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Assessing the Efficacy to Conduct the Multiple Sleep Latency Test With Actigraphy

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This study explored the efficacy of 1 actigraphy (ACT) brand, at different analytic settings, for use to administer the Multiple Sleep Latency Test (MSLT). Forty-one first-time postpartum mother and father participants were administered the MSLT with concurrent ACT. To identify ACT sleep onset latency (SOL), ACT signals were interpreted with iterations of different “wake threshold value” (WTV) and “immobile minutes for sleep onset” value (IMV) settings. The different iterations of ACT–SOL values were compared to MSLT–SOL values. The WTV settings did not affect ACT–SOL, but the ACT–SOL and MSLT–SOL significantly differed at each ACT–IMV setting. ACT consistently identified SOL too soon; however, future research, along with technological innovation, may identify a viable methodology to conduct an ambulatory MSLT.

Technological advances allow sleep medicine clinicians and researchers more valid and less-expensive methods of assessing sleep and sleepiness. The purpose of this study was to examine the validity of using actigraphy (ACT), at different analytic settings, to administer the Multiple Sleep Latency Test (MSLT; Carskadon et al., 1986).

The MSLT is the most widely used and accepted method to objectively index sleepiness via sleep onset latency (SOL; Afifi, Kushida, & Carskadon, 2005; Arand et al., 2005; Littner et al., 2005). For a description of MSLT practice parameters, see Littner et al. (2005). The MSLT is limited to the polysomnography (PSG) clinic or laboratory setting, and requires expertise to administer (Carskadon et al., 1986), making it relatively expensive, time-consuming, available primarily to those in more urban settings, and can be considered invasive by the patient/participant. The standard laboratory administration of the MSLT does not currently

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permit a naturalistic environment under which sleepiness can be measured, potentially limiting its ecological validity.

ACT, or activity-based monitoring, uses wrist movements to identify periods of sleep and wake via a piezoelectric accelerometer data interpretation via computer-based algorithms. ACT is a valid instrument for measurement of various sleep parameters among healthy adults, as well as among some clinical populations (Ancoli-Israel et al., 2003; de Souza et al., 2003; Paquet, Kawinska, & Carrier, 2007); furthermore, a Current Procedural Terminology Category code was established for ACT in 2009. For a description of ACT practice parameters, see Morgenthaler et al. (2007). Limitations of ACT include that its signals are vulnerable to sleep/wake misinterpretation within periods of immobility during wake, motility during sleep, and during sleep/wake transitions (Sadeh & Acebo, 2002). ACT is generally understood to prematurely identify SOL (de Souza et al., 2003; Morgenthaler et al., 2007). For example, a validation study of ACT among a sample of adults with insomnia indicated that when compared to PSG, ACT—when set to “high sensitivity”—was not a satisfactory measure of SOL (Lichstein et al., 2006). Conversely, when a variety of ACT settings were used to examine ACT and PSG agreement during a daytime nap, when set to the high sensitivity level, ACT significantly predicted sleep latency (Kanady, Drummond, & Mednick, in press). Together, these works indicate that ACT may be a viable option to identify sleep onset among certain populations and under certain conditions. Advantages of ACT include that it can be used in a naturalistic environment; it is relatively inexpensive; once activated, an actigraph is portable for several days; and actigraphs have a nonvolatile memory allowing transport to and from the clinic or research center even via postal mail.

Previous work has been conducted to examine methodologies that could accurately identify SOL (Abeyratne, Vinayak, Hukins, & Duce, 2009; Cantero, Atienza, Stickgold, & Hobson, 2002), and potentially provide ambulatory alternatives to the cumbersome laboratory-based MSLT protocol (McLaren, Hauri, Lin, & Harris, 2002). In addition to increased feasibility, an ambulatory MSLT may provide a more ecologically valid measure of sleepiness than the standard laboratory-based test because it may avoid an MSLT equivalent “first-night effect” (Agnew, Webb, & Williams, 1966).

Experts have called for further examinations of ACT to potentially broaden its clinical value (Morgenthaler et al., 2007); for example, ACT may have the capacity to screen for sleep disorders (Sadeh & Acebo, 2002), and can be used to identify stable sleep patterns prior to overnight PSG and MSLT (Morgenthaler et al., 2007). Furthermore, previous work indicates that, despite the tendency of ACT to misinterpret motion signals during sleep/wake transitions, specific analytic settings can be adjusted to yield distinctly different, and more accurate, data interpretations (Chae et al., 2009). If ACT accurately identifies SOL under specific analytic settings, the instrument could serve as a viable and more cost-effective method to conduct an ambulatory MSLT for research, or to screen individuals who may need further evaluation.

METHOD

Sample

Postpartum mother and father couples were recruited via a larger laboratory study of postpartum sleep, which was approved by the West Virginia University Office of Research Compliance insti-
tutional review board. Couples were first-time postpartum parents who cohabitated. Participants were administered informed consent and Health Insurance Portability and Accountability Act authorization prior to participation. These participants were selected as an appropriate group for this validation study because they were expected to have disturbed nocturnal sleep and generally high levels of sleepiness (due to infant nocturnal caregiving responsibilities), yet they would not have overt sleep disorders. Couples were excluded on the basis of a history of major depressive or anxiety disorder, a score ≥16 on the Center for Epidemiological Studies of Depression (Radloff, 1977), pregnancy with multiples, and prior diagnosis of a sleep disorder.

One father’s MSLT and two mothers’ MSLT–SOL values, for one nap each, were excluded from the analyses due to equipment malfunction and non-adherence to protocol, respectively. Excluded nap data were removed from the corresponding ACT–SOL averages. Participants were N = 41 first-time mothers (n = 21) and fathers (n = 20), who participated during their M = 6.93 (SD = 1.26) postpartum week.

Procedure

Participants wore the ACT and kept a concurrent sleep diary in their home environment the night prior to the MSLT. The following morning, participants came to the research laboratory within 2 hr of awakening for the day, were outfitted with PSG sensors, and were administered a four-nap MSLT (American Academy of Sleep Medicine [AASM], 2007; Littner et al., 2005) with concurrent wrist ACT. Four 20-min nap opportunities were provided every 2 hr starting from the first opportunity. Following PSG impedance checks and calibrations, each MSLT nap opportunity began with the instruction, “Please press the event marker on your actigraph. Please lie quietly, assume a comfortable position, keep your eyes closed, and try to fall asleep.” The instruction was simultaneous with the beginning of the PSG recording session (“lights out”). Sleep onset was scored according to standard criteria (AASM, 2007). If participants fell asleep within the first 5 min of the nap opportunity, the nap opportunity was terminated 20 min following lights out; if participants fell asleep after 5 min, the nap opportunity continued for 15 min following sleep onset. Participants were instructed to push the event marker on their actigraph simultaneous with termination of the nap opportunity. Between one of the nap opportunities, participants were verbally administered a 10-item sleep disorders symptoms screening chart to better understand their typical sleep behaviors; each item was rated on a scale of 0 (never) to 10 (severe) (Thorpy, 2003). Example survey items included, “Do you gasp, choke, or stop breathing during sleep?”; “Do your arms and legs jerk and twitch during sleep?”; and “Do you have occasional sleeplessness at home or during trips?”

Multiple Sleep Latency Test

The MSLT was conducted in the sleep research laboratory at West Virginia University. The PSG montage included four channels of electroencephalography (C3/M2, C4/M1, O1/M2, and O2/M1), electrooculography (right outer canthus/M1 and left outer canthus/M2), electromyography (submentalis), and electrocardiography. PSG was conducted with the Embla N7000 multichannel PSG recording system. Rembrandt software was used to manage, analyze, and archive PSG data.

The PSG data from the MSLT were visually scored according to the AASM PSG scoring criteria (AASM, 2007). Sleep onset was identified by the first epoch of three consecutive 30-sec
epochs that were unequivocally scored as sleep. SOL was scored as the time from the initiation of the MSLT trial (lights out) to sleep onset. The MSLT yielded SOL scores for each MSLT trial; these scores were then averaged to yield the MSLT–SOL.

ACT

Continuous, nonintrusive activity monitoring was recorded with Mini Mitter’s Actiwatch-64 (AW-64) actigraphs (Philips Respironics, Bend, OR). The highest resolution collection was set at 15-sec epochs, and a manual event marker was used. Actiware software version 5.5 was used to manage, analyze, and archive ACT data. Once ACT data were collected according to the 15-sec sampling epoch, the Actiware software permitted post hoc manipulations to specific analytic settings. The specific analytic settings impact the way the entire recorded sleep interval is interpreted and, thus, change the resultant sleep variables; for this study, we only examined the SOL variable.

The Actiware software algorithm utilizes analytic calculations that score individual epochs as sleep or wake with the use of the “wake threshold value” (WTV). An activity value for each epoch was compared to the WTV; epoch values greater than the WTV were scored as wake. The default WTV parameter setting for the AW-64 is 40. Three different WTVs were manipulated within the analysis software to examine these data: WTV 20, WTV 40, and WTV 80. At WTV 20, an activity value of 37 would indicate wake; at WTV 80, that same activity value would indicate sleep. The WTV settings used were based on the three optional settings provided by Actiware.

The Actiware software algorithm also concurrently utilizes an analytic calculation that scores the beginning of sleep onset with the use of the “immobile minutes for sleep onset” value (IMV). The IMV was the number of consecutive minutes that were scored as immobile (i.e., no movement) before ACT identified sleep onset. The default IMV parameter setting for the AW-64 is 10 min. Three different IMVs were manipulated within the analysis software to examine these data: IMV-2, IMV-5, and IMV-10. At IMV-2, four consecutive minutes of immobility would indicate sleep; at IMV-10, three consecutive minutes of immobility would not indicate sleep. The IMV-10 was the Actiware default setting; the other two settings used for analysis were chosen to provide an appropriate range of IMV values.

The Actiware software algorithm utilizes both the WTV and IMV analytical settings, together, to interpret each recorded sleep interval and yield resulting sleep variables. The variable of interest derived from ACT was SOL (ACT–SOL). ACT–SOL is the time in minutes between the press of the event marker (which corresponded to the MSLT “lights out”) and the first epoch that ACT scored as sleep. The applications of different ACT analytic settings lead to a variation of where ACT identified the first epoch of sleep; thus, each setting altered the ACT–SOL value. To be comparable to the MSLT–SOL, the ACT–SOL values were averaged for the four naps according to each manipulated analytic setting.

Statistical Analyses

SPSS 16.0 (SPSS, Inc., Chicago, IL) was used for statistical calculations; a \( p < .05 \) was considered statistically significant. Descriptive statistics were calculated for demographic, PSG, and ACT measures.

All iterations of the ACT WTV and IMV analytic settings were calculated, and were then used to independently examine the agreement between ACT–SOL and MSLT–SOL. Bland-
Altman graphical comparison plots (Altman & Bland, 1983) with reference to the MSLT–SOL were calculated to evaluate the level of agreement between MSLT–SOL and ACT–SOL. For this exploratory purpose, we considered a clinically successful level of agreement within \( \pm 2 \) min of no difference. Paired-samples \( t \) tests were calculated to examine differences between PSG–SOL and ACT–SOL measures, and Pearson correlations were calculated to examine associations between the variables.

### RESULTS

#### Participants

Participant descriptive information is shown in Table 1. As indicated by previous night ACT data, parents appeared sleep disturbed. The sleep disorder symptom screening score was low, and no sleep disorder symptom was significantly associated with MSLT–SOL values; this supports our intention to include participants with sleep disturbance who were without overt sleep disorder symptoms. Mothers and fathers were combined within the analyses because they were not expected to differ on their motoric profiles, and the range of sleepiness levels would be widened, allowing each Bland-Altman plot to reveal agreement across a larger spectrum of samples.

#### ACT-Adjusted Parameter Settings

Mean differences between MSLT–SOL and ACT–SOL were calculated for the nine combinations of ACT analytic settings. Although wake threshold settings are known to change the way that ACT measures sleep and wake (Paquet et al., 2007), WTV alterations did not have an effect on how SOL was identified in this study. Therefore, changing the WTV parameter did

<table>
<thead>
<tr>
<th>Variable</th>
<th>( M \pm SD )</th>
<th>Range</th>
<th>PSG–SOL Difference</th>
<th>( M \pm SD )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>27.65</td>
<td>4.72</td>
<td>18.44–38.44</td>
<td>—</td>
</tr>
<tr>
<td>Education (years)</td>
<td>15.59</td>
<td>3.58</td>
<td>9.00–23.00</td>
<td>—</td>
</tr>
<tr>
<td>Income ($$)</td>
<td>56,091</td>
<td>34,320</td>
<td>6,900–110,000</td>
<td>—</td>
</tr>
<tr>
<td>Nocturnal sleep time (minutes)</td>
<td>345.60</td>
<td>78.80</td>
<td>208.80–477.75</td>
<td>—</td>
</tr>
<tr>
<td>Nocturnal sleep efficiency (%)</td>
<td>79.50</td>
<td>8.50</td>
<td>55.52–92.24</td>
<td>—</td>
</tr>
<tr>
<td>Sleep disorders symptoms (average)</td>
<td>2.24</td>
<td>1.43</td>
<td>0.00–6.70</td>
<td>—</td>
</tr>
<tr>
<td>PSG–SOL (minutes)</td>
<td>9.96</td>
<td>4.64</td>
<td>3.13–20.00</td>
<td>—</td>
</tr>
<tr>
<td>ACT–SOL IMV-2 (minutes)</td>
<td>0.67</td>
<td>0.69</td>
<td>0.00–2.69</td>
<td>9.29</td>
</tr>
<tr>
<td>ACT–SOL IMV-5 (minutes)</td>
<td>2.18</td>
<td>2.46</td>
<td>0.06–10.31</td>
<td>7.82</td>
</tr>
<tr>
<td>ACT–SOL(^a) IMV-10 (minutes)</td>
<td>6.46</td>
<td>5.60</td>
<td>0.13–20.00</td>
<td>3.49</td>
</tr>
</tbody>
</table>

*Note.* PSG = polysomnography; SOL = sleep onset latency; ACT = actigraphy; IMV = immobile minutes for sleep onset.

\(^a\)Indicates ACT default value settings.
not affect the difference between ACT and PSG SOL times, whereas the IMV parameter did. Therefore, we used only the default WTV = 40 paired with the three IMV parameter values to examine MSLT–SOL and ACT–SOL agreement (see Figure 1). The difference between MSLT–SOL and ACT–SOL was significant at IMV-2, \( t(40) = 12.80, p < .001 \); IMV-5, \( t(40) = 9.50, p < .001 \); and IMV-10, \( t(40) = 3.29, p < .01 \). MSLT–SOL and ACT–SOL were not significantly correlated at IMV-2 (\( r = .07, p = .68 \)), IMV-5 (\( r = .01, p = .94 \)), and IMV-10 (\( r = .13, p = .42 \)). Again, WTV = 40 and IMV-10 were ACT default value settings. Mean difference values between MSLT–SOL and ACT–SOL are indicated in Table 1.

Nap-by-Nap Comparisons

For exploratory purposes, we examined the possibility of comparing MSLT–SOL and ACT–SOL nap by nap instead of by average across all four nap opportunities. In line with this method, individual nap opportunity MSLT–SOLs and the default ACT–SOLs were significantly different, \( t(161) = 4.67, p < .001 \); and were not significantly associated (\( r = .03, p = .67 \)) even when controlling for the number of nap opportunities (\( r = .05, p = .52 \)).

DISCUSSION

Overall, ACT consistently identified sleep onset too soon. Different IMV settings affected the ACT data interpretation and, thus, altered MSLT–SOL and ACT–SOL agreement. However, none of the settings appeared to make ACT a viable option for administration of the MSLT as it was utilized in this study. We postulate that the reason ACT recorded immobility during PSG-identified wake was because participants followed the MSLT instructions—to “lie quietly.” Therefore, a more sensitive ACT measure or algorithm may permit a more precise detection of a sleep/wake transition.

As demonstrated in Figure 1, the difference between ACT–SOL and MSLT–SOL appears linear for IMV-2 and IMV-5. This linear pattern is governed by the fact that when ACT signals were interpreted under shorter IMV settings, ACT almost immediately identified sleep onset for all nap opportunities. Therefore, when ACT–SOL (e.g., 0.5 min) and MSLT–SOL (e.g., 10 min) were subtracted, the plots show bias by the degree of the MSLT–SOL value. A data transformation to IMV-2 and IMV-5 would not appropriately adjust for the tendency of ACT to consistently identify SOL immediately upon the start of the nap opportunity. Among the default ACT values set at WTV-40 and IMV-10, there was more variability in ACT–SOL and PSG–SOL agreement. The default ACT settings did not appear to provide a reliable measure of SOL, especially when MSLT–SOL was approximately < 5 and > 10 min.

Although our results were negative, this study was an initial attempt to use a cost-effective and practical measure to identify sleep onset and facilitate the assessment of ambulatory MSLT. Similar to previous research that manipulated and sought ACT parameter settings that optimize ACT and PSG agreement (Chae et al., 2009), this work may guide future research and technological innovation to improve ACT measurement methods. Therefore, with innovation, ACT should not be ruled out as a possible instrument to conduct an ambulatory MSLT. Unpublished data indicate that ACT can only accurately (Generalizability Theory = 0.8) identify SOL after 14.6 nights of recording (Hall, personal communication), so either ACT should be changed,
FIGURE 1  Difference between ACT-SOL (WTV-40: IMV-2, IMV-5, and IMV-10) and MSLT-SOL plotted against MSLT-SOL with lines indicating no difference and ≥ 2.5, ≥ 5, and ≥ 10 min differences between measures. *Note.* Points below the no-difference line represent ACT-SOL earlier than MSLT-SOL, and points above the no-difference line represent ACT-SOL later than MSLT-SOL. ACT = actigraphy; SOL = sleep onset latency; WTV = wake threshold value; IMV = immobile minutes for sleep onset; MSLT = Multiple Sleep Latency Test.
or a specific ACT-MSLT protocol might be developed. For example, an ACT-MSLT protocol may require ≥15 samples of sleep onset, possibly across multiple days, to accurately identify an equivalent standard MSLT derived value. Alternatively, a multi-method combination to minimize intrusion, but improve validity, could include improved ACT with event markers, self-reports (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973), skin temperatures (Kräuchi, Cajochen, Werth, & Wirz-Justice, 2000), jaw movements (Senny, Destiné, & Poirrier, 2009), pupillometry (McLaren et al., 2002), electrooculography (Virkkala, Hansan, Värrri, Himanen, & Härmä, 2007), or single channel electroencephalography (Abeyratne et al., 2009).

Throughout this report, we attempted to conform to recommendations for reporting standards (Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2006), but we also highlight some important methodological considerations. We did not perform a minute-by-minute analysis between ACT and PSG SOLs because SOL was the variable of interest rather than the assessment of arousals, transitions from wake to sleep, or transitions between sleep stages; therefore, the Bland–Altman plots provide a thorough description of agreement. Participants did not sleep in the laboratory the night before the MSLT because we used the MSLT to index sleepiness and not for clinical diagnostic purposes; we intended to index naturally occurring sleepiness among this sample by avoiding sleepiness derived from a potential first-night effect; and finally, due to the research questions being asked, we identified potential sleep disorders with the sleep disorders symptoms screening chart and did not intend to use the previous night sleep to assist in identifying rapid eye movement sleep during naps. In addition, this sample was exclusively sleep-disturbed postpartum parents who were otherwise healthy, recorded using one ACT brand, and may not generalize to other populations or systems. For example, individuals with specific sleep disorders, or different age groups, may have movement profiles that would alter actigraphic assessment of sleep onset. Specifically, patients with insomnia may have long motionless periods of wake, and those with sleep apnea may have high levels of activity from arousals during sleep. Future research could be conducted to examine the efficacy of different ACT brands to administer the MSLT among diverse samples.

As examined in this study, none of the altered ACT settings appeared to make it a viable option for administration of the MSLT. Additional ambulatory instruments measured concurrently with ACT may provide valuable information to provide a reliable and accurate assessment of SOL, which may be used to develop a system to conduct an ambulatory MSLT.

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REFERENCES


