A Comparative Analysis of Automated versus Manual Scoring of Actigraphy in Shift Workers doing 12 Hour Rotating Shifts

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INTRODUCTION
Actigraphy is a convenient and cost-effective method for assessing sleep/wake cycles, but methodological issues continue to limit the application and validity of the method, especially in shift workers. Estimates of sleep from actigraphy have been found to be less reliable as sleep becomes more disturbed and/or fragmented1,2, both of which are common in shift workers. Furthermore, most actigraphy scoring algorithms have been validated against nocturnal polysomnography (PSG) in healthy volunteers. Reid (1999) investigated the correlation between sleep recorded using PSG and actigraphy for both nocturnal and diurnal sleep periods during simulated 12 hour shift rotation. It was found that actigraphy scored inactivity as sleep when the subject was awake, which is a false negative, two to three times more when compared to PSG. The authors concluded that actigraphy is less proficient at determining sleep/wake in subjects during the day3.

As part of the Calgary Police Service Health and Human Performance Research Initiative Phase II protocol entitled “A Pilot Field-Study Evaluating the Feasibility of Objective Measurement of the Integrity of the Sleep/Wake/Rest Cycle During Rotating 10-12 hour Shifts and Critical Cognitive Processing at the Nocturnal and Diurnal Circadian Anchor Times and Post-Shift”4 an analysis of the actigraphy data revealed substantial discrepancy between actigraphic total sleep time (TST) and estimated time in bed (TIB) from sleep logs. Aware of the limitations associated with actigraphy when applied to a shift work population, a visual inspection of the automated scoring algorithm was conducted and compared to sleep logs. The automated scoring algorithm was observed to overestimate TST (Figure 1), (>8 hours), inconsistent with a shift work population (<7 hours). In addition, a review of self-reported sleep duration measured by the Pittsburgh Sleep Quality Index4 for both night shift/day shift and day sleep/night shift and estimated TIB from sleep logs, reinforced this inconsistency with the automated scoring. Therefore, a manual scoring method was developed and applied to better estimate TST is shift workers.

OBJECTIVE
To compare automated scoring algorithm versus manual scoring method in estimating TST in a shift work population.

METHODS
Nine subjects were monitored using the Basic Motionlogger® (Ambulatory Monitoring, Inc.) over 14 days of a 12 hour shift rotation (D/D/D/N/N/O/O/O/D/D/N). Subjects were instructed to wear the actigraph for 14 days on the non-dominant hand, 24 hours/day, keep a sleep log, in which they indicated bedtime (BT) and wake time (WT) and naps, and press the event marker button to indicate lights off and lights on. Activity data was recorded using the Basic Motionlogger® (Ambulatory Monitoring, Inc.), which contains an accelerometer with sensitivity 0.01g and a fixed 2-3Hz bandpass. Actigraph data was collected using Proportional Integrating Measure (PIM). Epoch length of 60 seconds was selected with a sampling rate of 10 Hz. Action4 scoring software4 was used to process the actigraph data. Data was used to compare automated scoring algorithm (University of California, San Diego (UCSD))5 and manual scoring method to estimate TST over 14 days of rotating 12 hour shifts. TST is defined as the number epochs (60 seconds) scored as sleep within a 24 hour (06:00-06:00) period.

MANUAL SCORING RULES
The following rules were applied for the manual scoring method:
1. Sleep/wake data was scored using the UCSD algorithm.
2. The start of the main sleep period was determined from the event marker to indicate lights off or from sleep logs, where BT was indicated.
3. The end of the main sleep period was determined from the event marker to indicated lights on or from sleep logs, where WT was indicated.
4. Rescoring occurred up to where the event marker was pressed to indicate lights off.
5. If the event marker (lights off) was not pressed, rescoring occurred up to where BT was indicated in the sleep log.
6. Rescoring occurred after where the event marker was pressed to indicate lights on.
7. If the event marker (lights on) was not pressed, rescoring occurred after where WT was indicated in the sleep log.
8. Fifteen minutes or more of inactivity (zero) outside of the determined main sleep period was deleted; the authors assumed the device was taken off for showering.
9. Only data outside of the determined main sleep period was rescorded.

RESULTS
Comparative analysis of the automated scoring algorithm and manual scoring method was conducted. TIB calculated from the sleep logs was used as a benchmark for the comparison. Group means for (TIB and TST) were calculated across 14 days (Table 1 & Figure 2). Average estimated TIB per day (24 hours) for 14 days was 415 minutes (6.9 hours). TST (group mean) was calculated across 14 days. Average TST for automated scoring algorithm was 502 minutes (8.4 hours); manual scoring method was 391 minutes (6.5 hours). A discrepancy of 111 minutes (1.85 hours) was detected between the automated scoring algorithm and manual scoring method; with automated overestimating TST.

DISCUSSION/CONCLUSION
Manual scoring method provided a better estimate of TST in this group of shift workers. This analysis exemplifies the importance of utilizing sleep logs and event markers in conjunction with actigraphy. Moreover, inaccurate identification of sleep periods or sleep lengths can lead to misinterpretation and improper application of clinical interventions. It is important to weigh the benefits and limitations associated with measurement techniques such as actigraphy, and implement steps to improve the accuracy of the data.

LIMITATIONS
1. Small sample size.
2. Manual scoring method has yet to be replicated and validated on a larger sample.
3. Event markers may be inaccurate; participants may have pushed the event marker earlier or later than they actually turned the lights on or/and lights off.
4. Subjective nature of the sleep logs; participants may be inaccurate in estimating BT and WT.

STRENGTHS
1. Real life shift work conditions not simulated shift work conditions.
2. Analysis captured the range of sleep periods associated with shift work; day shift, night shift and days off.
3. Actigraphy compliance rate over 14 days was excellent. Subjects consistently wore the actigraph across the 14 days and filled out the sleep logs.
4. Compliance can be attributed to the training subjects received prior to the study about proper wear of the actigraph and reminders from the research assistant.

REFERENCES
6. Action4 Ltd. Ambulatory Monitoring, Inc. Ardsley, NY, USA.