

# Advances in clinical actigraphy

**Abbreviations:** PSG, polysomnography; LPSG, limited polysomnography; TST, total sleep time, SE, sleep efficiency; SOL, sleep-onset latency; WASO, wake after sleep onset

## Introduction

Improvements in clinical actigraphy over the last decade, such as piezoelectric sensors, enhanced digital storage, heightened accuracy, and improved reliability of data interpretation has rendered clinical actigraphy a valuable asset in the diagnostic armamentarium for the sleep medicine clinician. Currently available actigraphy devices are able to retain relevant information relating to body movement for many weeks, and automated algorithms within software packages facilitate the identification of sleep and wakefulness with increasing precision. The actigraph therefore conveys, and quite clearly, an accurate report of body movements over prolonged periods. The raw scores, based on levels of activity, are translated to sleep-wake output on the basis of computerized algorithms. This facilitates a meaningful understanding of daily sleep-wake cycles, and so, with this data, the clinician can feel more confident in the diagnosis and management of circadian rhythm disorders, sleep-wake misperception, insomnia, hypersomnia, and sleep disordered breathing.<sup>1</sup> This overall represents staggering progress from the conception of actigraphy in 1995, at which point the American Academy of Sleep Medicine had stated that actigraphy should be reserved exclusively as a research tool, and its role in the clinical arena was deemed merely questionable.<sup>2</sup> The sleep history, sleep diaries, full laboratory polysomnography (PSG), home limited polysomnography (LPSG) and actigraphy each have their own inherent merit in the assessment of sleep complaints, with their individual advantages and disadvantages. Actigraphy can be useful where PSG may not be readily available to complement home based sleep studies. In more recent times actigraphy has broadened its potential use, and has shown promise in the assessment and management of periodic limb movement disorder. Validity of actigraphy is clearly of paramount importance. Overall the findings from a series of studies indicate that actigraphy is useful in the estimation of total sleep time (TST), sleep efficiency (SE), and the amount of wake after sleep onset (WASO). On the other hand, estimating sleep-onset latency (SOL), particularly in the context of subjects with sleep disorders, is perhaps less robust. Polysomnography remains the gold standard sleep medicine investigation for the majority of sleep complaints. However, conceiving a valid and reliable means to compare both tests has proven to be challenging. Accurately synchronising epochs from actigraphy with corresponding values from PSG is in fact technically difficult.<sup>3</sup> If epochs from each source were to drift apart the comparison itself becomes meaningless. To further heighten the problem is the fact that the epoch by actigraphy is often adopted to be 1minute, and that from PSG, by convention, is 30seconds. Placement of the actigraph device itself also has a bearing on the output. Although initial studies indicated no differences from actigraphs placed on various locations (e.g. dominant wrist, non-dominant wrist, ankle or trunk)<sup>4,5</sup> a later study suggested that wrist location was most appropriate for determining wake.<sup>6</sup>

Variability in the criteria used for defining the various parameters impact on research considering the strengths of actigraphy itself. For example, SOL was determined to be 0.53 if sleep was defined

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by actigraphy after a single minute of actigraphy-identified sleep, but increased substantially to 0.94 if sleep onset is regarded as the beginning of the first period containing 20minutes sleep by actigraphy estimation, with only a maximum of 1 minute of intervening wakefulness.<sup>7</sup> Predicting sleep onset and offset, TST, and SE is more accurately established by actigraphy as compared to sleep diaries maintained by patients themselves.<sup>8</sup> This discrepancy, however, can be particularly useful when counseling patients with sleep-wake misperceptions, if both tests were to be performed in parallel.<sup>9</sup> It therefore appears the validity of actigraphy compared to PSG is influenced by a number of variables, namely the study population, how the various endpoints are defined, the strength of the statistical correlation which is deemed satisfactory, and the settings of the scoring software adopted.<sup>10</sup> However, considering the evidence overall and when compared to PSG, actigraph is a valid and reliable method for detecting sleep (Table 1). One particular benefit of actigraphy is that there does not appear to be a first night effect, at least in subjects without sleep disorders,<sup>4</sup> an obvious benefit when only one night of recording is feasible. Total sleep time, at least for subjects with insomnia, have been reported to be more accurately recorded by sleep logs as opposed to actigraphs, when both methods are compared to PSG. However, for actigraphy, there was a consistent within-subject, or night-to-night correlation between actigraph and PSG total sleep time.<sup>9</sup> This suggests that those factors which contribute to error in determining sleep and wakefulness for actigraphy tend to be consistent from night to night. These may include factors such as periodic leg movements and periods of minimal activity during extended periods of nocturnal wakefulness. It therefore seems reasonable to conclude that, at least for subjects with insomnia, actigraphy may be useful in the assessment of sleep variability and to assess the impact of treatment directed to insomnia. The use of actigraphy in this context probably overestimates total sleep time and the number of awakenings, and underestimates sleep latency when compared to sleep logs.<sup>11</sup> These differences are attenuated somewhat post treatment, with a relatively greater improvement in sleep logs when compared to outcomes determined by actigraphy. Although sleep logs provide information to assist in the diagnosis of circadian rhythm disorders, actigraphy offers objective evidence about rest-activity that serves to substantiate logs, or alternatively calls them into question. This is one of the more common indications for actigraphy testing.<sup>12-15</sup> There are sufficiently reproducible actigraphy findings from individuals with circadian

rhythm disorders when compared to those from normal sleepers.<sup>13</sup> This also holds true for assessing treatment responses, as actigraphy is able to detect phase advances in response to melatonin treatment which sleep logs failed to do.

A number of protocols have emerged to attempt to use actigraphy to detect the presence of obstructive sleep apnoea. In essence, all of these protocols rely on the principle that apnoea patients have more fragmented sleep, and that this fragmented sleep is manifested in body movements that can be measured. While this may seem feasible, studies have demonstrated that the sensitivity of such a technique to detect an apnoea index greater than 5 was only 5%.<sup>16</sup> Further attempts to increase the strength of this approach by means of using tibial placement of the actigraph which yielded more favourable findings, yet this did not yield statistically significant correlations with EEG arousals, and it was not possible to predict with sufficient confidence the degree of sleep disordered breathing present.<sup>17</sup> Perhaps the most feasible and natural applications of actigraphy is in the identification and assessment of periodic limb movement disorder. By studying PSG data and actigraphy data recorded in parallel, there has previously been reported to be a high correlation between the two collection methods, although actigraphy substantially underestimated

the number of movements as determined by EMG.<sup>18</sup> It is possible this may be as a result of the low sensitivity of the actigraph used. It seems reasonable to regard actigraphy may be of use to follow treatment responses in periodic limb movement disorders, but yet cannot to be used for diagnostic purposes.<sup>19</sup>

Rechtschaffen and Rales established standards for scoring polysomnography in 1968. The time has now arrived for parallel standards to be established for actigraphy. This may include the standardization for digital integration, standardizing units of measurement, such as g-force units, so as to enable comparison from various devices, and agree on minimal standards for computer programmes which facilitate the interpretation of actigraphy output. The convenience of actigraphy, however, must be offset against its reliability when compared to PSG. It clearly has limitations as a standalone device. Furthermore, determination of actigraphy's potential usefulness must also consider alternative methods that may in fact be equally, or perhaps less expensive, such as self report. Ultimately, field tests will continue to help us to understand the merit of actigraphy. What actigraphy can do, how well it can do it, and when it should be used continue to evolve.

**Table 1** Actigraphy compared with PSG

Study/Yr	Sample	Subjects	Comparison	Findings
Marino et al. <sup>20</sup>	77	Insomnia subjects, night workers and control subjects	Actigraphy vs PSG	Actigraphy was sensitive (0.965) and accurate (0.863), although specificity was low (0.329) when compared to PSG. Significant differences were present for WASO for both tests.
Wang et al. <sup>21</sup>	39	Lung cancer patients	Actigraphy vs sleep diary	87% congruency between actigraphy and sleep diary
Sánchez-Ortuño et al. <sup>22</sup>	62	Insomnia and control subjects	Actigraphy vs PSG vs sleep diary	No differences in WASO, TST or SE
Natale et al. <sup>23</sup>	408	Insomnia and control subjects	Actigraphy in insomnia vs control	Actigraphy showed significant differences in SOL, TST, WASO, SE and NA >5 between insomnia subjects and control subjects.
Chae et al. <sup>24</sup>	33	Sleep apnoea patients with and without PLMD	Actigraphy vs PSG	SL determined by actigraphy was underestimated when PSG latencies were short and overestimated when PSG latencies long.
Blackwell et al. <sup>25</sup>	68	Adult females	Actigraphy vs PSG	Actigraphy underestimated TST by 68 min for those sleeping < 5h and overestimated TST by 31 min for subjects with SE <70% as compared to PSG. Using optimal modalities sleep parameters TST, WASO, and SE did not differ from PSG by more than 17.9, 6.8 min, and 3.8% respectively.
Paquet et al. <sup>26</sup>	15	Healthy subjects	Actigraphy vs PSG	Low specificity for actigraphy to determine sleep (generally <50%), with actigraphy overestimating total sleep time and sleep efficiency
Kushida et al. <sup>9</sup>	100	Sleep disordered patients	Actigraphy vs PSG	TST and SE did not differ significantly between PSG and actigraphy. AWISO was not significantly different between actigraphy and PSG.
Reid et al. <sup>27</sup>	32	Shift workers	Actigraphy vs PSG	High agreement reported between actigraphy and PSG for EEG measures of sleep (80-90%) with high correlations for sleep durations for various age groups (0.77-0.96). However, sleep efficiency correlation was unreliable by actigraphy.
Jean-louis et al. <sup>28</sup>	-	Healthy adults	Actigraphy vs PSG	Actigraphy was highly correlated with PSG for differentiating sleep from wake with correlations for total sleep time (TST) being 0.97.
Cole et al. <sup>7</sup>	41	18 normals, 23 with sleep or psychiatric disorders	Actigraphy vs PSG	Actigraphy distinguished sleep from wakefulness approximately 88% of the time. Actigraphy determination of SE and SOL correlated 0.82 and 0.90 with parameters scored from PSG.

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## Conflict of interest

The author declares no conflict of interest.

## References

- Morgenthaler T, Alessi C, Friedman L, et al. Practice parameters for the use of actigraphy in the assessment of sleep and sleep disorders: an update for 2007. *Sleep*. 2007;30(4):519–529.
- Practice parameters for the use of actigraphy in the clinical assessment of sleep disorders. American Sleep Disorders Association. *Sleep*. 1995;18:285–287.
- Pollak CP, Tryon WW, Nagaraja H, et al. How accurately does wrist actigraphy identify the states of sleep and wakefulness?. *Sleep*. 2001;24(8):957–965.
- Jean-Louis G, Von Gizycki H, Zizi F, et al. The actigraph data analysis software: I. A novel approach to scoring and interpreting sleep–wake activity. *Percept Mot Skills*. 1997;85(1):207–216.
- Sadeh A, Sharkey KM, Carskadon MA. Activity-based sleep–wake identification: an empirical test of methodological issues. *Sleep*. 1994;17(3):201–207.
- Middelkoop HA, van Dam EM, Smilde–van den Doel DA, et al. 45–hour continuous quintuple–site actimetry: relations between trunk and limb movements and effects of circadian sleep–wake rhythmicity. *Psychophysiology*. 1997;34(2):199–203.
- Cole RJ, Kripke DF, Gruen W, et al. Automatic sleep/wake identification from wrist activity. *Sleep*. 1992;15(5):461–469.
- Monk TH, Buysse DJ, Rose LR. Wrist actigraphic measures of sleep in space. *Sleep*. 1999;22(7):948–954.
- Kushida CA, Chang A, Gadkary C, et al. Comparison of actigraphic, polysomnographic, and subjective assessment of sleep parameters in sleep–disordered patients. *Sleep Med*. 2001;2(5):389–396.
- Jean-Louis G, von Gizycki H, Zizi F, et al. Determination of sleep and wakefulness with the actigraph data analysis software (ADAS). *Sleep*. 1996;19(9):739–743.
- Guilleminault C, Clerk A, Black J, et al. Nondrug treatment trials in psychophysiological insomnia. *Arch Intern Med*. 1995;155(8):838–844.
- Cole RJ, Smith JS, Alcalá YC, et al. Bright–light mask treatment of delayed sleep phase syndrome. *J Biol Rhythms*. 2002;17(1):89–101.
- Minors D, Akerstedt T, Atkinson G, et al. The difference between activity when in bed and out of bed. I. Healthy subjects and selected patients. *Chronobiol Int*. 1996;13(1):27–34.
- Dagan Y, Yovel I, Hallis D, et al. Evaluating the role of melatonin in the long–term treatment of delayed sleep phase syndrome (DSPS). *Chronobiol Int*. 1998;15(2):181–190.
- Kamei Y, Hayakawa T, Urata J, et al. Melatonin treatment for circadian rhythm sleep disorders. *Psychiatry Clin Neurosci*. 1998;54(3):381–382.
- Middelkoop HA, Knuistingh Neven A, van Hilten JJ, et al. Wrist actigraphic assessment of sleep in 116 community based subjects suspected of obstructive sleep apnoea syndrome. *Thorax*. 1995;50(3):284–289.
- Drinnan MJ, Murray A, White JE, et al. Evaluation of activity–based techniques to identify transient arousal in respiratory sleep disorders. *J Sleep Res*. 1996;5(3):173–180.
- Sforza E, Zamagni M, Petiav C, et al. Actigraphy and leg movements during sleep: a validation study. *J Clin Neurophysiol*. 1999;16(2):154–160.
- Chambers MJ. Actigraphy and insomnia: a closer look. Part 1. *Sleep*. 1994;17(5):405–408; discussion 408–410.
- Marino M, Li Y, Rueschman MN, et al. Measuring sleep: accuracy, sensitivity, and specificity of wrist actigraphy compared to polysomnography. *Sleep*. 2013;36(11):1747–1755.
- Wang SY, Chang HJ, Lin CC. Sleep disturbances among patients with non–small cell lung cancer in Taiwan: congruence between sleep log and actigraphy. *Cancer Nurs*. 2010;33(1):E11–17.
- Sanchez–Ortuno MM, Edinger JD, Means MK, et al. Home is where sleep is: an ecological approach to test the validity of actigraphy for the assessment of insomnia. *J Clin Sleep Med*. 2010;6(1):21–29.
- Natale V, Plazzi G, Martoni M. Actigraphy in the assessment of insomnia: a quantitative approach. *Sleep*. 2009;32(6):767–771.
- Chae KY, Kripke DF, Poceta JS, et al. Evaluation of immobility time for sleep latency in actigraphy. *Sleep Med*. 2009;10(6):621–625.
- Blackwell T, Redline S, Ancoli–Israel S, et al. Comparison of sleep parameters from actigraphy and polysomnography in older women: the SOF study. *Sleep*. 2008;31(2):283–291.
- Paquet J, Kawinska A, Carrier J. Wake detection capacity of actigraphy during sleep. *Sleep*. 2007;30(10):1362–1369.
- Reid K, Dawson D. Correlation between wrist activity monitor and electrophysiological measures of sleep in a simulated shiftwork environment for younger and older subjects. *Sleep*. 1999;22(3):378–385.
- Jean-Louis G, Kripke DF, Mason WJ, et al. Sleep estimation from wrist movement quantified by different actigraphic modalities. *J Neurosci Methods*. 2001;105(2):185–191.