs. However, the results of this study provide important information about toddler sleep that adds to other published information in the field.

## Conclusions

Two sources of information about toddler sleep characteristics were investigated and difference in parent reported and actigraph recorded bedtime/ sleep onset, wake times/ sleep offset, total nighttime sleep, and total sleep (total nighttime and nap time sleep) were identified. To better characterize sleep, especially indicators of sleep duration, some changes in the types of information obtained from parents in sleep diary are needed. The importance of gaining a better understanding of sleep duration is underscored by the findings from the examination of parent reports of toddler sleep problems and temperament. Sleep problems and temperament were more consistently related to the total sleep measures – both total nighttime and total sleep (nighttime and nap time). More information is needed on how these findings with toddlers 30 months of age relate to findings obtained with older toddlers and children.

## Acknowledgments

### Funding

National Institutes of Health: 1R01HD073202-01

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**Table 1**

Descriptive Statistics For Sleep Diary, Actigraph, Temperament and Sleep Problems

	<b>Mean (SD)</b>	<b>Range</b>	<b>Sample Size</b>
<u>Sleep Diary</u>			
Bedtime	8:43 pm (40.17)	7:20 pm – 10:01 pm	63
Wake time	7:18 am (42.17)	5:51 am – 8:50 am	63
Nighttime Sleep	10.53 hrs (40.28)	9.17 hrs – 12.15 hrs	63
Total Sleep (Night and Nap)	12.43 hrs (50.43)	10.28 hrs – 14.05 hrs	62
<u>Actigraph</u>			
Sleep Onset	9:23 pm (43.98)	7:53 pm – 10:54 pm	60
Sleep Offset	6:56 am (42.8)	5:32 am – 8:39 am	60
Nighttime Sleep	7.97 hrs (1.10)	5.30 hrs – 10.37 hrs	60
Total Sleep (Night And Nap)	9.38 hrs (1.17)	6.40 hrs – 11.93 hrs	52
<u>Temperament</u>			
Activity level	4.99 (.89)	3.0 – 6.86	64
Approach	4.87 (.75)	3.17 – 7.00	64
Fear	3.02 (.89)	1.00 – 4.83	64
Soothability	5.20 (.91)	2.17 – 6.83	64
<u>Child Sleep Habits Questionnaire</u>			
Sleep Problems	19.44 (7.27)	8 – 34	64

Table 2

## Correlations Between Sleep, Sleep Problems and Temperament

	Temperament			CSHQ Sleep Problems	
	Activity Level	Approach	Fear	Soothability	
Sleep Diary					
Bed Time	.130	.076	.112	-.113	.255*
Wake time	-.077	.118	.063	.004	-.079
Nighttime Sleep	-.243	-.020	.028	.096	-.314*
Total Sleep (Night and Nap)	-.138	-.101	-.093	.145	-.290*
Actigraph					
Sleep Onset	.251	.173	.132	-.146	.291*
Sleep Offset	-.047	.055	.060	.004	.153
Nighttime Sleep	-.313*	-.083	-.121	.183	-.237
Total Sleep (Night And Nap)	-.212	.021	-.079	.274*	-.219
Child Sleep Habits Questionnaire					
Sleep Problems	.183	.094	.371**	-.389**	X

\* p &lt; .05,

\*\*

p &lt; .01,

\*\*\*

p &lt; .001

**Table 3**

Regression of Parent and Actigraph Reported Sleep on Temperament

	<b>B</b>	<b>SE B</b>	<b><math>\beta</math></b>
<u>Activity Level</u>			
PR Bedtime	312.485	368.859	.117
PR Waketime	-368.902	388.287	-.131
PR Nighttime Sleep	-693.399	363.079	-.258
PR Total Sleep	-374.473	463.238	-.112
AR Sleep Onset	640.339	409.976	.213
AR Sleep Offset	-205.949	416.735	-.070
AR Nighttime Sleep	-1431.078	609.022	<b>-.314*</b>
AR Total Sleep	-814.387	748.862	-.162
<u>Approach</u>			
PR Bedtime	460.408	453.643	.014
PR Waketime	525.768	477.537	.156
PR Nighttime Sleep	197.309	446.534	.061
PR Total Sleep	-190.132	568.149	-.048
AR Sleep Onset	262.666	490.704	.076
AR Sleep Offset	221.513	498.795	.066
AR Nighttime Sleep	278.204	728.944	.053
AR Total Sleep	406.667	876.274	.070
<u>Fear</u>			
PR Bedtime	238.760	376.179	.086
PR Waketime	96.385	395.992	.033
PR Nighttime Sleep	113.509	370.283	.041
PR Total Sleep	-179.460	470.537	-.052
AR Sleep Onset	223.748	397.727	.077
AR Sleep Offset	139.422	404.284	.049
AR Nighttime Sleep	-388.961	590.826	-.088
AR Total Sleep	129.471	689.290	.028
<b>Soothability</b>			
PR Bedtime	-225.666	349.559	-.086
PR Waketime	15.403	367.971	.006
PR Nighttime Sleep	231.390	344.081	.088
PR Total Sleep	411.026	438.434	.125
AR Sleep Onset	-306.162	380.581	-.106
AR Sleep Offset	37.2	386.856	.013
AR Nighttime Sleep	616.963	565.355	.141
AR Total Sleep	1326.432	639.397	<b>.303*</b>

\*  $p < .05$ \* *Note.* PR refers to parent report of sleep and AR refers to actigraph record of sleep.

**Table 4**

Regression of Variability In Parent and Actigraph Reported Sleep On Temperament

	<b>B</b>	<b>SE B</b>	<b>β</b>
<u>Activity Level</u>			
PR Bedtime	336.837	438.390	.106
PR Waketime	44.085	167.209	.035
PR Nighttime Sleep	284.896	164.703	.217
PR Total Sleep	206.480	607.941	.047
AR Sleep Onset	3.718	3.024	.156
AR Sleep Offset	-.142	2.453	-.008
AR Nighttime Sleep	5.792	3.784	.211
AR Total Sleep	231.138	259.492	.133
<u>Approach</u>			
PR Bedtime	381.861	539.156	.100
PR Waketime	-96.517	205.642	-.065
PR Nighttime Sleep	-184.236	202.561	-.117
PR Total Sleep	-310.738	721.288	-.062
AR Sleep Onset	-1.032	3.620	-.037
AR Sleep Offset	5.160	2.936	.249
AR Nighttime Sleep	3.415	4.529	.107
AR Total Sleep	-67.952	303.643	-.034
<u>Fear</u>			
PR Bedtime	-40.443	447.089	-.012
PR Waketime	323.712	170.527	.252
PR Nighttime Sleep	182.733	167.971	.135
PR Total Sleep	34.366	594.385	.008
AR Sleep Onset	8.307	2.934	<b>.359*</b>
AR Sleep Offset	-.609	2.380	-.035
AR Nighttime Sleep	.206	3.671	.008
AR Total Sleep	-371.184	238.850	-.236
<u>Soothability</u>			
PR Bedtime	-174.329	415.452	-.056
PR Waketime	-120.578	158.460	-.099
PR Nighttime Sleep	-439.716	156.085	<b>-.340*</b>
PR Total Sleep	-660.530	562.335	-.160
AR Sleep Onset	-4.310	2.807	-.188
AR Sleep Offset	-2.905	2.277	-.169
AR Nighttime Sleep	-1.396	3.513	-.053
AR Total Sleep	-367.635	221.561	-.243

\* p &lt; .05

\* Note. PR refers to parent report of sleep and AR refers to actigraph record of sleep.