Validating Actigraphy as a Measure of Sleep for Preschool Children

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Study Objectives: The algorithms used to derive sleep variables from actigraphy were developed with adults. Because children change position during sleep more often than adults, algorithms may detect wakefulness when the child is actually sleeping (false negative). This study compares the validity of three algorithms for detecting sleep with actigraphy by comparing them to PSG in preschoolers. The putative influence of device location (wrist or ankle) is also examined.

Methods: Twelve children aged 2 to 5 years simultaneously wore an actigraph on an ankle and a wrist (Actiwatch-L, Mini-Mitter/Respironics) during a night of PSG recording at home. Three algorithms were tested: one recommended for adults and two designed to decrease false negative detection of sleep in children.

Results: Actigraphy generally showed good sensitivity (> 95%; PSG sleep detection) but low specificity ($\pm$ 50%;

PSG wake detection). Intraclass correlations between PSG and actigraphy variables were strong (> 0.80) for sleep latency, sleep duration, and sleep efficiency, but weak for number of awakenings (< 0.40). The two algorithms designed for children enhanced the validity of actigraphy in preschoolers and increased the proportion of actigraphy-scored wake epochs scored that were also PSG-identified as wake. Sleep variables derived from the ankle and wrist were not statistically different.

Conclusion: Despite the weak detection of wakefulness, Actiwatch-L appears to be a useful instrument for assessing sleep in preschoolers when used with an adapted algorithm.

Keywords: Actigraphy, polysomnography, validation, children

Citation: Bélanger M; Bernier A; Paquet J; Simard V; Julie Carrier J. Validating actigraphy as a measure of sleep for preschool children. *J Clin Sleep Med* 2013;9(7):701-706.

Sleep is considered to be of paramount importance for brain development during the first two years of life.¹ In fact, children spend over half of their first two years of life sleeping, with daily sleep duration decreasing from 14.5 to about 13 hours between 6 months and 2 years of age.^{2,3} In the preschool years, daily sleep needs remain high, decreasing from 13 hours at 2 years to about 11 hours at 5 years.^{2,4} During infancy and childhood, frequent night awakenings or difficulty falling asleep are among the most frequent developmental complaints. Studies estimate that from 10% to 75% of parents report that their children have sleep problems.⁵ Importantly, sleep problems tend to persist during childhood⁶ and are associated with several adverse consequences for behavioral, cognitive, and emotional health. For example, it has been shown that sleep problems are associated with behavioral and emotional self-regulation problems.⁷ In fact, results suggest that when the sleep of preschoolers is insufficient or fragmented by wakefulness, they show more difficulty inhibiting emotional responses and more frequent impulsive and aggressive behavior.⁸ Poor sleep quality also seems associated with obesity in preschool children.⁹ Studies further suggest that sleep problems, whether occurring in infancy¹⁰ or at school age,^{4,11} are associated with lower cognitive performance. In light of the prevalence and the serious consequences of pediatric sleep problems, it is essential to accurately measure sleep quality in young children.

Studies and clinicians use different methods to assess children's sleep, each presenting strengths and weaknesses. For

BRIEF SUMMARY

Current Knowledge/Study Rationale: The algorithms used to derive sleep variables from actigraphy were developed with adults. Because children change position during sleep more often than adults, algorithms may detect wakefulness when the child is actually sleeping (false negative). This study compares the validity of three algorithms for detecting sleep with actigraphy by comparing them to PSG in preschoolers.

Study Impact: Despite the weak detection of wakefulness, Actiwatch-L appears to be a useful instrument for assessing sleep in preschoolers when used with an adapted algorithm. However, further studies are needed to validate its ability to detect wakefulness in pediatric populations with sleep disturbances.

example, parental retrospective child sleep questionnaires and prospective sleep diaries are often criticized because parents can notice that their children awaken only when the children signal it.¹² These measures are also influenced by the reporter's perception (usually the mother).¹³ Videosomnography and direct behavioral observations are often used in home settings, but they may interfere with family routines and privacy.¹³ Although polysomnography (PSG) is the gold standard for measuring sleep,^{13,14} it requires considerable equipment and technical resources. Furthermore, this invasive method may interfere with sleep, and therefore mask habitual sleep quality.¹³

Actigraphy, which uses a watch-size movement sensor to determine sleep and wake episodes, provides a useful alternative: the device is small and inexpensive, and it allows for

Figure 1—Linear regression between activity counts at the wrist and ankle

Equation and percentage of fit are also illustrated.

multiple-day data collection. Actigraphy is also easily used in a child's natural environment, thereby conferring ecological validity to collected sleep data. However, the standard algorithms proposed in the literature were developed with adults, and have not been definitively validated with children. Because it has been shown that children change position during sleep more often than adults,¹⁵ it is crucial to develop child-specific algorithms. Sitnick et al.¹⁹ showed that an algorithm commonly used with adults is too sensitive with a population of young children, resulting in high false negative rates (i.e., actigraphy detects wakefulness when the child is probably sleeping). In fact, although several studies with infants and children have reported that various actigraphy devices are highly correlated (> 80%) with PSG or videosomnography,^{14,16-23} most of these studies have shown very low ability to correctly identify wakefulness^{14,17,19,22} and hence, sleep fragmentation.²⁴ Nevertheless, the American Academy of Sleep Medicine (AASM) states that the use of actigraphy in normal children and special pediatric populations is indicated for the assessment of sleep patterns and response to treatment.^{25,26} However, the AASM also mentions that additional research is warranted to further refine and broaden the clinical utilization of actigraphy. Notably, additional research is needed to validate actigraphy against PSG.

Sitnick and colleagues proposed adapting an adult algorithm to reduce false negatives when the child is sleeping but shows high activity.¹⁹ However, this algorithm has not been validated in preschoolers against PSG. The present study aims to compare the validity of three algorithms for detecting sleep with actigraphy by comparing them to PSG in preschoolers.

Three algorithms are tested: one recommended for adults and two designed to decrease false negative detections of wakefulness. Because preschool is a transition period between infancy (when the actigraph is worn on the ankle because the wrist is too small for most devices) and school age (when the device is most frequently worn on the wrist), we also examined the putative influence of device location (wrist or ankle).

METHODS

Subjects

Twelve children (4 boys, 8 girls) aged from 2 to 5 years ($M = 3.1$, $SD = 1.0$) participated in this study. None had sleep problems, according to their parents. The project was approved by the institutional review board of the investigators' university. The parents of all participants signed a consent form that informed them on the nature and risks of participating, and they received financial compensation for the study.

Procedures

Children simultaneously wore an actigraph (Actiwatch-L, Mini-Mitter/Respironics) on the non-dominant ankle and wrist during a night of PSG recording in their home. A qualified technician and a research assistant went to the homes 1 h before each child's usual bedtime (as previously reported by the parents over the phone) to install the PSG and actigraphy recording equipment. No child refused to wear the equipment. Precise synchronization between the PSG and actigraph is required to assess epoch-by-epoch concordance. Prior to each sleep recording, the PSG and the actigraphs were precisely synchronized with the main server. PSG records and actigraphy activity bursts were then visually inspected to detect any temporal gaps between the 2 measures. Once the child was asleep, the technician and the research assistant left the home. The research assistant returned in the morning to remove the electrodes and bring the equipment back to the laboratory.

Measures

Actigraphy

Non-dominant wrist and ankle activity were recorded using an Actiwatch-L (Mini Mitter Co., Inc., Respironics, Inc., Bend, OR). Actigraphy data were collected in 30-s epochs. Two Actiwatch-L activity monitors were used. The same monitor was used on the wrist or the ankle for all children. To calibrate the 2 monitors, they were fixed to a piece of wood ($3/4'' \times 3'' \times 12''$) that rotated on a vertical axis at 15 different intensities. Estimated activity counts differed between the 2 actigraphs even if induced movements at the 15 intensities were identical for the 2 actigraphs (see **Figure 1**). Consequently, a regression was used to adjust the monitor with higher activity counts (ankle) to activity counts of the other (wrist; $y = 0.513x$). Both raw and adjusted data are presented in this paper.

PSG Recordings

A digital ambulatory sleep recording system (Vitaport-3 System; TEMEC Instruments, Kerkrade, The Netherlands) was used to record sleep at home. Electroencephalograph (EEG) electrodes (Cz, Oz) were placed according to the international 10-20 system, using a referential montage with linked ears, right and left electrooculogram (EOG), and chin electromyogram (EMG). EEG signals were filtered at 70 Hz (low pass) with 1-s time constant and digitized at a sampling rate of 256 Hz. Sleep stages were scored visually on-screen with 30-s epochs (Stellate System, Montreal) according to the AASM cri-

teria,²⁷ but using only the C4 derivation. The 30-s epochs were chosen to match the 30-s actigraphy epochs.

Data Analysis

Two sets of analyses were performed to determine PSG and actigraphy agreement: an epoch-by-epoch agreement analysis and a sleep variables concordance analysis. The epoch-by-epoch agreement analysis provided sensitivity, specificity, accuracy, and negative predictive value (NPV) parameters. Sensitivity was defined as the proportion of all epochs scored as sleep by PSG that were also scored as sleep by actigraphy. Specificity was the proportion of all epochs scored as wake by PSG that were also scored as wake by actigraphy. Accuracy was the proportion of all epochs correctly identified by actigraphy. NPV was the proportion of epochs scored as wake by actigraphy that were also scored as wake by PSG. The second set of analyses involved comparisons between sleep variables estimated with PSG and with actigraphy.

Three methods of scoring the actigraphy-derived sleep/wake activity counts were applied. The first 2 were threshold-based method algorithms included in the Actiwatch-L software (Mini Mitter Inc. Respironics, Inc. Bend, OR). Actiware uses a weighting algorithm with 3 different thresholds: low (20), medium (40), and high (80), which were validated on sleep disordered patients. They score original activity counts by a weighting scheme that reflects the temporal distance relative to the scored epoch. Each 30-s epoch is rescored as follows:

$$A = 0.04E_{-4} + 0.04E_{-3} + 0.2E_{-2} + 0.2E_{-1} + 2E_0 + 0.2E_{+1} + 0.2E_{+2} + 0.04E_{+3} + 0.04E_{+4}$$

where A = the sum of activity counts for the 30-s scored epoch and the surrounding epochs; and E_n = the activity counts for the previous, successive, and scored epoch. If the summed activity count exceeds the defined threshold, the epoch is scored as wake; otherwise it is scored as sleep. The 40 (ACT40) and 80 (ACT80) activity count thresholds were used in the present study because the ACT40 is widely used with adult populations, whereas the ACT80 requires more movement to score an epoch as wake (and thus could presumably be more appropriate for children, who move more frequently than adults when asleep).

The third actigraphy scoring method (AlgoSmooth) used in the current study is described in a paper by Sitnick and colleagues¹⁹ and has never been validated with PSG. These authors rescored or secondarily “smoothed” actigraphy data derived from the ACT40 sensitivity threshold to reduce the number of awakenings per night to a range more consistent with parent diaries and video recordings. More precisely, this method requires a minimum 2-min awakening period following sleep onset (WASO) to score an awakening. The scoring criteria are:

1. When ≥ 2 consecutive minutes with activity counts > 100 were immediately preceded by any activity count above 0, that epoch was considered the start of the awakening;
2. The end of a wake period, or a return to sleep, was scored at the first of 3 consecutive 0s (no activity).

This third method was automated using an Excel (Microsoft, Redmond, WA) spreadsheet.

Four sleep variables were calculated, with the same definitions for PSG and the 3 actigraphy scoring algorithms. The sleep variables derived from PSG, from the 2 threshold-based method algorithms (ACT40 and ACT80) and from the smoothed algorithm (AlgoSmooth), were calculated using an in-house visual C++ program. Sleep latency was defined as the number of minutes from the time of lights off to the first 10 successive sleep epochs (the default criterion for the Actiware program). Total sleep time (TST) was the number of minutes scored as sleep from lights off to lights on. The number of awakenings was equal to the number of wake periods. Sleep efficiency (SE) was $TST/\text{total recording time} \times 100$.

Statistical Analyses

Two-way repeated measures ANOVAs with activity type (ankle, raw wrist, and adjusted wrist) and algorithm (ACT40, ACT80, and AlgoSmooth) as factors were performed on sensitivity (ability to detect PSG sleep), specificity (ability to detect PSG wake), accuracy (PSG sleep and PSG wake), and NPV (percentage of wake detected by actigraphy that is PSG wake). Similarly, 2-way repeated measures ANOVAs with activity type (ankle, raw wrist, and adjusted wrist) and scoring method (PSG, ACT40, ACT80, and AlgoSmooth) as factors were performed on sleep variables. Simple effect analyses were performed when significant activity type by algorithm interactions were found. The post hoc Tukey HSD test was used for multiple comparisons of means on significant main effects. Since repeated measures had more than 2 levels, the Huynh-Feldt correction for sphericity was applied, but epsilon values and original degrees of freedom are reported. The Dunnett post hoc test was also used to determine whether the results derived from the actigraphy algorithms differed significantly from the PSG-derived results. Finally, to assess PSG and actigraphy agreement, intraclass correlations were computed on the 4 sleep variables. Statistical analyses were conducted using SPSS version 17 (SPSS Inc., Chicago, IL). Significance level was set at 0.05.

RESULTS

Epoch-by-Epoch Agreement

Sensitivity, specificity, accuracy, and NPV values (means and SD) derived from epoch-by-epoch comparisons between each actigraphy scoring algorithm and PSG for the 3 activity types are presented in **Table 1**. Overall, sensitivity was higher than 88%, whereas specificity was lower (from 57% to 81%).

A 2-way repeated measures ANOVA performed on sensitivity revealed an interaction between algorithm and activity type, $F_{4,44} = 13.02$, $p < 0.001$; $\epsilon = 0.63$. AlgoSmooth showed the highest sensitivity and ACT40 the lowest, with ACT80 in between, but these differences were more pronounced for adjusted wrist data. A significant interaction between algorithm and activity type was also found for specificity, $F_{4,44} = 4.08$, $p = 0.045$, $\epsilon = 0.38$. ACT40 showed the highest specificity and AlgoSmooth showed the lowest, with ACT80 in between, for both adjusted wrist and ankle data. For raw wrist data, ACT40 also showed the highest specificity, but specificity did not differ between ACT80 and AlgoSmooth activity type. The 2-way repeated measures ANOVA performed on accuracy revealed an

Table 1—Means ($\pm$ SD) for sleep sensitivity, specificity, accuracy, and NPV of epoch-by-epoch comparisons with PSG of the three actigraphy scoring algorithms with the three activity types

Statistical parameter	Activity type	Scoring algorithms		
		ACT40	ACT80	AlgoSmooth
Sensitivity (%)	Ankle	90.5 (2.8)	95.0 (1.8)	97.6 (2.1)
	Raw wrist	92.7 (2.7)	95.8 (1.9)	98.7 (1.3)
	Adjusted wrist	87.9 (2.7)	93.4 (1.6)	97.7 (1.6)
Specificity (%)	Ankle	75.1 (19.2)	65.0 (18.8)	57.7 (26.3)
	Raw wrist	69.9 (16.4)	56.7 (18.4)	58.7 (21.1)
	Adjusted wrist	81.0 (14.8)	70.9 (16.3)	61.2 (21.1)
Accuracy (%)	Ankle	89.3 (3.5)	92.1 (2.9)	94.6 (2.9)
	Raw wrist	90.7 (3.0)	92.4 (2.6)	95.6 (2.0)
	Adjusted wrist	87.5 (2.8)	91.4 (2.1)	95.0 (2.2)
NPV (%)	Ankle	41.7 (13.7)	53.7 (15.3)	76.8 (17.0)
	Raw wrist	47.4 (15.8)	55.0 (18.8)	81.0 (13.0)
	Adjusted wrist	39.4 (13.3)	49.6 (14.7)	72.1 (14.1)

ACT40, Actiware medium threshold algorithm; ACT80, Actiware high threshold algorithm; AlgoSmooth, Sitnick et al.'s smoothing algorithm; NPV, negative predictive value.

Table 2—Sleep parameters (mean $\pm$ SD) scored with PSG and estimated by the three actigraphy scoring algorithms with the three activity types

Sleep parameters	Activity type	PSG ^a	Scoring algorithms		
			ACT40	ACT80	AlgoSmooth
Sleep latency (min)	Ankle	34.5 (20.2)	31.9 (22.3)	29.3 (22.2)	28.9 (21.8)
	Raw wrist		34.3 (23.8)	33.0 (24.0)	29.9 (22.1)
	Adjusted wrist		34.3 (21.5)	32.3 (22.2)	32.7 (21.5)
Total sleep time (min)	Ankle	558.8 (49.2)	518.7 (49.0)**	549.3 (49.5)	564.0 (50.7)
	Raw wrist		533.8 (49.5)**	558.5 (50.6)	571.8 (54.0)**
	Adjusted wrist		500.7 (48.2)**	537.3 (50.0)**	565.1 (54.0)
Sleep efficiency (%)	Ankle	90.9 (3.5)	84.4 (4.9)**	89.4 (4.3)	92.1 (5.1)
	Raw wrist		86.8 (3.9)**	90.8 (3.2)	92.8 (3.9)*
	Adjusted wrist		81.5 (4.3)**	87.4 (3.5)**	91.9 (4.1)
Number of awakenings	Ankle	23.0 (9.8)	59.0 (9.5)**	51.1 (12.5)**	3.1 (2.0)**
	Raw wrist		60.0 (13.5)**	49.1 (14.5)**	2.2 (1.3)**
	Adjusted wrist		58.3 (11.0)**	57.3 (14.1)**	3.3 (1.4)**

^aActivity type does not apply to PSG. ACT40, Actiware medium threshold algorithm; ACT80, Actiware high threshold algorithm; AlgoSmooth, Sitnick et al.'s smoothing algorithm. Asterisks denote a significant difference (* $p \leq 0.05$ and ** $p \leq 0.01$) between the sleep parameters derived from PSG and from actigraphy algorithms.

interaction between algorithm and activity type, $F_{4,44} = 5.92$, $p = 0.003$; $\epsilon = 0.70$. AlgoSmooth showed the highest accuracy and ACT40 the lowest, with ACT80 in between, but these differences were more pronounced for adjusted wrist data. A 2-way repeated measures ANOVA performed on NPV showed an algorithm effect only, $F_{2,22} = 33.0$, $p < 0.001$, $\epsilon = 0.52$. Post hoc mean comparisons showed significant differences ($p < 0.05$) among the 3 algorithms, with AlgoSmooth showing the highest NPV (AlgoSmooth: 76.6%; ACT80: 52.7%; and ACT40: 42.8%).

Sleep Variable Concordance

Sleep variables calculated from PSG and estimated with the 3 actigraphy scoring algorithms for the 3 activity types are pre-

sented in **Table 2**. Sleep latency derived from the 3 algorithms did not differ significantly from PSG. A significant interaction between algorithm and activity type was found for TST ($F_{6,66} = 10.81$, $p < 0.01$; $\epsilon = 0.62$) and for SE ($F_{6,66} = 13.42$, $p < 0.001$; $\epsilon = 0.78$). Dunnett post hoc results showed that the ACT40 algorithm underestimated TST by > 25 min and SE by $> 4\%$ ($p < 0.001$) compared to PSG for the 3 activity types (ankle, raw wrist, and adjusted wrist). TST and SE derived from ACT80 and AlgoSmooth did not differ significantly from PSG when using ankle or raw wrist data. However, when using adjusted wrist data, ACT80 underestimated TST by 21 min and SE by 3.5% ($p < 0.001$), whereas AlgoSmooth overestimated TST by 6 min and SE by 1% ($p < 0.001$). Finally, a 2-way repeated measures ANOVA performed on number of awaken-

Table 3—Intraclass correlations between sleep parameters (mean $\pm$ SD) scored with PSG and estimated by the three actigraphy scoring algorithms with the three activity types

Sleep parameters	Activity type	Scoring algorithms		
		ACT40	ACT80	AlgoSmooth
Sleep latency (min)	Ankle	0.83*	0.85*	0.81*
	Raw wrist	0.92*	0.92*	0.75*
	Adjusted wrist	0.96*	0.96*	0.93*
Total sleep time (min)	Ankle	0.94*	0.95*	0.91*
	Raw wrist	0.94*	0.95*	0.98*
	Adjusted wrist	0.94*	0.97*	0.98*
Sleep efficiency (%)	Ankle	0.80*	0.81*	0.77*
	Raw wrist	0.73*	0.70*	0.93*
	Adjusted wrist	0.76*	0.82*	0.90*
No. of awakenings	Ankle	0.01	0.09	0.14
	Raw wrist	0.42	0.32	0.05
	Adjusted wrist	0.28	0.36	0.36

ACT40, Actiware medium threshold algorithm; ACT80, Actiware high threshold algorithm; AlgoSmooth, Sitnick et al.'s smoothing algorithm. * $p \leq 0.01$.

ings showed an algorithm effect only, $F_{6,66} = 139.93$, $p < 0.001$, $\epsilon = 0.62$, with ACT40 and ACT80 yielding a significantly higher number of awakenings and AlgoSmooth a lower number of awakenings than PSG ($p < 0.001$).

Table 3 shows the intraclass correlations between sleep parameters derived from PSG and estimated from the 3 actigraphy scoring algorithms for the 3 activity types. In general, the correlation coefficients were high for all algorithms and activity types regarding sleep latency (ICC > 0.75), TST (ICC > 0.91), and SE (ICC > 0.70). In contrast, the correlations were low for all algorithms and activity types regarding number of awakenings (ICC < 0.42).

DISCUSSION

We evaluated the ability of the Actiwatch-L device to detect sleep/wake in preschool children using three algorithms. Results clearly showed that the Actiwatch-L is better able to detect sleep than to detect wake. Importantly, ACT80 and AlgoSmooth enhanced the ability of actigraphy to detect sleep in preschool children compared to ACT40. However, ACT80 and AlgoSmooth decreased the ability of actigraphy to detect wakefulness compared to ACT40. The low specificity (about 60% of PSG wakefulness is scored as wakefulness by actigraphy) observed in our data is similar to that found in previous studies that compared different brands of actigraphy with PSG in infants^{14,20} and children,^{17,21} highlighting the difficulty of correctly identifying wake with actigraphy. Nevertheless, when the actigraphs scored wake, AlgoSmooth showed higher agreement with PSG (NPV = 76.6%) than the other two algorithms (42.8% and 52.7%), suggesting that AlgoSmooth is better suited for this purpose. Importantly, the general accuracy of actigraphy to detect sleep and wake remained high, despite the low specificity, probably because most of the assessed intervals consisted of sleep.

Statistical comparisons between sleep variables derived from actigraphy and PSG as well as intraclass correlations

suggest that ACT80 and AlgoSmooth performed better overall than ACT40 in preschoolers. Except for number of awakenings, ACT80 and AlgoSmooth showed no substantial differences from PSG, and intraclass correlations were high. Consequently, the results suggest that ACT80 and particularly AlgoSmooth should be used with populations of preschoolers. The two Actiware algorithms (ACT40 and ACT80) clearly overestimated the number of awakenings, whereas AlgoSmooth underestimated them. These results indicate that number of awakenings is not a valid indicator of sleep quality when assessed with actigraphy in preschoolers. For this reason, we attempted to adapt the smoothing algorithm (AlgoSmooth) described by Sitnick and colleagues¹⁹ to increase the number of awakenings detected. The adapted criteria were: (1) when there was 1 or more consecutive minute(s) with activity counts greater than 100, that epoch was considered to be the start of the awakening; (2) the end of a wake period, or a return to sleep, was scored at the first of 3 consecutive 0s (no activity). This method was automated using a Matlab function and was applied to the wrist data. The number of awakenings estimated by this adapted algorithm did not significantly differ from the number of awakenings derived from PSG ($M = 22.6$, $SD = 6.0$ for the adapted algorithm vs $M = 23.0$, $SD = 9.8$ for PSG, $t_{11} = -0.20$, $p = 0.85$). Unfortunately this was at the expense of sensitivity and accuracy; these were significantly lower with AlgoSmooth, which had higher values (sensitivity: $M = 88.4$; $SD = 4.2$, $t_{11} = -5.83$, $p < 0.001$; accuracy: $M = 87.8$; $SD = 3.6$, $t_{11} = -7.11$, $p < 0.001$). Hence compared to PSG, the adapted algorithm showed lower sleep efficiency ($M = 80.6$; $SD = 6.2$ vs $M = 90.9$, $SD = 3.5$; $t_{11} = -9.85$, $p < 0.001$) and reduced sleep duration ($M = 495.5$; $SD = 56.3$ vs $M = 558.8$, $SD = 49.2$; $t_{11} = -10.07$, $p < 0.001$), and was therefore discarded. These results further suggest that actigraphy-derived number of awakenings is not a valid indicator of sleep quality with preschoolers.

To our knowledge, most laboratories use actigraphy without calibration. In this study, when similar movements were

induced, estimated activity counts differed between the two actigraphs. The criteria for most algorithms to determine wake and sleep require absolute activity counts. Thus, for similar movements, actigraphs with higher activity counts will detect more wakefulness than those with lower activity counts. This is reflected in our data by lower sleep efficiency with adjusted than raw wrist data. Importantly however, when using ACT80 or AlgoSmooth, sleep variables derived from ankle, raw wrist, and adjusted wrist data were comparable.

Overall, the Actiwatch-L appears to be an effective instrument for assessing sleep in preschoolers. However, further studies are needed to validate its ability to detect wakefulness in pediatric populations with sleep disturbances.

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ACKNOWLEDGMENTS

This study was supported by funding from the Fonds de Recherche en Santé du Québec (FRSQ) and the Natural Sciences and Engineering Research Council of Canada (NSERC). We thank Sonia Frenette (project coordinator), Manon Robert (research assistant), Nicolas Pellerin, and Jonathan Godbout (computer programmers) for help with data collection and analysis.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication August, 2012

Submitted in final revised form January, 2013

Accepted for publication February, 2013

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DISCLOSURE STATEMENT

This was not an industry supported study. The authors have indicated no financial conflicts of interest.