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Original research

Software thresholds alter the bias of actigraphy for monitoring sleep in team-sport athletes

Kate L. Fuller[a,*], Laura Juliff[b], Christopher J. Gore[a], Jeremiah J. Peiffer[b], Shona L. Halson[a]

[a] Department of Physiology, Australian Institute of Sport, Australia
[b] School of Psychology and Exercise Science, Murdoch University, Australia

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ABSTRACT

Objectives: Actical® actigraphy is commonly used to monitor athlete sleep. The proprietary software, called Actiware®, processes data with three different sleep-wake thresholds (Low, Medium or High), but there is no standardisation regarding their use. The purpose of this study was to examine validity and bias of the sleep-wake thresholds for processing Actical® sleep data in team sport athletes.
Design: Validation study comparing actigraph against accepted gold standard polysomnography (PSG).
Methods: Sixty seven nights of sleep were recorded simultaneously with polysomnography and Actical® devices. Individual night data was compared across five sleep measures for each sleep-wake threshold using Actiware® software. Accuracy of each sleep-wake threshold compared with PSG was evaluated from mean bias with 95% confidence limits, Pearson moment-product correlation and associated standard error of estimate.
Results: The Medium threshold generated the smallest mean bias compared with polysomnography for total sleep time (8.5 min), sleep efficiency (1.8%) and wake after sleep onset (−4.1 min); whereas the Low threshold had the smallest bias (7.5 min) for wake bouts. Bias in sleep onset latency was the same across thresholds (−9.5 min). The standard error of the estimate was similar across all thresholds; total sleep time ~25 min, sleep efficiency ~4.5%, wake after sleep onset ~21 min, and wake bouts ~8 counts.
Conclusions: Sleep parameters measured by the Actical® device are greatly influenced by the sleep-wake threshold applied. In the present study the Medium threshold produced the smallest bias for most parameters compared with PSG. Given the magnitude of measurement variability, confidence limits should be employed when interpreting changes in sleep parameters.

1. Introduction

Sleep is widely accepted as a critical component of the recovery process for an elite athlete.[1,2] As such, monitoring an athlete's sleep has become commonplace as sport scientists look for ways to improve sleep, recovery, and optimise performance. Monitoring sleep using the accepted gold standard method of polysomnography (PSG) is impractical for most athletes since it requires specialist equipment and staff to collect and analyse the data. Also, because PSG monitoring often requires the subject to sleep in a laboratory or setting outside their home environment, long term monitoring of an individual's sleep, or monitoring multiple athletes simultaneously is problematic. For these reasons, actigraphy has become a popular low-cost, non-invasive alternative for collecting sleep data of athletes. Worn on the wrist, actigraph monitors contain a multidirectional accelerometer that detects movements and employs software algorithms to distinguish sleep from wakefulness based on the level of movement.[3] These small devices can store several days and nights of data before downloading to a computer, allowing users to monitor multiple athletes over consecutive nights in any environment; home or away at competition.

The Actical® (Philips Respironics) is an actigraph commonly employed by sport scientists to monitor sleep behaviour in elite athletes.[2,4] Data from the Actical® device can be converted into a format which allows for processing with the Actiware® analysis software (Philips Respironics). This software uses algorithms to process data based on one of three Actiware® sleep-wake threshold settings (Low, Medium and High). Although the sleep-wake threshold algorithms were originally developed and validated with sleep disordered patients, the algorithms and Actical® devices have been validated on a range of populations including sleep disordered

* Corresponding author.
E-mail addresses: Kate.fuller@ausport.gov.au, kate.fuller@icloud.com (K.L. Fuller).

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and healthy adults.[5–8] There is however, currently no standardised protocol regarding the use of different threshold settings.

Previous research studies investigating the sleep behaviour of elite athletes have used the Medium sleep-wake threshold, based on the work of other industry researchers using this threshold setting.[2,4] Recently, researchers compared the validity of wrist actigraphy across all three Actiware® threshold settings in elite endurance cyclists.[1] Whilst good agreement was observed between activity monitors and PSG for each of the three sleep-wake thresholds (81–90%), the devices underestimated sleep duration and overestimated wake duration depending on which threshold was applied. In contrast to studies using the Medium threshold, Sargent et al.[1] recommended the High sleep-wake threshold be employed when using Actical® actigraphy with elite cyclists.

Considering the widespread use of actigraphy with elite athletes, we sought to expand to work of Sargent et al.[1] to include elite team-sport athletes. Due to the lack of standardisation of the sleep-wake threshold settings used to analyse Actical® data, the aim of this study was to examine the validity and potential bias of the three software thresholds compared with polysomnography. Also, given the way the actigraphy and PSG data is used in a practical setting, only time matched, overall night data values were used for comparison rather than an epoch to epoch analysis which has been used by previous researchers.[3,7]

2. Methods

Participants were 21 male elite team-sport athletes (age: 22.5 ± 2.7 year) from the premier Australian Rules Football League (n = 10) and Australian Rugby League (n = 11). Participants completed a Pittsburgh Scale for Evaluation of Sleep Quality questionnaire to establish inclusion in the study.[9] Exclusion criteria included; shift workers, participants on medication which could impact study results, parents with newborns, presence of primary sleep disorders, and consumption of more than five caffeine beverages per day. Informed consent was obtained from each participant and the study was approved by the Ethics Committees of Murdoch University and the Australian Institute of Sport.

Participants' sleep was assessed using PSG and concurrent actigraphy on four occasions. All athletes were in pre-season training at the time of the study. Data was collected as part of an intervention sleep study which was a randomised, parallel group, single blind experimental design comparing neurofeedback to a sham group. Sixty-seven successful observations were recorded, after some recordings were excluded due to technical issues (n = 16) or participant illness (n = 1). All participants slept in their own bedroom within an apartment. Bedtimes and awakening times were ad libitum; however, the time when bedroom lights were turned off (bedtime) and on (awakening time) was noted. Clocks on the PSG and Actical® devices were synchronised to align the two recording devices. For both devices, the following time-matched, summary measures were collected and calculated for each night: sleep onset latency (SOL), total sleep time (TST), sleep efficiency (SE), wake after sleep onset (WASO) and number of wake bouts. SOL was calculated as time from lights out until the onset of sleep. TST calculated as the total duration of epochs scored as sleep between lights off and on; SE was defined as the percentage of time asleep between lights off and on; WASO was calculated as the number of minutes spent awake between sleep onset and final awakening; wake bouts was defined as the number of discreet wake periods experienced after sleep onset and before final awakening.

Polysomnography (Compumedics Siesta 802 system; Compumedics, Texas, USA) was recorded following the technical specifications of the American Academy of Sleep Medicine manual for the scoring of sleep and associated events.[10] Polysomnograph montage included; four electroencephalogram (EEG) electrodes according to the international 10–20 electrode placement system (F4-A1, C4-A1, C3-A2, O2-A1); two electrooculogram electrodes (Left and Right eye); chin electromyogram (EMG1, EMG2) placed on the mentalis and submentalis; right and left anterior tibialis piezo EMG; thoracic and abdominal respiratory bands; pulse oximeter on the index finger of the non-dominant hand; oronasal airflow sensor; and a single modified lead 11 placement for electrocardiogram (ECG). Signals from each PSG system were stored in a data card within the system as well as transmitted to a laptop in an adjacent room where a researcher monitored the signals throughout the night. All data was scored in 30 s epochs according to the American Academy of Sleep Medicine scoring criteria by a trained specialist, unaware of the participants' intervention condition.[10] The studies were reviewed according to the same criteria by a second sleep specialist blinded to the study design.

Actigraphy data were collected using Actical® Z series activity monitors (Actical® Z series part number 198-0200-03; Philips Respironics, Oregon, USA) worn on the non-dominant wrist. Each activity monitor contains a 3-axis piezoelectric accelerometer sampled at 32 Hz, which generates a voltage when it undergoes a change in acceleration. Sensitive to movements in the 0.5–3 Hz range, the Actical® device records the mean of activity, or movement, sampled each second with the means summed to create activity counts for each 1 min epoch. Actiware® 5.61 activity and sleep analysis software (Mini Mitter Philips/Respironics, Oregon, USA) was used to set up, download and process the data. An activity score was generated for each epoch as a weighted average of the activity count for the current epoch and that of the surrounding epochs (±2 min).[11] Data from the Actical® was assessed as sleep or wake based on whether or not the activity scores exceeded a set wake sensitivity threshold. For the purpose of this study, data from the actigraph devices was processed for all three wake sensitivity thresholds; Low (>20 activity counts scored as wake), Medium (>40 activity counts scored as wake), High (>80 activity counts scored as wake). Time in bed was calculated using the 'lights off' and 'lights on' times recorded on the PSG system. SOL was calculated as the time from lights out until sleep onset and as such, the results for this sleep parameter do not change across the three sleep-wake thresholds.

In previous studies, agreement rates of epoch-by-epoch data have been used to compare PSG and actigraphy, however this technique is not considered fully appropriate as a measure of concordance.[3,12] For this reason, and due to the way PSG and actigraphy data are reported in a practical setting, time matched overall night data values (TST, SE, SOL, WASO and wake bouts) for PSG and Actical® threshold sensitivities (Low, Medium and High) were used for comparison.

Accuracy of each sleep-wake threshold compared with PSG was evaluated by determining mean bias and corresponding ninety-five percent confidence limits (95% CL), as well as the Pearson moment-product correlation and associated standard error of estimate (SEE). Magnitudes of the Pearson correlations were interpreted using the descriptors of Hopkins, low (0.1–0.3), moderate (0.3–0.5), large (0.5–0.7), very large (0.7–0.9).[13] Bland–Altman plots of absolute error in Actical® from the mean of the PSG and Actical® data across all sleep parameters were conducted.[14] The bias, correlation and Bland–Altman analyses were conducted with GraphPad Prism version 6.01 (GraphPad Software, La Jolla, California, USA), with magnitudes from specialised Excel spreadsheets.[15]

3. Results

Data comparing the three sleep-wake threshold settings on the Actical® devices to PSG are presented in Table 1. Bland–Altman