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Defining the Roles of Actigraphy and Parent Logs for Assessing Sleep Variables in Preschool Children

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Abstract

Actigraphy provides a non-invasive objective means to assess sleep–wake cycles. In young children, parent logs can also be useful for obtaining sleep–wake information. The authors hypothesized that actigraphy and parent logs were both equally valid instruments in healthy preschool-aged children. The authors studied 59 children aged 3 to 5 years in full-time day care. Each child was screened for medical problems and developmental delays before being fitted with an actigraphy watch, which was worn for 1 week. Parents maintained logs of sleep and wakefulness during the same period, with input from day care workers. In general, parents overestimated the amount of nighttime sleep measured by actigraphy by 13% to 22% (all significant). Although there was no difference in sleep onset times, parents reported later rise times on the weekend and fewer nighttime awakenings. There was no significant difference between parent logs and actigraphy with regard to daytime napping. The authors conclude that parent logs are best utilized in assessing daytime sleep and sleep onset, whereas actigraphy should be used to assess nighttime sleep and sleep offset time.

Assessment of sleep in preschoolers over several days of normal activity is a challenge. Sleep is often assessed by relying on logs kept by parents. An objective assessment of sleep may be obtained using actigraphy. An actigraph is an accelerometer that records motion. This is generally worn on the non-dominant wrist and resembles a wrist watch. The actigraph provides a convenient and non-invasive means to assess patterns of activity that reflect sleep–wake cycles in ambulatory participants across several consecutive days and nights, and is particularly helpful in assessing advanced and delayed sleep (Lockley, Skene, & Arendt, 1999). Reliability of actigraphy is acceptable in young children when compared with polysomnography (Hyde et al., 2007). Recently, Spruyt, Gozal, Dayyat, Roman, and Molfese (2010) also reported that the actigraph was reliable in assessing sleep quantity in school-aged children (aged 4–8 years) compared to polysomnography. Even in older children (ages 6–11), actigraphy is a useful tool for assessing sleep duration and awakenings compared to parent surveys (Holley, Hill, & Stevenson, 2010). The practice parameters

issued by the American Academy of Sleep Medicine recommend that actigraphy be used in situations when polysomnography is not available or is otherwise not practical or feasible (Morgenthaler, Alessi, & Friedman, 2007). One distinct advantage of actigraphy is that sleep assessment is done in the individual's normal sleep environment, removing "first night effect" bias. In addition, minimal technical support is required for data collection.

Despite its practical advantages, actigraphy does have its limitations because it is based on motion detection, not neurophysiological assessment of sleep (Hyde et al., 2007). For example, absence of movement during quiet activities may be misinterpreted as a period of sleep. Conversely, restlessness during sleep may be misinterpreted as wakefulness (Sadeh & Acebo, 2002). Recently, studies have coupled sleep logs with actigraphy monitoring to increase accuracy of the actigraphy, often as a backup for what is scored by caregivers as sleep and awake time (Acebo et al., 2005; Goodlin-Jones, Waters, & Anders, 2009).

Assessing childhood sleep exclusively via parent logs has an advantage over actigraphy, as it requires no specialized equipment. Indeed, there are a number of pediatric studies assessing the reliability of parent logs for reporting sleep–wake cycles time in children and infants (Iwasaki et al., 2010; Sadeh, 1996; Tikotzky & Sadeh, 2001; Werner, Molinari, Guyer, & Jenni, 2008). These studies suggest that, in general, parent logs were reliable for recoding sleep onset and offset, but were less reliable for recording awakenings. The decreased reliability for night awakenings could result from contented sleeplessness, where an awake child does not always alert parents. On the other hand, at least one other study in children reported a large discrepancy between parent logs and actigraphy. The discrepancy was due to lack of reporting of night awakenings by parents (Acebo et al., 2005; Werner et al., 2008).

Thus, although both parent report and actigraphy represent well-established, non-invasive, naturalistic measures of activity and sleep behaviors, the agreement between the methods has been inconsistent, particularly in younger children. To clarify this issue, we conducted a study to monitor sleep–wake cycles in typically developing preschool children using both actigraphy and parent logs of sleep–wake times. The purpose of the study was to determine the typical sleep patterns in this age group and to examine the consistency and agreement between the two methods. In contrast to other studies using both actigraphy and parent logs, one goal of this study was to delineate whether one method was preferable for specific types of sleep parameters. We hypothesized that the parent logs would provide a valid method for assessing sleep patterns and, hence, there would be no significant differences between nap onset and offset times, sleep onset and offset times, total sleep time, and nocturnal awakenings recorded by the two methods.

METHOD

Participants

After institutional review board approval, typically developing boys and girls, ages 3 to 5 years, were recruited from local day care centers to participate in a larger study of sleep patterns and their impact on neurocognitive function. Children were excluded from the study if they had been identified as having medical problems, took medications chronically, or had developmental delays. At the time of study entry, children were screened for developmental delays with the Peabody Picture Vocabulary Test–Fourth Edition (PPVT–IV; Dunn & Dunn, 2007). Ten children were excluded from the study because they were found to be taking medications chronically.

Screening Assessment

PPVT-IV (Dunn & Dunn, 2007)—The PPVT-IV is a measure of single-word listening vocabulary and a screening test of verbal ability, as well as an estimate of intellectual functioning. The child is presented four pictures at a time and asked to point to a picture that represents a particular word. Children were excluded if they scored more than 1 *SD* below the mean for age (standard score <85).

Sleep Assessments

Parent logs—Parents were instructed to maintain sleep logs for the duration of the study (see Figure 1). When the child was in day care, day care workers monitored nap times and reported to parents at the end of the day. Afternoon nap times were recorded before bedtime. Bedtime, sleep latency, awakenings, and sleep end time were recorded the following morning. Sleep onset time was calculated by adding sleep latency to the bedtime. Parent logs were adapted from those utilized for clinical care in the Sleep Center at the Children's Hospital of Philadelphia.

Actigraphy—Children were fitted with a Minimitter Motionlogger Actiwatch (Ambulatory Monitoring, Inc., Ardsley, NY) set in zero-crossing mode. Information is accumulated over a fixed 1-min time interval, considered as an epoch. The watch was worn for 1 week (i.e., Monday–Monday) on the non-dominant wrist. Sleep–wake cycles were scored with the Action W (Version 2.6) software program (Ambulatory Monitoring, Inc., Ardsley, NY). Sleep epochs were determined based on the Sadeh algorithm (Sadeh, Sharkey, & Carskadon, 1994). This algorithm is computed as $PS = 7.601 - 0.065MW5 - 1.08NAT - 0.056SD6 - 0.0731\ln(ACT)$. PS is the probability of sleep; MW5 is the average number of activity counts during the scored epoch and a window of five epochs preceding and following it; NAT is the number of epochs with an activity level equal to or higher than 50, but lower than 100, activity counts in a window of 11 min; SD6 is the standard deviation of the activity counts during the scored epoch and the five epochs preceding it; $\ln(ACT)$ is the natural logarithm of the number of activity counts during the scored epoch. If PS is zero or greater, the specific epoch is scored as sleep; otherwise, it is scored as wake (Souza, Benedito-Silva, & Noguerira, 2003). Scoring was completed independently of parent logs, except if there were prolonged periods of inactivity during normal awake times. In these instances, parent logs were reviewed for notations indicating that the watch was removed from the child. Nighttime awakenings were scored if the awakening lasted 5 min or more. The variables of interest from actigraphy data included napping sleep onset and offset, napping duration, nighttime sleep onset and offset, duration of nighttime sleep, total weekday daytime napping, total daytime weekend napping, total weekday nighttime sleep, and total weekend nighttime sleep.

Definitions of Sleep Phases

Napping was defined by any discrete period of sleep between 9 a.m. and 6 p.m. separated from morning sleep offset time by 1 hr. If a child was sleeping continuously through the morning, the period of sleep was still considered nighttime sleep. Nighttime sleep was defined as sleep between 6 p.m. to 9 a.m. These times were consistent with day care center operation hours, which were generally from 9 a.m. to 6 p.m. Weekday sleep was defined as sleep on Monday through Friday, whereas weekend sleep occurred on Saturday or Sunday. The times were based on calculations from scoring sleep through the Action W software program utilizing the Sadeh algorithm (Sadeh et al., 1994).

Data Analysis

Data analysis was performed with GB-STAT v. 9.0 for Microsoft Windows and in SAS Version 9.1. Bedtimes and rise times were converted to minutes past midnight to enable statistical analysis: [Number of Hours Past Midnight + 60) + Number of Minutes Past the Hour. For example, 6:35 a.m. was equivalent to $(6 \times 60) + 35 = 395$ min. Means and standard deviations for sleep variables were calculated for actigraphy and parent report measures, assessing total weekday and weekend sleep, as well as average daily sleep. The paired t test was used to compare the differences in the amount of sleep across the week and nighttime awakenings using both actigraphy and parent log data. Significance was set at $p < .05$. A two-way repeated measures ANOVA and post hoc analyses using Tukey honestly significant difference tests were used to compare bedtimes and rise times and evaluate day-to-day variability.

RESULTS

Sample Characteristics

Seventy-four participants were recruited. Ten participants were found to be taking medications and were excluded, leaving 64 eligible participants who were enrolled in the study. Five children dropped out of the study due to noncompliance with the actigraphy watch, and were excluded from the data analysis. Thus, a total of 59 children completed the study. The sample included 29 boys and 30 girls. The mean age of the sample was 4.3 years ($SD = 0.75$). Racial distribution of the sample was as follows: 58% African American, 22% Caucasian, 5% Asian, and 15% multiracial.

Weekday and Weekend Sleep Variables

Means and standard deviations for weekday and weekend napping and nighttime sleep, assessed by actigraphy and parent log, are listed in Table 1. Overall, compared to actigraphy data, parents overestimated their children's amount of nighttime sleep; however, weekday nap durations did not differ significantly between logs and actigraphy. Parents reported more nighttime sleep than was recorded by actigraphy on both weekdays and weekends (both $ps < .001$), which resulted in a significant increase of estimated nighttime sleep.

Sleep Onset Times, Rise Times, and Awakenings

To better define the observed difference in nighttime sleep between actigraphy and parent logs, sleep onset times, sleep offset times, and awakenings were analyzed for both actigraphy and parent log data. For sleep onset time, there were no significant main effects for modality, $F(1, 725) = 0.50$, $p = .48$, suggesting that, across days, parents reported similar sleep onset times compared with actigraphy data. There were also no significant effects for day of the week, $F(6, 725) = 1.10$, $p = .36$, indicating similar sleep times on different days of the week; and no significant Modality $\times$ Day interaction, $F(6, 725) = 0.20$, $p = .99$.

In contrast, for sleep offset time, there was a significant main effect for modality, $F(1, 778) = 4.50$, $p = .034$, such that, across days, parents reported that their child rose later than the times measured by actigraphy. There was also a significant main effect for day of the week, $F(6, 778) = 9.10$, $p < .001$, indicating different wake times on different days of the week; and a significant Modality $\times$ Day interaction $F(6, 778) = 2.10$, $p = .05$, suggesting different daily patterns of reported wake time between parent report and actigraphy. Daily differences between parent log and actigraphy data for sleep offset times are also listed in Table 2. There was a significant difference between parent logs and actigraphy reports for sleep offset times on Thursdays, Saturdays, and Sundays. In all cases, parents reported later sleep offset times compared to actigraphy data. Patterns of day-to-day variability for sleep offset

time within modality are listed in Table 3. The intraclass correlation for pooled data was 0.885 from Monday to Friday and 0.903 from Monday through Sunday. For actigraphy data, there was a pattern of later sleep offset time on Fridays and Saturdays compared to other days of the week. For parent log data, there was more variability; although, for the most part, parents reported later sleep offset times on weekends compared to weekdays.

Data for nighttime awakenings recorded by actigraphy and parent log are listed in Table 4. For number of awakenings, there was a main effect for modality, $F(1, 104) = 253.80, p < .0001$, such that parents reported significantly fewer awakenings on all 7 nights compared to actigraphy data. The main effect for day of the week, $F(6, 99) = 1.80, p = .10$, and the Modality $\times$ Day interaction were not significant, $F(6, 99) = 1.90, p = .09$, suggesting that the number of awakenings per night was consistent throughout the week. In other words, there was no significant night-to-night variability.

DISCUSSION

Although other studies report accuracy of parent logs compared to actigraphy (Hyde et al., 2007), we found differing results among typically developing preschoolers. Specifically, using actigraphy as the standard, parent logs appear to be accurate when reporting daytime napping. This is likely due to better monitoring during the day by parents and day care workers compared to nighttime sleep where parents are less likely to be physically present in the room. The consistency between actigraphy and sleep logs during daytime sleep was also found in another study of preschoolers in full-time childcare (Ward, Gay, Anders, Alkon, & Lee, 2007). In contrast, patterns of reporting nighttime sleep were less consistent. Parents reported a significantly greater amount of nighttime sleep compared to actigraphy. This discrepancy is most likely related to the difference in nighttime awakenings since parent logs were consistent with sleep onset and offset times identified by actigraphy. Like other studies, parents tend to underreport nighttime awakenings (Acebo et al., 2005; Iwasaki et al., 2010); however, the number of awakenings reported in this study is slightly lower than that found in other studies of children this age (Acebo et al., 2005; Iwasaki et al., 2010). The discrepancy between parental reports of nighttime sleep could be related to the degree of independence at this age, such that parents are not alerted by the children when they are awake in bed. It is also possible that since children this age require less attention at night from parents, parents are less accurate in assessing sleep continuity. These children are able to fall back asleep without parental intervention, since parents are not reporting these awakenings. It is important to emphasize that night awakenings are a normal phenomenon; most children are able to fall back asleep without parental intervention, which may be a product of good sleep hygiene and favorable sleep onset associations.

The overall sleep pattern found by this study was that preschool children are napping more on weekdays and sleeping less at night when they nap during the day (see Table 1). Ward et al. (2007) also noted a similar pattern of napping and reduced nighttime sleep on weekdays in children in full-time day care. These data also show that those children who nap more go to bed significantly later on weekends and (not surprisingly) wake up significantly later on weekends. Of note, the amount of nighttime sleep during the weekends is higher than during the week. It is possible that children's sleep periods on weekends tend toward more nighttime sleep and less daytime sleep. It is not clear if there is a direct cause-effect relationship for this change. In other words, it is not known whether children sleep more at night because they are not napping or whether they are napping less because they are getting more sleep at night. Another possible explanation for the decreased napping on weekends is that the home environment is different (potentially less structured) and perhaps less conducive to sleep, especially if there are other siblings in the home who do not nap.

A surprising finding in our data was the average time that children were actually falling asleep as assessed from actigraphy. Even on weekdays, our preschool-aged children were actually falling asleep after 10:00 p.m. This finding is much later than that found by the National Sleep Foundation (2004) polls, which indicate that the average falling asleep time was 8:55 p.m. for this age range. Although it is not known why bedtimes in our participants were so late, it can be hypothesized that working parents are putting their children to sleep later because they spend less time with them during the day. However, later bedtimes may mean that these children are not given an adequate sleep opportunity at night, which may lead to daytime sleepiness and naps. A child's bedtime is likely determined by family-related factors such as socioeconomic status; parental ages, habits, and cultures; as well as factors related to the child's sleep patterns. This trial was not designed to examine these factors. Of note, a study comparing napping patterns between African American and Caucasian preschoolers found that African American children napped more and slept less at night (Crosby, LeBourgeois, & Harsh, 2005). Whereas the Crosby et al. study did not report times related to sleep onset, it is possible that racial differences may contribute to our findings since a high proportion of our participants were African American. The next step in understanding this relationship would be a randomized trial to regulate bedtimes in order to determine whether there is an effect on napping time.

Limitations of the study include its observational design and that conclusions are based on children in full-time day care centers. It is unclear whether similar patterns would be replicated in children who are not in day care. Furthermore, there may be observational bias in caregivers who were aware that their child was being monitored by the actigraphy watch. It is not clear whether caregivers changed their practices since it was known that the child was wearing an actigraph watch (i.e., Hawthorne effect). Finally, it should be noted that actigraphy provides an estimate of sleep. In summary, our findings represent more detailed guidance on which form of data collection to use, depending on which variables are of interest. These data indicate that parents of typically developing preschoolers may overestimate their children's nighttime sleep on parent logs, as a function of underreporting night awakenings. Conversely, for daytime napping, parental reports are more accurate. Based on our results, we would recommend that sleep assessment at night be assessed primarily using actigraphy, whereas parent logs can be used for daytime sleep assessment and as a reliable backup to the actigraphy results.

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Name: _____ DOB: _____

Fill this form out **JUST BEFORE** going to bed

Today is _____ Today's Date ____ / ____ / ____

What time is it now? _____ am/pm Did your child go to school today? ____ Yes ____ No

Was your child sick today? ____ Yes ____ No If yes, with what? _____

Write times the following occurred (and circle AM or PM)	START	END	START	END
Shower or Bath	AM PM	AM PM	AM PM	AM PM
Took off the actigraph	AM PM	AM PM	AM PM	AM PM
Nap (or accidentally fell asleep)	AM PM	AM PM	AM PM	AM PM
Very quiet activity (e.g., going to the movies)	AM PM	AM PM	AM PM	AM PM

Fill this form out **FIRST THING** in the morning

	Circle AM or PM
LAST NIGHT	
What time did your child get into bed?	AM PM
What time did your child fall asleep?	AM PM
How long did it take your child to fall asleep?	minutes
After falling asleep, how many times did your child wake up during the night?	(circle one) 0 1 2 3 more
THIS MORNING	
What time did your child wake up?	AM PM
What time did your child get out of bed this morning?	AM PM

FIGURE 1.
Parent log form.

TABLE 1

Comparison of Amount of Sleep Totals by Method

Variable	Actigraphy (in Hours)			Parent Log (in Hours)			t	p
	M	SD	n	M	SD	n		
Weekday naps	5.1	3.7	54	5.10	3.90	58	0.19	.85
Weekend naps	1.1	1.3	50	1.50	1.50	57	-1.48	.14
Total napping	6.5	4.3	49	6.45	4.46	57	0.04	.97
Weekday night	42.5	5.6	54	47.30	5.50	54	-5.33	<.0001
Weekend night	16.6	4.5	50	19.00	3.00	57	-2.96	.0004
Total nights	59.8	8.0	49	59.40	21.30	53	-5.01	<.0001
Total sleep	66.1	6.1	49	63.50	25.10	52	-5.07	<.0001

Note. Weekday includes 5 days (Monday–Friday); weekend includes 2 days (Saturday & Sunday); total includes 7 days. Paired *t* tests were used for analyses.

TABLE 2

Sleep Onset Times and Offset Times by Day

Variable	Actigraphy			Parent Log		
	M	SD	n	M	SD	p
Sleep onset time						
Monday	22:05	91	54	9:55	73	.093
Tuesday	22:08	76	55	9:58	93	.074
Wednesday	22:14	89	54	9:35	84	.01
Thursday	22:09	76	54	9:33	80	.283
Friday	22:15	172	52	9:29	95	.724
Saturday	22:38	107	50	10:04	101	.495
Sunday	21:59	83	49	9:53	111	.61
Sleep offset time						
Monday	6:46	73	54	6:56	47	.265
Tuesday	6:46	60	55	6:50	47	.825
Wednesday	6:52	67	54	6:55	54	.834
Thursday	6:52	67	54	7:09	54	.026
Friday	7:39	76	52	7:16	80	.109
Saturday	7:26	86	50	7:54	82	.048
Sunday	6:48	69	49	7:24	81	.003

Note. Standard deviation calculations are based on number of minutes when time is converted to number of minutes after midnight. All times represented in military time.

TABLE 3

Day-to-Day Variability of Sleep Offset Times

Variable	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Actigraphy							
Monday							
Tuesday	.992						
Wednesday	.547	.669					
Thursday	.561	.675	.982				
Friday	$p < .0001$	$p < .0001$	$p < .0001$	$p < .0001$			
Saturday	$p < .0001$	$p < .001$	.002	.004	.359		
Sunday	.491	.928	.809	.466	$p < .0001$	.001	
Parent logs							
Monday							
Tuesday	.181						
Wednesday	.730	.511					
Thursday	.127	.018	.021				
Friday	.331	.175	.267	.915			
Saturday	$p < .0001$	$p < .0001$	$p < .0001$	$p < .0001$	.002		
Sunday	.031	.002	.01	.153	.23	.001	
ICC (actigraphy vs. parent logs)	.758	.676	.577	.750	.788	.178	.722

Note. Significance levels are for post hoc Tukey honestly significant difference tests.

TABLE 4
 Number of Awakenings Each Night ($M \pm SD$) Recorded by Actigraphy and Parent Log

Variable	Actigraphy			Parent Log			t	p	n ²
	M	SD	n	M	SD	n			
Monday	5.89	3.53	54	0.67	0.97	57	10.48	<.001	.5
Tuesday	6.33	3.14	55	0.57	0.92	58	13.05	<.001	.6
Wednesday	6.50	3.34	54	0.48	0.80	58	12.74	<.001	.6
Thursday	6.80	3.57	54	0.45	0.88	58	12.69	<.001	.59
Friday	6.52	3.85	54	0.45	0.75	58	11.35	<.001	.54
Saturday	5.50	3.48	50	0.48	0.78	58	9.94	<.001	.48
Sunday	5.47	3.12	51	0.34	0.61	58	11.49	<.001	.55