

Practice Parameters for the Role of Actigraphy in the Study of Sleep and Circadian Rhythms: An Update for 2002

An American Academy of Sleep Medicine Report

Standards of Practice Committee of the American Academy of Sleep Medicine

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Summary: Actigraphy is a method used to study sleep-wake patterns and circadian rhythms by assessing movement, most commonly of the wrist. These evidence-based practice parameters are an update to the Practice Parameters for the Use of Actigraphy in the Clinical Assessment of Sleep Disorders, published in 1995. These practice parameters were developed by the Standards of Practice Committee and reviewed and approved by the Board of Directors of the American Academy of Sleep Medicine. Recommendations are based on the accompanying comprehensive review of the medical literature regarding the role of actigraphy, which was developed by a task force commissioned by the American Academy of Sleep Medicine. The following recommendations serve as a guide to the appropriate use of actigraphy. Actigraphy is reliable and valid for detecting sleep in normal, healthy populations, but less reliable for detecting disturbed sleep. Although actigraphy is not indicated for the routine diagnosis, assessment, or management of any of the sleep disorders, it may serve as a useful adjunct to routine clinical evaluation of insomnia, circadian-rhythm disorders, and excessive sleepiness, and may be helpful in the assessment of specific aspects of some disorders, such as insomnia and restless legs syndrome/periodic limb movement disorder. The assessment of daytime sleepiness, the demonstration of multiday human-rest activity patterns, and the estimation of sleep-wake patterns are potential uses of actigraphy in clinical situations where other tech-

niques cannot provide similar information (e.g., psychiatric ward patients). Superiority of actigraphy placement on different parts of the body is not currently established. Actigraphy may be useful in characterizing and monitoring circadian rhythm patterns or disturbances in certain special populations (e.g., children, demented individuals), and appears useful as an outcome measure in certain applications and populations. Although actigraphy may be a useful adjunct to portable sleep apnea testing, the use of actigraphy alone in the detection of sleep apnea is not currently established. Specific technical recommendations are discussed, such as using concomitant completion of a sleep log for artifact rejection and timing of lights out and on; conducting actigraphy studies for a minimum of three consecutive 24-hour periods; requiring raw data inspection; permitting some preprocessing of movement counts; stating that epoch lengths up to 1 minute are usually sufficient, except for circadian rhythm assessment; requiring interpretation to be performed manually by visual inspection; and allowing automatic scoring in addition to manual scoring methods.

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INTRODUCTION

ACTIGRAPHY UTILIZES A PORTABLE DEVICE (ACTIGRAPH) THAT RECORDS MOVEMENT OVER EXTENDED PERIODS OF TIME AND IS WORN MOST COMMONLY ON THE WRIST. Sleep-wake patterns are estimated from periods of activity and inactivity based on this movement. Since the publication of the previous practice parameter,¹ actigraph technology has markedly improved. In addition, actigraphy has been increasingly used to study patients with sleep disorders, to determine circadian rhythm activity cycles, and to determine the effect of a treatment on sleep. This update reports new evidence for the role of actigraphy in the study of sleep-wake patterns and circadian rhythms, published since the first expert review; grades the evidence available; and modifies and replaces the 1995 practice parameters.

METHODS

On the basis of this review and noted references, the Standards of Practice Committee of the AASM, in conjunction with specialists and other interested parties, developed the recommendations included in this

paper. In most cases, the conclusions are based on evidence from studies published in peer-reviewed journals that were evaluated as noted in the evidence tables of the companion review paper. However, when scientific data are absent, insufficient, or inconclusive, the recommendations are based upon consensus opinion. The strength of each recommendation is based on the level of the evidence available or on consensus when evidence is lacking.

The Board of Directors of the AASM approved these recommendations. All authors of this review, members of Standards of Practice Committee, and the AASM Board of Directors completed detailed conflict-of-interest statements and were found to have none with regard to this subject.

These practice parameters define principles of practice that should meet the needs of most patients in most situations. These guidelines should not, however, be considered inclusive of all proper methods of care or exclusive of other methods of care reasonably directed toward obtaining the same results. The ultimate judgment regarding the propriety of any specific care must be made by the physician in light of the individual circumstances presented by the patient and the available diagnostic and treatment options as resources.

The AASM expects these guidelines to have a positive impact on professional behavior, patient outcomes, and possibly, health care costs. These practice parameters reflect the state of knowledge at the time of development and will be reviewed, updated, and revised, as new information becomes available. The 189 articles entered in the evidence tables of the companion review paper were based on the Standards of Practice Committee's levels of evidence (Table 1) for evidentiary articles, which are used to support the strength of the recommendations (Table 2) in this paper. Square-bracketed numbers in this paper refer to sections, tables, or references in the accompanying review paper. Other citations, noted by superscripted numbers, refer to the reference list at the end of this paper.

BACKGROUND

Actigraphy is based on the principle that there is reduced movement during sleep and increased movement during wake. Since its development in the early 1970's, actigraphs have become lighter, more durable, water resistant, and have included features such as event markers and ambient light sensors. A modern actigraph uses accelerometers to detect wrist (alternatively ankle and trunk) movement, which is sampled several times a second. These data are stored within the actigraph for up to several weeks. The length of time the actigraph is able to record data is typically dependent on the actigraph's epoch length (i.e., the period of time that the actigraphy data is averaged), which is usually 30 seconds or 1 minute.

The individual under study is advised to wear the actigraph continuously for a given period of time (usually a minimum of 1 week). In addition, a sleep diary is frequently given to the individual to complete during the time period. This latter information is often used to establish the lights off and lights on time for each 24-hour period. At the end of this period, the actigraph is returned to the clinician's office for analysis. The actigraph is then typically attached to a "reader", a device connected to a computer that allows downloading of the data from the actigraph's memory storage to the computer's hard drive. A computer program enables analysis of these data. At a minimum, a typical program displays and prints a histogram, which shows the individual's activity levels for each epoch over successive 24-hr periods. However, the computer programs usually can estimate sleep and wake based upon user- or computer algorithm-defined thresholds of activity. Thus, the estimated sleep-wake parameters such as sleep latency, total sleep time, number and frequency of awakenings, sleep efficiency can be derived. Circadian rhythm parameters, such as the amplitude (peak-to-nadir difference)

or acrophase (time of peak activity), can also be typically obtained.

The original practice parameter on actigraphy in 1995¹ stated that, "actigraphy is generally accepted as a useful research device; the role of actigraphy in the clinical evaluation of sleep disorders is, however, less clear." Since this time, actigraphy has been increasingly used in both research and clinical arenas. The accompanying paper reviews four major areas: actigraphic technology, actigraphy in sleep disorders, actigraphy and circadian rhythms, and actigraphy used in other clinical studies. The following recommendations reflect the evidence obtained from the review.

RECOMMENDATIONS

The following are recommendations of the Standards of Practice Committee and the Board of Directors of the American Academy of Sleep Medicine. The classification of evidence was adapted from the suggestions of Sackett² (Table 1) and modified by Ancoli-Israel and colleagues (see accompanying review paper) to fit the actigraphy literature. Recommendations are given as standards, guidelines and options, as defined in Table 2.

1. Actigraphy is reliable and valid for detecting sleep in normal, healthy adult populations. (Standard) [4.2, 4.3; Table 2]

This is a new recommendation. There are one Level I, Grade A [17] and two Level III, Grade C [16,18] studies indicating that actigraphy is a reliable measure (i.e., different actigraphy methodology result in the same output). These studies used either newer and older generations of instruments of the same make and model worn on the same wrist in healthy adults, two actigraphs worn with one on each wrist or two on the same wrist of healthy adults, or actigraphs from two different manufactures worn by the same subjects.

Although the methods for assessing actigraphy validity differ, there are two Level I, Grade A [17,19], one Level II, Grade B [22], six Level III, Grade C [21,23,25,26,27,28] studies indicating that actigraphy is a valid measure (i.e., adequate comparison to a "gold standard", such as polysomnography) in normal, healthy adults.

2. Actigraphy is not indicated for the routine diagnosis, assessment of severity, or management of any of the sleep disorders. However, it may be useful in the assessment of specific aspects of the following disorders. (a) Insomnia – assessment of sleep variability, measurement of treatment effects, and detection of sleep phase alterations in insomnia secondary to circadian rhythm disturbance. (b) Restless legs syndrome/periodic limb movement disorder – assessment of treatment effects. (Guideline) [4.6, 5.1, 5.2, 5.5, 5.6, 6.3; Tables 2, 3]

This recommendation is a modification of the recommendation of the previous practice parameter paper.¹ These recommendations are based on five Level IV, Grade C-b [45,50,51,55,56] and four Level V, Grade D [52,53,54,57] studies for insomnia, and one Level I, Grade A [72], three Level IV, Grade C-b [18,50,73], and two Level V, Grade D-b [39,52] studies for restless legs syndrome/periodic limb movement disorder.

Table 1—Levels of Evidence for Actigraphy

Level ¹	Grade ²	Criteria
1	A	Blind, prospective comparison of results obtained by actigraphy to those obtained by a reference standard ³ on an appropriate spectrum of subjects <i>and</i> number of patients.
2	B	Blind, prospective comparison of results obtained by actigraphy to those obtained by a reference standard ³ on a limited spectrum of subjects <i>or</i> number of patients.
3	C	Comparison of results obtained by actigraphy to those obtained by a reference standard ³ , but not blind, not prospective or otherwise methodologically limited.
4	C	a - Adequate comparison of results obtained by actigraphy to those obtained by a non-standard reference ³ ; <i>or</i> b - Actigraphy not compared to any reference, but actigraph results demonstrated ability to detect significant difference between groups or conditions in well-designed trial.
5	D	Actigraphy not adequately compared to any reference, and <i>either</i> a - Actigraph not used in a well-designed trial, <i>or</i> b - Actigraph used in such a trial but did not demonstrate ability to detect significant difference between groups or conditions.

¹ Level refers to level of evidence.

² Grade refers to grade of recommendation.

³ Reference standards for actigraphic evaluation of sleep and circadian rhythms may include, as appropriate, polysomnography, oximetry, melatonin rhythms, core body temperature rhythms, and/or other generally accepted "gold standards," applied in an acceptable manner. Non-standard references include such items as sleep logs, spousal reports, other experimental monitors, etc.

Table 2—AASM Levels of Recommendations

Term	Definition
Standard	This is a generally accepted patient-care strategy, which reflects a high degree of clinical certainty. The term standard generally implies the use of Level I Evidence, which directly addresses the clinical issue, or overwhelming Level II Evidence.
Guideline	This is a patient-care strategy, which reflects a moderate degree of clinical certainty. The term guideline implies the use of Level II Evidence or a consensus of Level III Evidence
Option	This is a patient-care strategy, which reflects uncertain clinical use. The term option implies either inconclusive or conflicting evidence or conflicting expert opinion.

ADAPTED FROM EDDY³

- (a) In the case of insomnia secondary to circadian rhythm disturbance (including delayed sleep phase syndrome), there are one Level I, Grade A [61] and one Level II, Grade B [44] studies to indicate that the circadian phase of wrist activity covaries with the phase of melatonin secretion in DSPS, supporting the use of actigraphy in helping to diagnose this condition.
- (b) There are one Level I, Grade A [72] and one Level IV, Grade C [73] studies reporting the successful use of actigraphy in the evaluation of treatment effects for the restless legs syndrome. There are one Level IV, Grade C [50], and one Level V, Grade D [52] studies indicating that actigraphy is useful in the assessment of treatment effects in patients with either restless legs syndrome or periodic limb movement disorder. However, there is one Level V, Grade D-b study [39] indicating that actigraphy may not be able to accurately detect periodic limb movements during sleep.

There is insufficient evidence for use in the assessment of the following sleep disorders. Although studies exist reporting use of actigraphy in the assessment of fatal familial insomnia [74], non-24-hour sleep-wake syndrome [75,76], REM sleep behavior disorder [77], and post-traumatic delayed sleep phase syndrome [59], these studies did not compare the actigraphy data to PSG nor did they indicate whether the actigraph alone was sufficient to diagnose the conditions.

- 3. Actigraphy may be a useful adjunct to a detailed history, examination, and subjective sleep diary for the diagnosis and treatment of insomnia, circadian-rhythm disorders, and excessive sleepiness under certain conditions: (a) When demonstration of multiday rest-activity patterns is necessary to diagnose, document severity and guide the proper treatment. (b) When more objective information regarding the day-to-day timing, amount or patterns of a patient's sleep is necessary for optimal clinical decision-making. (c) When the severity of a sleep disturbance reported by the patient or caretaker seems inconsistent with clinical impressions or laboratory findings. (d) To clarify the effects of, and (under some instances) compliance with, pharmacologic, behavioral, phototherapeutic or chronotherapeutic treatment. (e) In symptomatic patients for whom an accurate history cannot be obtained and in whom polysomnographic study has already been conducted, or is considered unlikely to be of much diagnostic benefit, or is not yet clearly indicated (because of the absence of accurate historical data) or is not immediately available. (Option)**

This recommendation is essentially the same recommendation as the previous recommendation¹ and is based on committee consensus.

- 4. The use of actigraphy may be useful in assessing daytime sleepiness in situations where a more standard technique, such as the multiple sleep latency test, is not practical. (Option) [4.5; Table 2]**

This is a new recommendation, and it is based on one Level II, Grade B study [37] examining the effects of diphenhydramine vs. placebo on daytime sleepiness. Although the study showed that the multiple sleep latency test (MSLT) was more sensitive than actigraphy to sleep loss, daytime actigraphy reflected prior sleep loss with more epochs of inactivity, suggesting more daytime sleep. However, the authors commented that the actigraphy software was not specifically developed to assess daytime sleepiness, and also that there is considerable variation in movement and activity during the daytime versus inactivity at night. The authors concluded that actigraphy during the day may yield a more accurate index of the effects of sleepiness, particularly since actigraphy is not restricted to use in the laboratory as is the MSLT and this latter test is conducted in a manner conducive to sleep, with most behavioral demands eliminated.

- 5. Superiority of actigraphy placement on different parts of the body is not currently established. (Guideline) [4.7; Table 2]**

This is a new recommendation. There are two Level IV, Grade C studies [40,41] indicating that wrist placement (particularly dominant wrist for detecting wake) was superior to ankle placement, which was in turn superior to trunk placement. However, there are one Level I, Grade A [17] and one Level III, Grade C [16] studies indicating no difference between data collected from actigraphs placed on different locations (e.g., dominant wrist, non-dominant wrist, ankle, or trunk).

- 6. Actigraphy is an effective means of demonstrating multiday human rest-activity patterns and may be used to estimate sleep-wake patterns in clinical situations where a sleep log, observations, or other methods cannot provide similar information. However, concomitant completion of a sleep log during the period of actigraphy use provides important supplemental data for the purpose of artifact rejection and for marking bedtime and lights on, which in turn, allows the accurate determination of sleep parameters by actigraphy. (Option) [4.3, 4.4, 4.8, 4.9, 6.1, 6.2, 6.3; Tables 2, 4]**

This recommendation is a modification of the recommendation of the previous practice parameter paper.¹

Actigraphy appears to be a good measure of entrained sleep phase as determined by polysomnography, as well as a high correlate of entrained endogenous circadian phase. There are four Level III, Grade C [21,32,87,91], eleven Level IV, Grade C [85,92,93,94,95,97,102,106,109,110,111], two Level V, Grade D [86,98] studies indicating the use of actigraphy in the studies of circadian rhythms and circadian rhythm disturbances. There are one Level I, Grade A [43], four Level II, Grade B [44,89,90,118], four Level III, Grade C [21,87,11,121], two Level V, Grade D [98,120] studies comparing actigraphy favorably to other correlates of circadian rest-activity patterns, such as melatonin, temperature, and cortisol.

Observations by nurses or research staff on psychiatric (Level IV, Grade C) [30] or nursing home residents (Level III, Grade C) [26], respectively, yield conflicting results when compared to actigraphy. One study (Level I, Grade A) [29] revealed that actigraphy and sleep logs yielded similar data for sleep timing, duration, onset, and offset, but not for sleep latency, number and duration of nocturnal awakenings or number of naps.

Sleep logs may not correctly identify naps; actigraphy enables identification of naps that volunteers do not report on their sleep logs but may also identify naps when none exist [88,103]. Concomitant completion of a sleep log, including a record of actigraph removal, can also help with identifying and rejecting artifacts such as those stemming from not using the device, movements associated with respiration, postural blocking of arm movements, and externally-imposed movement from riding in vehicles [21].

- 7. Actigraphy may be useful in characterizing and monitoring circadian rhythm patterns or disturbances in the following special populations: (a) the elderly and nursing home patients with and without dementia; (b) newborns, infants, children, and adolescents; (c) hypertensive individuals; (d) depressed or schizophrenic patients; and (e) individuals in inaccessible situations (e.g., space flight). (Option) [4.3, 4.4, 4.9, 5.3, 6.1, 6.2, 6.5, 6.6, 6.7, 6.8; Tables 2 – 4]**

This is a new recommendation.

- (a) There are nine Level IV, Grade C [100,101,109,116,122,123,124,125,126] and one Level V, Grade D [108] studies reporting the use of actigraphy in the analysis of circadian rhythms in aging and dementia. Actigraphy has also been shown to be useful in assessing sleep in nursing home patients (one Level III, Grade C study) [26].

- (b) There is one Level IV, Grade C study for newborns [64], two Level IV, Grade C study for infants [33,34], one Level IV, Grade C study for children [35], and three Grade IV, Level C studies for children and adolescents [33,34,36] demonstrating that actigraphy provides useful data for analysis of sleep parameters. There are also one Level IV, Grade C [62] and one Level V, Grade D [63] studies reporting the utility of actigraphy in assessing disturbed sleep in children with HIV and autism, respectively. Developmental differences in sleep patterns ranging from children to the elderly have also been effectively studied using actigraphy (three Level IV, Grade C studies) [66-68].
- (c) Actigraphy has been used to explore circadian patterns of blood pressure in hypertensive individuals, as well as the circadian therapeutic effectiveness of anti-hypertensive medications (three Level IV, Grade C studies) [128-130].
- (d) There are four Level IV, Grade C [107,132,133,134], one Level V, Grade D [131] studies indicating the successful use of actigraphy in the evaluation of circadian rhythms in depressed or schizophrenic patients.
- (e) Lastly, there are two Level III, Grade C [31,32] studies indicating that actigraphy is an effective and efficient means of evaluating sleep during space flight, when polysomnography would be too cumbersome.
- 8. Actigraphy appears useful as an outcome measure in: (a) interventional trials in patients with sleep disorders; (b) outcome studies of healthy adults; (c) patients with certain medical and psychiatric conditions; and (d) children and the elderly. (Option) [4.6, 5.1 - 5.5, 7.1 - 7.8; Tables 2, 3, 5]**

This is a new recommendation.

- (a) There are two Level I, Grade A [61,72], three Level II, Grade B [19,44,136], one Level III, Grade C [71], eleven Level IV, Grade C [18,45,50,51,55,56,69,73,135,137,138], and six Level V, Grade D [39,52,53,54,57,70] studies indicating that actigraphy can be useful as an outcome measure in clinical trials in sleep-disordered patients. Insomnia, restless legs syndrome, periodic limb movement disorder, and obstructive sleep apnea were the sleep disorders most commonly evaluated in interventional trials.
- (b) There are seven Level IV, Grade C [122,140,141,142,143,146,147] and three Level V, Grade D [139,144,145] studies indicating that actigraphy can be useful in outcome studies of healthy adults. Subjects have been enrolled in outcome studies using benzodiazepine receptor antagonists, caffeine, and antihistamines; other studies using this healthy adult population have used actigraphy to examine gender and racial differences, menopause, the effects of combat missions, and co-sleeping effects with bed partners.
- (c) There are six Level IV, Grade C [126,148,149,150,151,153] and one Level V, Grade D [152] studies indicating that actigraphy can be useful in outcome studies of patients with medical and psychiatric conditions. For example, the effects of cancer-related fatigue, cirrhosis, and coronary artery bypass grafts on actigraphy measures have been evaluated in some of these studies.
- (d) Lastly, there are studies indicating that actigraphy can be useful in outcome studies of children (three Level IV, Grade C [168-170] and two Level V, Grade D [117,167] studies) and the elderly (twelve Level IV, Grade C [110,112,135,136,138,158,159,160,161,162,164,165] and two Level V, Grade D [163,166] studies). Children with attention deficit/hyperactivity disorder, history of abuse, major depression or dysthymia, neurologic conditions, as well as the effects of melatonin or ethanol in breast milk on children were studied. Elderly subjects or nursing-home residents who were either healthy or suffered from dementia or incontinence were studied using actigraphy.

9. Actigraphy may be useful in determining the rest-activity pattern during portable sleep apnea testing. However, the use of actigraphy alone in the detection of obstructive sleep apnea is not currently established. (Option) [5.4; Table 3]

This recommendation is a modification of the recommendation of the previous practice parameter paper.¹ There is one Level III, Grade C [71] study indicating that actigraphy modestly improves sleep apnea severity estimates when combined with portable sleep apnea testing. However, there are one Level IV, Grade C [69] and one Level V, Grade D [70] studies indicating that sleep-disordered breathing could not be accurately predicted from actigraphy alone, versus one Level IV, Grade C study [137] reporting that actigraphy may be useful in distinguishing sleep apnea cases from normal controls.

10. Actigraphic studies should be conducted for a minimum of three consecutive 24-hour periods, but this length of time is highly dependent upon the specific use in a given individual. (Option) [4.4; Table 2]

This recommendation is a modification of the recommendation of the previous practice parameter paper.¹ The recommendation for the minimum number of 24-hour periods is based on committee consensus opinion. However, in certain applications, such as examining sleep-wake patterns in a patient with a circadian rhythm disorder, three consecutive 24-hour periods may not be sufficient to characterize this disorder [34,36].

11. Inspection of raw data following procedures outlined, and algorithms validated for, the specific device in use is necessary. Some preprocessing of movement counts is acceptable, and epoch lengths up to 1 minute are usually sufficient except for circadian rhythm assessment. Automatic scoring may be used in addition to manual methods of scoring. (Option)

This recommendation is a modification and combination of two of the recommendations of the previous practice parameter paper,¹ and is based on committee consensus opinion. Examination of raw data is important to reject obvious artifacts, such as long periods with zero activity, or abnormally high activity at unexpected times. With regard to 1 minute epochs, this degree of resolution may not be necessary for circadian rhythm assessment (e.g., circadian temperature, melatonin rhythms).

RECOMMENDATIONS FOR FUTURE RESEARCH

There is a pressing need for research comparing actigraph methodology in order to establish standards of actigraphic technique. It is difficult to establish standards at the present time, given the variety of different actigraphs available, the different technology and algorithms for detecting movement, and the lack of standardized units of activity measures. Future actigraphy studies should report data indicating the device and scoring algorithm used as well as the threshold setting of the device (if any), and sensitivity, specificity, and artifact rejection for the device. These data would enable different devices and algorithms to be readily compared.

In terms of the data analysis, minimum standards for the type of information available to the clinician from the computerized analysis need to be established. The type of analysis of circadian parameters and data pertaining to specific sleep disorders also require standardization. In addition, standardized norms for the actigraphy results for healthy children and adults as well as for patients with various sleep and circadian conditions need to be established. Although there are convincing data indicating that actigraphy is reliable and valid for detecting sleep in normal, healthy adult populations, further work is need to establish reliability and validity for detecting sleep in patients with sleep disorders.

Finally, additional aspects in actigraphy that warrant further study include: (a) optimal placement for actigraphy devices (dominant vs.

non-dominant wrist, ankle, or trunk); (b) use of actigraphic light sensors and event marker in enhancing data collection; (c) overestimation of sleep by actigraphy; and (d) effectiveness of actigraphy during waking hours.

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