Actigraph Placement and Sleep Estimation in Children

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INTRODUCTION

CHILDREN’S SLEEP DISTURBANCES HAVE NOT BEEN STUDIED AS EXTENSIVELY AS THOSE OF ADULTS. Because present knowledge is largely based on parental reports, a considerable limitation is imposed, as some parents may be unaware of their child’s sleep problems.1,2 Inclusion of the child as an additional informant may increase the validity of studies. However, it is unclear how valid and reliable children’s reports are and how to deal with possible discrepancies arising between the two informants. Therefore, objective measurements, such as polysomnography (PSG) or actigraphy, constitute an important part of sleep research in children.

During recent years, activity-based sleep assessment has become an important method in sleep research. It is more cost-effective and easier to apply than PSG, the gold standard of sleep research, but as it is based only on motor activity and not EEG measurements, the resulting data is, in this respect, only an estimate of sleep quantity and quality. However, previous research has shown that sleep-wake states can actually be identified well from the motor activity levels recorded by actigraphs using the algorithm developed by Sadeh et al.3 The minute-by-minute agreement between actigraphically derived measures and PSG scoring has been reported to be 89.9% in children and 91.2% in adolescents.3,4 Although the scoring algorithms have not established validity for waist-worn monitors, some researchers consider the waist to be a superior actigraph attachment site in children because of higher level of user-comfort.6,9 The risk for mechanical disturbances caused for example, by humidity or blows may also decrease when the monitors are worn at the waist.

Placement of the activity monitor can affect the recorded mean activity as reported by van Hulst et al.5 Significant differences were found between the trunk and the extremities, but not between dominant and non-dominant wrists; sleep assessment was not performed. In contrast, Sadeh et al. found differences between dominant and non-dominant wrists, but the sleep variables remained similar.4 Glod et al. compared sleep estimates derived from wrist- and waist-worn monitors in six children in their study of abused children.6 They found a good correlation between wrist- and waist-measured sleep efficiency, but no other analyses were reported. We found no other studies reporting the effect of monitor placement on sleep estimation in children. More research of this issue was called for in a recent review.7 The purpose of the present study was to assess the influence of actigraph placement on the wrist and waist on recorded activity levels and estimated sleep variables in children.

METHODS

The study group consisted of 20 volunteers (6 boys and 14 girls, mean age 10.5 years, range 7.3—13.3 years) recruited from public primary schools by advertisement. Written informed consent was obtained from the parents and a verbal assent from the child. All children were medication-free, Caucasian, and of Finnish nationality. The Mini-MotionLogger actigraphs (Ambulatory Monitoring, Inc., Ardsley, NY) were concomitantly worn on the non-dominant wrist and the belt for a continuous 72-hour period during an ordinary school week. The parents kept logs on monitor removal times, bedtimes (lights off), and waking times (lights on) and they were given exact instructions how the adequate bedtime is defined (not to include, for example, reading times).

The data were analyzed by ACT2000 and AW2 software. The raw activity data was thoroughly inspected for accuracy of reported bedtimes and rise times as well as monitor removal periods before it was scored using the algorithm developed by Sadeh et al.,3 which is based on total activity counts obtained during a one-minute epoch. The down periods were defined according to parental reports and included a total of 69702 minutes. Both individual and total agreement percentages of the two sleep-wake estimations based on wrist and waist recordings were calculated on a minute-by-minute basis.

Study Objectives: To determine whether actigraph placement affects sleep estimation in children.
Design: Descriptive study.
Setting: Naturalistic setting.
Participants: Twenty children aged 7-12 years from primary schools.
Interventions: N/A
Measurements: Motor activity was measured from the waist and non-dominant wrist with actigraphs for three consecutive days during a school week.

Results: The minute-by-minute agreement of sleep-wake states between the two measurement sites was 92.5%. Wrist- and waist-recorded sleep parameters correlated well and the mean values did not differ.

Conclusions: Although the placement of the actigraph slightly affected the measured activity parameters, its influence on 3-night mean sleep estimates in children was not statistically significant.

Key words: Actigraph; child; sleep

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Sleep estimates (sleep duration, sleep onset latency, sleep percentage, sleep efficiency) were then averaged across the three measurement days and were subjected to other statistical analyses. Means and 95% confidence intervals of each parameter were calculated. Differences between the two monitor attachment sites were compared. Simple comparisons between the two placements were done using paired t-tests or Wilcoxon signed-rank tests. Pearson or Spearman correlation coefficients were calculated. Non-parametric tests were selected if the distributions of the two parameters were not normal (nocturnal activity, sleep duration, and sleep latency). The statistical significance level was set at p<0.05.

**RESULTS**

The waist scoring agreed with the wrist scoring in 75.3% of the wake minutes during the down period and in 95.6% of the sleep minutes. The overall (minute-by-minute) agreement between the two placements was 92.5% (range 82.3%—97.7%). The agreement percentage was below 90% in four cases. The mean values of the variables are presented in Table 1. Diurnal activity was lower at truncal placement than at wrist, but nocturnal activity was not significantly affected by attachment site. The means of all four sleep variables were quite similar regardless of monitor placement (all p-values > 0.1).

The mean differences between the two placements were very small (Table 1). However, in some cases the wrist and waist recorded sleep estimates (especially sleep duration and sleep latency) were in disagreement. The discrepancies were consistently clustered in certain individuals, while among the most children all sleep estimates corresponded well.

All wrist- and waist-recorded activity and sleep variables correlated moderately well or well. The coefficient for diurnal activity was not significant (r=0.39, p=0.087), but the coefficient for nocturnal activity was (r=0.91, p<0.001). All coefficients of the sleep variables were significant: sleep duration (r=0.78, p<0.001), sleep latency (r=0.78, p<0.001), sleep percentage (r=0.89, p<0.001) and sleep efficiency (r=0.91, p<0.001).

**DISCUSSION**

Less diurnal activity was gathered when the actigraph was attached at the waist rather than at wrist, whereas mean nocturnal activities were similar. The results from the two sleep-wake scorings agreed for 92.5% of the minutes. None of the mean sleep estimates were found to be significantly affected by placement, but there were inter-individual differences in the agreement of the two measurements, especially in sleep duration and latency. Van Hilten et al. previously reported higher activity levels with wrist-worn devices as compared with those of truncal placement. They concluded that the variation in the recorded diurnal activity reflects dissimilarity of movements of the trunk and distal extremities, while nocturnal activity is likely to consist mainly of large body movements, such as postural shifts, which are adequately registered regardless of monitor placement.

Actigraph based sleep-wake identification has been shown to be relatively independent of moderate changes in activity. Glod et al. also reported a relatively high correlation of sleep efficiency derived from recordings on the waist and the wrist of six children. Our findings are in accordance with these results. However, the present study is limited by a rather small sample size. Therefore studies with more statistical power are needed to support our findings. Furthermore, PSG studies would give valuable information of the actual accuracy of waist measurements, because minute-by-minute agreement rates have been previously reported only for PSG and wrist-worn activity monitors.

In conclusion, no marked differences in the mean values of the sleep parameters were found between the waist- and wrist-worn monitors. However, the monitor placement had some effect on the recorded sleep duration and sleep latency in certain individuals, which is important to notice. Actigraphy is always a more objective measure of children's sleep than the parental reports only, and the present study suggests that it is possible to use waist-worn actigraphs to get estimates of sleep quantity and quality in children.

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**Table 1—Mean activity and sleep parameters based on simultaneous waist and wrist recordings**

<table>
<thead>
<tr>
<th></th>
<th>Wrist</th>
<th>Waist</th>
<th>Difference</th>
<th>SD</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diurnal activity</td>
<td>235.89 (229.24-242.54)</td>
<td>214.61 (207.50-221.71)</td>
<td>21.28 (-38.18-36.66)</td>
<td>15.18</td>
<td>16.22</td>
</tr>
<tr>
<td>Nocturnal activity</td>
<td>19.90 (16.46-23.35)</td>
<td>18.57 (15.39-21.75)</td>
<td>1.34 (-3.94-6.89)</td>
<td>6.79</td>
<td>3.01</td>
</tr>
<tr>
<td>Sleep duration¹</td>
<td>475.95 (456.68-495.21)</td>
<td>477.02 (456.15-497.88)</td>
<td>-1.07 (-30.33-33.33)</td>
<td>44.59</td>
<td>16.68</td>
</tr>
<tr>
<td>Sleep latency</td>
<td>27.22 (19.10-35.33)</td>
<td>28.14 (19.91-36.36)</td>
<td>-0.92 (-33.67-10.67)</td>
<td>17.58</td>
<td>8.26</td>
</tr>
<tr>
<td>Sleep percentage²</td>
<td>84.74 (82.07-87.42)</td>
<td>84.96 (81.85-88.06)</td>
<td>-0.21 (-5.50-5.63)</td>
<td>5.72</td>
<td>2.98</td>
</tr>
<tr>
<td>Sleep efficiency</td>
<td>89.54 (87.13-91.94)</td>
<td>89.83 (86.90-92.76)</td>
<td>-0.29 (-5.50-5.51)</td>
<td>5.13</td>
<td>2.68</td>
</tr>
</tbody>
</table>

¹ Wilcoxon signed-rank test
² T-test

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1) Sleep duration constitutes of total number of minutes scored as sleep during the down period; 2) Sleep percentage includes sleep latency, whereas sleep efficiency does not.
REFERENCES