Practice Parameters for the Use of Actigraphy in the Assessment of Sleep and Sleep Disorders: An Update for 2007

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Background: Actigraphy is increasingly used in sleep research and the clinical care of patients with sleep and circadian rhythm abnormalities. The following practice parameters update the previous practice parameters published in 2003 for the use of actigraphy in the study of sleep and circadian rhythms.

Methods: Based upon a systematic grading of evidence, members of the Standards of Practice Committee, including those with expertise in the use of actigraphy, developed these practice parameters as a guide to the appropriate use of actigraphy, both as a diagnostic tool in the evaluation of sleep disorders and as an outcome measure of treatment efficacy in clinical settings with appropriate patient populations.

Recommendations: Actigraphy provides an acceptably accurate estimate of sleep patterns in normal, healthy adult populations and inpatients suspected of certain sleep disorders. More specifically, actigraphy is indicated to assist in the evaluation of patients with advanced sleep phase syndrome (ASPS), delayed sleep phase syndrome (DSPS), and shift work disorder. Additionally, there is some evidence to support the use of actigraphy in the evaluation of patients suspected of jet lag disorder and non-24hr sleep/wake syndrome (including that associated with blindness). When polysomnography is not available, actigraphy is indicated to estimate total sleep time in patients with obstructive sleep apnea. In patients with insomnia and hypersomnia, there is evidence to support the use of actigraphy in the characterization of circadian rhythms and sleep patterns/disturbances. In assessing response to therapy, actigraphy has proven useful as an outcome measure in patients with circadian rhythm disorders and insomnia. In older adults (including older nursing home residents), in whom traditional sleep monitoring can be difficult, actigraphy is indicated for characterizing sleep and circadian patterns and to document treatment responses. Similarly, in normal infants and children, as well as special pediatric populations, actigraphy has proven useful for delineating sleep patterns and documenting treatment responses.

Conclusions: Recent research utilizing actigraphy in the assessment and management of sleep disorders has allowed the development of evidence-based recommendations for the use of actigraphy in the clinical setting. Additional research is warranted to further refine and broaden its clinical value.

Keywords: Circadian rhythms, actigraphy, advanced sleep phase syndrome, delayed sleep phase syndrome, shift work disorder

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1. INTRODUCTION

ACTIGRAPHY INVOLVES USE OF A PORTABLE DEVICE THAT RECORDS MOVEMENT OVER EXTENDED PERIODS OF TIME, AND HAS BEEN USED EXTENSIVELY IN the study of sleep and circadian rhythms. Since the publication of the last American Academy of Sleep Medicine (AASM) practice parameters on the use of actigraphy,[1] there has been an explosion in the number of research articles utilizing actigraphy to estimate sleep and circadian rhythms. In response to this new literature, and the growing use of actigraphy in clinical sleep medicine, the AASM Standards of Practice Committee (SPC) undertook the development of these revised guidelines on the clinical use of this technology.

Since the last review, additional literature has been published that addresses the use of actigraphy in the evaluation of insomnia,

circadian rhythm sleep disorders, sleep related breathing disorders, determination of response to therapy, and in the evaluation of sleep patterns among special populations. This literature, in combination with growing clinical experience with actigraphy, led to the inclusion of actigraphy as a measure of sleep duration and sleep patterns in the diagnostic criteria for several specific sleep disorders in the second edition of the International Classification of Sleep Disorders.[2] Actigraphy is listed as a diagnostic tool in the ICSD-2 primarily when sleep patterns must be assessed over time, making polysomnography impractical. For example, the ICSD-2 diagnostic criteria for most circadian rhythm disorders requires demonstration of abnormalities in the timing of the habitual sleep pattern using either actigraphy or sleep logs for seven days or more. The ICSD-2 also suggests that actigraphy may be used to document inconsistencies between objective and subjective measures of sleep timing in paradoxical insomnia, and as an aid in assessment of habitual sleep time and circadian pattern in patients with behaviorally induced insufficient sleep syndrome and idiopathic hypersomnia with and without long sleep times. Actigraphy is additionally recommended as an adjunct to the Multiple Sleep Latency Test to document a stable sleep pattern and adequate sleep times prior to the test.

However, it should be noted that although the ICSD-2 reflects consensus among experts regarding disease classification and di-

agnostic criteria, there is great variability in the evidence supporting these diagnoses and criteria. In some cases, only face validity and clinical experience guided the criteria, while in others there was a wealth of supportive research evidence. The purpose of the present document is to provide an updated, evidence-based review of the use and indications for actigraphy in the evaluation of sleep and sleep disorders. The title of the 2002 actigraphy parameter paper was modified from that of the first one, published in 1995, which was titled: "Practice Parameters for the Use of Actigraphy *in The Clinical Assessment Of Sleep Disorders.*" The 2002 paper was titled: "Practice Parameters for the Role of Actigraphy *in the Study of Sleep and Circadian Rhythms*: An Update for 2002." This change implied an emphasis on the uses of actigraphy in research. However, the current parameter paper returns to the original focus on an evidence-based review of the use of actigraphy in the assessment and management of sleep disorders in the clinical setting.

2. METHODS

The SPC of the AASM commissioned among its members those individuals with expertise in the use of actigraphy to conduct this review. These content experts were appointed in January 2006 to review and grade evidence in the peer-reviewed scientific literature regarding the use of actigraphy in sleep and circadian rhythm disorders. A computerized search was performed using the search terms actigraph, actigraphy, actigraphic monitoring, actigraphic recording, actimeter, actometer, wrist activity, rest activity, or sleep-wake and found 3641 titles. These were then cross-checked with 32,211 titles found using the search terms: sleep disorders, circadian rhythm, or sleep, to yield 1884 titles. This total was then limited to those published between 2001 and 2005 with a minimum of 8 subjects studied by actigraphy, those in English, those from the core clinical journals, and those with emphasis on diagnosis (using the Ovid search engine) as a modifier to yield 155 articles. After review of abstracts from these articles to determine if they met inclusion criteria, plus of articles identified by pearling, a total 108 articles (see accompanying evidence table) were included. Initial data extraction, preliminary evidence grading in accordance with the standards in Table 1, and initial data entry into evidence tables was performed by professionals commissioned by the AASM SPC to expedite the review process. This classification of evidence, based on suggestions of Sackett,[3] is similar to that of the prior review and practice parameter paper commissioned by the AASM SPC.[1] Some modifications of evidence level criteria were applied by the AASM SPC to this update of the practice parameters for actigraphy to insure the evidence classification was in keeping with recent updates in the literature for the field of evidence grading[4] (see Table 1). All evidence table entries were reviewed and, if appropriate, revised by AASM SPC content experts. Thus, all evidence grading was performed by independent review of the article by two experts, including members of the SPC; areas of disagreement were addressed, and, if needed, the chair of the AASM SPC arbitrated the final decision on evidence level.

Three methodological issues engendered considerable debate and discussion by the SPC:

1. Blinding. Typically, evidence graded as Level 1 according to Sackett criteria requires blinding. In evaluations of the therapeutic efficacy of medications, this means that neither the patients nor the researchers know whether the intervention is active drug or placebo. In the case of the evaluation of actigraphy in comparison to a reference standard (such as polysomnography), this could be interpreted as requiring that the person scoring actigraphy is unaware of the results of polysomnography scoring. Few studies actually specified whether this was the case. Given the technology used and the typical methodology currently used for scoring actigraphic recordings (computer executed scoring programs), it is unlikely that researchers remembered the results of the polysomnograms or simultaneously reviewed both recordings. However, even when using computer scoring of actigraphic data, most situations require manual input of start and stop times. Thus, after considerable discussion, the SPC elected the more conservative approach and required an explicit declaration of blinding for a study to receive a Level 1 rating. Some members of the Committee felt that this may have underestimated the quality of the evidence for use of actigraphy.

2. Reference standard. The majority of the studies evaluated actigraphy in comparison to a reference standard. In some cases these were objective measures, such as polysomnography or dim light melatonin onset; in other cases the reference was subjective, including sleep logs and estimates of sleep quality. For the purposes of this review, we chose appropriate reference standards based on specific diagnostic categories. Reference standards for insomnia included PSG and/or sleep logs; for circadian rhythm sleep disorders, PSG, phase markers, and/or sleep logs; for sleep apnea, PSG; for restless legs syndrome and periodic limb movements during sleep, PSG; for infants, caregiver reported observations; for elderly or demented persons, phase markers, sleep logs, and/or caregiver reports; and for healthy controls, PSG, phase markers, or sleep logs. The inclusion of research using subjective reference standards (such as sleep logs, self-reported sleep, and caregiver report) reflects the fact that many studies required the study of patients over multiple sleep cycles or other circumstances where traditional PSG as a reference standard was impractical (e.g., infants and nursing home residents). As such, research which compares actigraphy to subjective reference standards does not necessarily imply a greater accuracy with either method, but it does provide evidence as to the level of agreement between these methods. In addition, some studies did not compare actigraphy with a reference standard but were useful for this review for other reasons. For example, some studies used actigraphy to assess treatment effects, or compared results from one actigraphy scoring algorithm against another. As in the prior 2002 actigraphy review, the SPC elected to include evidence from these studies which did not compare actigraphy to a reference standard but otherwise provided important information for the current review. However, there was a change in the grading criteria for these studies, where those studies which did not directly compare results of actigraphy with a reference standard within participants, but did provide data that allowed comparison of group means from actigraphy data and appropriate reference standards, could be scored as Level 3, rather than Level 4 or 5, as in the 2002 actigraphy review (see Table 1).

3. What does actigraphy measure? Many studies used actigraphy data to estimate polysomnographic measures such as total sleep time or wake after sleep onset. However, actigraphy simply measures movement of a limb. Although it can be highly sensitive and there are sophisticated algorithms that purport to accurately estimate other parameters, it does not measure the same param-

eters as an electroencephalogram. It therefore does not measure sleep as it is commonly defined[5] and does not measure the subjective experience of sleep (as do sleep logs and questionnaires). In addition, systematic discrepancies between actigraphy and these measures have been documented. For example, actigraphy generally underestimates sleep onset latency because many subjects are inactive and awake for a period of time prior to electroencephalographically defined sleep.[6,7] Likewise, a recent epidemiologic study reports systematic overestimation of sleep time by sleep logs as compared to actigraphy.[8] On the other hand, insomnia patients frequently underestimate TST in their sleep logs.[9] Reflecting these issues, in the current report, actigraphy will generally be described as measuring "sleep pattern" (defined as the circadian pattern of sleep and wakefulness over multiple sleep cycles) and the presence or absence of increased wake time after sleep onset. The exception to this will be in the section where total sleep time during one night of testing is estimated by actigraphy as an aid in the evaluation of sleep apnea and in the calculation of the apnea-hypopnea index in patients with suspected sleep apnea.

On the basis of this review the AASM SPC developed the recommendations included in this paper. In all but one condition, that regarding the use of actigraphy in hypersomnia, the recommendations were based on evidence from studies published in peer-reviewed journals that were evaluated as noted above and specified in the description accompanying each recommendation. In developing the recommendation regarding use of actigraphy in hypersomnia, there was insufficient scientific data, but the SPC felt clinical guidance was indicated for use of actigraphy in this condition, so the Rand/UCLA Appropriateness Method was used to develop the recommendation by identifying the degree of agreement among the sleep experts in the SPC after review of the limited data available. The Rand/UCLA Appropriateness Method[10] combines the best available scientific evidence with the collective judgment of experts to yield statements regarding the appropriateness of performing procedures. Our expert panel rated the appropriateness of this indication in two rounds by individually completing rating sheets. Based on these ratings, we classified the indication as appropriate, uncertain, or inappropriate. We determined that if there were strict agreement that the procedure was appropriate, it would be assigned an "option" level recommendation. The certainty of all the other recommendations was assigned according to available evidence levels, as noted in Table 2.

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 expected to obtain the same results. The ultimate judgment regarding appropriateness of any specific therapy must be made by the physician and patient, in light of the individual circumstances presented by the patient, available diagnostic tools, accessible treatment options, resources available, and other relevant factors.

The AASM expects these guidelines to have an impact on professional behavior, patient outcomes, and, possibly, health care costs. These practice parameters reflect the state of knowledge at the time of publication and will be reviewed, updated, and revised as new information becomes available. This practice parameter paper is referenced, where appropriate, with articles to support the recommendation(s). New recommendations, as well as those that are the same as, similar to, or an expansion of recommendations in the prior practice parameters are noted in the text.

3. RESULTS AND RECOMMENDATIONS

Of the 108 studies reviewed for this project (see evidence table), 44 used sleep logs alone as a reference standard, 16 used polysomnography alone, and 10 used both sleep logs and polysomnography with which actigraphic ratings could be objectively compared. Thirty-eight studies did not compare actigraphy to a reference standard, as defined in Table 1. Of the 70 studies that did compare actigraphy to a reference standard, 17 investigated patients with circadian rhythm sleep disorders, 15 studied patients with insomnia (including two studies of depressed patients), 11 were studies of pediatric patients, 7 were studies of elderly subjects with and without dementia, 7 studied normal subjects, and 5 studied patients with sleep related breathing disorders. Eight of the 70 studies were based on a variety of other patient populations including 2 with nocturnal eating disorders, 2 with restless legs syndrome, and one each of the following patient populations: alcoholics, atypical sexual behavior during sleep, cystic fibrosis, and mixed hypersomnias.

The following are recommendations of the AASM SPC and BOD regarding the use of actigraphy in clinical practice. The reviewed literature involved a variety of actigraphic monitors and scoring algorithms. When described in the article, the particular actigraphic device and/or algorithm used are listed in the evidence tables. Clinicians using actigraphy in practice should ensure that they are familiar with the operational characteristics of their equipment for the specific task employed.

3.1 Use of actigraphy in the evaluation of sleep disorders

3.1.1 Actigraphy is a valid way to assist in determining sleep patterns in normal, healthy adult populations (Standard), and in patients suspected of certain sleep disorders. (Option-Guideline-Standard; see specific parameter below)

This is an expansion of the previous standard (that was limited to the validity and reliability in detecting sleep in normal, healthy adult populations) to include specific patient populations, such as patients with insomnia and those suspected of having circadian rhythm sleep disorders. Specific indications for actigraphy will be addressed in the parameters below. In the current review, additional evidence was identified supporting use of actigraphy in normal, healthy controls, and in patients with various sleep disorders. Supportive studies includes nine with evidence Level 1; ten with Level 2; thirty-eight Level 3; six with Level 4 and six graded as Level 5. The conclusion in the preponderance of studies was that actigraphy was correlated with the reference standard (as defined in Table 1), especially for those studies rated by the SPC at higher evidence levels. Pearson r values were reported for total sleep time comparisons between actigraphy and polysomnography in eight studies.[7,9,11-17] The range was 0.15 to 0.92, with an simple average of 0.71. All but the lowest r values were statistically significant. The lowest value was reported studying patients suspected of sleep apnea.[16] Three additional studies reported percentage agreement for total sleep time between actigraphy and polysomnography of 90% in normal subjects,[18] 84% in patients

1.	Blind, prospective comparison of results obtained by actigraphy to those obtained by a reference standard* on an appropriate spectrum of subjects and number of patients.
2.	Comparison of results obtained by actigraphy to those obtained by a reference standard* but blinding not specified, not prospective, or on a limited spectrum of subjects or number of patients.
3.	Comparison of results obtained by actigraphy to the mean value of a reference standard*, but not direct within-subject comparison, or otherwise methodologically limited.
4.	Actigraphy compared to nonstandard reference or group differences shown: a. Adequate comparison of results obtained by actigraphy to those obtained by a non-standard reference*; or b. Actigraphy not compared to any reference, but actigraphy results demonstrated ability to detect significant difference between groups or conditions in well-designed trial.
5.	Actigraphy not adequately compared to any reference, and either a. Actigraphy not used in a well-designed trial, or b. Actigraphy used in such a trial but did not demonstrate ability to detect significant difference between groups or conditions.

* Reference standards for actigraphic evaluation of sleep and circadian rhythms varied by diagnostic category, and included generally accepted "gold standards," applied in an acceptable manner. By diagnostic category, reference standards for insomnia included PSG and/or sleep logs; for circadian rhythm sleep disorders, PSG, phase markers, and/or sleep logs; for sleep apnea, PSG; for restless legs syndrome and periodic limb movements during sleep, PSG; for infants, caregiver reported observations; for elderly or demented persons, phase markers, sleep logs, and/or caregiver reports; and for healthy controls, PSG, phase markers, or sleep logs. Nonstandard references include such items applied outside their diagnostic category, or other experimental monitors.

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 1 evidence, which directly addresses the clinical issue, or overwhelming Level 2 evidence.
Guideline	This is a patient-care strategy, which reflects a moderate degree of clinical certainty. The term guideline implies the use of Level 2 evidence or a consensus of Level 3 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.

The AASM Board of Directors (BOD) approved these recommendations. All members of the AASM SPC and BOD completed detailed conflict-of-interest statements and were found to have no conflicts of interest with regard to this subject.

level was 3–5 in most studies included in the current review, there was good agreement among studies that actigraphy data correlate with polysomnography (when used), sleep logs, and markers of circadian phase in patients with circadian rhythm sleep disorders. There were two Level 3 studies of ASPS or DSPS patients.[20,21] There were four studies of shift work; three were Level 3,[22-24] and one was Level 4b.[25] There was one Level 3 study of blind subjects.[26] There was one Level 3[27] and one Level 4b[25] study of jet lag. Finally, there was one Level 4b study of patients with non-24-hr sleep/wake rhythm.[28]

3.1.3 When polysomnography is not available, actigraphy is indicated as a method to estimate total sleep time in patients with obstructive sleep apnea syndrome. Combined with a validated way of monitoring respiratory events, use of actigraphy may improve accuracy in assessing the severity of obstructive sleep apnea compared with using time in bed. (Standard)

This parameter is a modification of the previous parameter regarding use of actigraphy in evaluation of sleep disordered breathing, and is based on three Level 1 studies.[6,14,29] Since the last parameter paper, several additional studies have evaluated both general purpose actigraphs and specially optimized actigraphy in patients with sleep disordered breathing. Many of the studies have focused on the accuracy or usefulness of actigraphy in estimating total sleep time (TST) in patients with sleep apnea and combining this with tests of respiratory function in order to calculate the most common measure of apnea severity, the apnea-hypopnea index (AHI). Actigraphy can provide an assessment of TST (as it does in some other disorders), and when used along with a valid test for the presence and type of breathing abnormality, can improve the calculation of AHI compared with using time in bed. Several other studies used actigraphy as part of research protocols evaluating sleep pattern of patients with OSA without actually comparing actigraphy results to a sleep standard. No studies propose actigraphy alone as a method of determine the presence of sleep apnea.

One study (Level 1)[14] found a high correlation (r = 0.90, P = 0.0001) between TST measured by PSG (pTST) and TST estimated by actigraphy (aTST) in patients with obstructive sleep apnea syndrome. Agreement using the Bland and Altman method

with sleep related breathing disorders,[6] and 84% in infants.[19]

With the exception of the study by Penzel et al,[16] most authors concluded that actigraphy is significantly correlated with polysomnography in the measurement of total sleep time. For example, Vallieres and Morin[9] concluded, "these results suggest that actigraphy is a reliable method for assessing sleep-wake patterns and for monitoring treatment response among insomnia patients." In a study of normal subjects, de Souza et al[12] reported that "applying automatic sleep scoring to motor activity resulted in a good accuracy (91%) with both the algorithms … in comparison to PSG." In general, the agreement between actigraphy and polysomnography was higher than the agreement between actigraphy and sleep logs.

3.1.2 Actigraphy is indicated to assist in the evaluation of patients suspected of advanced sleep phase syndrome (ASPS), delayed sleep phase syndrome (DSPS), and shift work sleep disorder (Guideline); and circadian rhythm disorders, including jet lag and non-24-hour sleep/wake syndrome [including that associated with blindness] (Option)

This is a modification of the recommendation from the prior practice parameter paper and expands the role of actigraphy in the diagnosis of circadian rhythm sleep disorders. The use of actigraphy for evaluation of circadian rhythm disorders is based on additional evidence included in this review. Although the evidence

found the difference between pTST and aTST was only 2.5 min, but there were notable overestimations and underestimations in three of the 26 patients. In another study, Elbaz et al[29] (Level 1) also found excellent correlation between pTST and aTST (r = 0.74, P <0.0001). In the latter study, the AHI, calculated as the apneas plus hypopneas per hour of actigraphically determined sleep (aAHI) was compared with PSG results, again showing excellent correlation (r = 0.976, P <0.0001). The aAHI was more accurate than an AHI determined by dividing the apneas plus hypopneas by time in bed, indicating that the addition of actigraphy improved accuracy when estimating the AHI without EEG measured sleep time. In both of these studies, the accuracy of actigraphy evaluated using Bland Altman methods declined in patients with more severe sleep apnea, but in the study of Elbaz et al,[29] only 1 of 20 patients were overclassified with respect to OSA severity by the aAHI (severe instead of moderate severity), and none were underclassified. Thus, it appears that even though the estimate of TST becomes less accurate as apneas and hypopneas increase, the actigraphically derived AHI in most cases accurately classifies moderate or severe sleep apnea. Actigraphically estimated TST in milder cases of sleep apnea appear to be quite accurate, especially if using specially optimized actigraphs and evaluation algorithms. These Level 1 studies were performed in a sleep laboratory, and extrapolation to the home environment could introduce issues not anticipated. However, most other studies reviewed for this paper involved use of actigraphy outside the sleep laboratory and had low data failure rates. Because of the complexity of data analysis, evaluations of sleep disordered breathing severity that use actigraphy to estimate TST should be interpreted with caution by experienced sleep clinicians who are familiar with the performance characteristics of the particular actigraphic system employed.

Another Level 1 study evaluated 228 patients using a special actigraphic system optimized to patients with suspected sleep disordered breathing.[6] Using epoch by epoch comparison of sleep versus wake determined actigraphically versus PSG across all subjects, sensitivity of detecting sleep was 88.8%, specificity was 69.5%, and agreement was 84%. Sensitivity and agreement tended to go down with increasing SDB levels (from 91% to 85%, and 86% to 79%, respectively). Specificity was less affected by increasing SDB levels (ranged between 68% and 71%). Considering all subjects, aTST versus pTST was 690 ± 152 and 690 ± 154 minutes, respectively (P >0.05). However, a Level 2 study[16] utilizing the same optimized device found no significant correlation between pTST and aTST. Bland-Altman comparison showed much scatter, with mean of the differences in TST = 12.17 ± 64.5 min. Another (Level 4b) study[30] using the same device found a good correlation between the arousal index estimated from a device using peripheral arterial tonometry changes to detect arousal and actigraphy to estimate sleep time, and the arousal index determined by conventional PSG methods (r = 0.87, P <0.0001). In this study there was no report of actual TST or number of PAT arousals; only the ratio was reported. Therefore, the contribution of actigraphy to the reported correlation could not be evaluated.

Finally, two studies used actigraphy to estimate TST in patients with sleep disordered breathing without formal comparison to another measure of TST. Larkin et al (Level 4b)[31] found that mean TST correlated with changes in C-reactive protein in adolescents with sleep apnea. Noseda et al (Level 5a)[32] used leg actigraphy to measure treatment-induced changes in leg activity in patients with sleep disordered breathing, and did detect treatment effects, but

the study was otherwise methodologically limited for estimating the utility of actigraphy.

3.1.4. Actigraphy is indicated as a method to characterize circadian rhythm patterns or sleep disturbances in individuals with insomnia, including insomnia associated with depression. (Option)

This is similar to the prior recommendation. There were two Level 5b studies[33,34] characterizing sleep patterns in individuals with complaints of insomnia. There were two Level 3[35,36] studies and one Level 4b[37] study indicating that actigraphy is a way to characterize sleep or circadian rhythms in patients with a depressive disorder.

3.1.5 Actigraphy is indicated as a way to determine circadian pattern and estimate average daily sleep time in individuals complaining of hypersomnia (Option).

There were no studies identified that compared actigraphy versus the clinical history plus sleep logs (or another reference standard) to estimate mean sleep time or sleep pattern when evaluating patients with hypersomnia as a complaint. One Level 3 study evaluated patients diagnosed with a variety of hypersomnia disorders, including narcolepsy, idiopathic hypersomnia, hypersomnia associated with psychiatric disorders, HIV-encephalopathy, brainstem stroke, periodic hypersomnia, postviral illness, and head trauma.[38] Actigraphy was used to determine the average daily sleep time over one week prior to evaluation with PSG and MSLT, and biochemical assessment. Actigraphy estimated mean sleep time varied between diagnostic groups, with patients with hypersomnia associated with psychiatric disorders sleeping longer on average (P <0.037 by Wilcoxon rank sums method, our own analysis of their data). Actigraphically determined TST averaged ≥9 hours per day in 11 of 27 patients, including all but one patient with hypersomnia associated with psychiatric disorders, and none of the patients diagnosed with narcolepsy or idiopathic hypersomnia. The shortest mean aTST was 7.44 hours per day in the idiopathic hypersomnia group. The authors indicated that history plus the results of actigraphy, PSG, and MSLT contributed to the diagnosis of disorders of hypersomnolence, but the exact role of actigraphy in interpreting MSLT or assigning diagnoses was not described.

The complaint of sleepiness must be evaluated in the context of recent sleep duration and pattern before a judgment can be made as to the pathologic nature of the complaint. The guidelines developed for the MSLT[39] indicate that sleep logs may be obtained for 1 week prior to the PSG/MSLT to assess sleep-wake schedules and assist in interpretation of results, while the ICSD-2 indicates that "the sleep-wake schedule must have been standardized for at least seven days before the polysomnographic testing (and documented by sleep log or actigraphy)" in order to properly interpret an MSLT. However, some individuals, such as those with impaired cognition, literacy, or motivation may be unable to keep accurate sleep logs, and both over- and underreporting of total sleep time and pattern have been of concern. Therefore, the committee used the Rand/UCLA Appropriateness Method (described above) to determine expert consensus regarding this parameter on the indications for use of actigraphy in hypersomnia. There was agreement that actigraphy is an appropriate way to ensure stable sleep patterns and adequate sleep duration prior to PSG and MSLT.

3.2 Use of actigraphy in assessing the response to therapy of sleep disorders

3.2.1 Actigraphy is useful as an outcome measure in evaluating the response to treatment for circadian rhythm disorders. (Guideline)

This is the same as the recommendation in the previous practice parameters paper. Additional evidence shows that changes in actigraphy measures are in agreement with other outcome measures in the assessment of response to intervention in patients with circadian rhythm sleep disorders.

There were two additional Level 3 studies using actigraphy as an outcome measure in the treatment of jet lag[40,41] and one additional Level 3 study using actigraphy as an outcome measure in a study of shift work.[42]

3.2.2 Actigraphy is useful for evaluating the response to treatment for patients with insomnia, including insomnia associated with depressive disorders. (Guideline)

This is the same as the recommendation from the previous practice parameter paper. There were one additional Level 1,[43] two Level 2,[9,44] two Level 3,[45,46] and two Level 5b studies[33,34] indicating that actigraphy is useful in detecting treatment response in people diagnosed with insomnia. In addition there were two Level 3[47,48] studies indicating that actigraphy is a useful adjunct in detecting treatment response in people diagnosed with disrupted sleep or circadian rhythms associated with a depressive disorder.

3.3 Use of actigraphy in special populations and special situations

3.3.1 Actigraphy is useful for characterizing and monitoring sleep and circadian rhythm patterns and to document treatment outcome (in terms of sleep patterns and circadian rhythms) among older adults living in the community, particularly when used in conjunction with other measures such as sleep diaries and/or caregiver observations. (Guideline)

This recommendation is a modification of the previous practice parameter paper. The evidence for use of actigraphy to characterize and monitor sleep and circadian rhythm patterns among older adults living in the community is based on two additional studies identified in the current review that addressed the use of actigraphy in normal older adults. There were one Level 2[49] and one Level 3[50] study using actigraphy to evaluate sleep and circadian rhythms in normal older people. In the Level 2 study by Ceolim et al[49] there were significant correlations (P <0.005) between sleep log and actigraphic variables (e.g., TST) collected for 23 days in over 76% of a sample of healthy older people. In the Level 3 study of a sample of 103 community-dwelling older adults,[50] actigraphic measures correlated with subjective reports in subjects without sleep complaints but not in those complaining about their sleep. Although able to distinguish between noncomplaining good sleepers and complaining poor sleepers, actigraphy was not able to distinguish between other categories of sleepers in this sample. Results of this study provided evidence of actigraphy's ability to determine TST and sleep onset latency (in women only) for those not able to provide sleep diary information.

The evidence for use of actigraphy to document treatment outcome (in terms of sleep patterns and circadian rhythms) among older adults living in the community is based on two additional Level 3 studies.[51,52] In a placebo-controlled trial[51] of melatonin treatment in healthy older adults presenting either with or without sleep complaints, sleep diaries were used as the reference standard. There was little difference in subjective and actigraphically estimated sleep quality on either measure in either group as a result of melatonin treatment. In the other study,[52] both in-laboratory and at-home measures were taken to determine the effects of daytime naps on nocturnal sleep and performance. In the at-home condition, TST and sleep efficiency were consistent when compared between actigraphy and sleep log results.

3.3.2 Actigraphy is indicated for characterizing and monitoring sleep and circadian rhythm patterns and to document treatment outcome (in terms of sleep patterns and circadian rhythms) among older nursing home residents (in whom traditional sleep monitoring by polysomnography can be difficult to perform and/or interpret). (Guideline)

This is a modification of the recommendation of the previous practice parameter paper. The evidence for the use of actigraphy to characterize and monitor sleep and circadian rhythm patterns among older adults living in nursing homes is based on five additional studies in the nursing home setting. Two Level 3 studies,[53,54] two Level 4 studies,[55,56] and one Level 5b study[57] were identified. Several studies used observer ratings as the reference standard for comparison with actigraphy. One Level 3 study[53] found that although results were similar between nursing staff and actigraphy for some sleep measures, nursing staff noted less sleep disruption during the night (WASO) than was recorded by actigraphy. Another Level 3 study[54] was able to discriminate diagnostic subtypes among dementia patients according to patterns of activity and core body temperature rhythms. Two Level 4 studies examined patterns of rest/activity in relation to presence or absence or Level of dementia. A Level 4b study[55] found that actigraphic rest/activity patterns differentiated patients with mild dementia from those advanced to the moderate stage. Similarly, a Level 4a study[56] was able to distinguish demented from nondemented subjects on the basis of daytime and nocturnal activity levels. Further they found that functional ability was associated with diurnal patterns of activity.

The evidence for use of actigraphy to document treatment outcome (in terms of sleep patterns and circadian rhythms) among older nursing home residents is based on 13 additional treatment outcome studies, including two Level 2[17,58] and three Level 3 studies.[59-61] Furthermore, there were six Level 4[62-67] and two Level 5b[68,69] studies evaluating treatment outcomes in dementia or nursing home populations. One Level 2 study[58] tested the effects of withdrawal of antipsychotic medication on sleep/wake activity and on behavioral and psychological symptoms in nursing home residents.[58] Actigraphic results were compared with psychiatric inventory responses, and restlessness was significantly associated with mean 24-hr actigraphic measures of activity (r = 0.60, P = 0.001) and nocturnal sleep problems were significantly associated with nighttime activity levels. (r = 0.60, P = 0.001). In another Level 2 study[17] of a randomized controlled trial comparing the effects of two different doses of melatonin and placebo on sleep in Alzheimer disease patients found no significant differences on sleep outcome by actigraphy between treatment groups. However, a subset of seven subjects had simultaneous actigraphy

and PSG for a period of 18 days and the TST estimated by actigraphy correlated highly with PSG (r= 0.92, P <0.01). In addition, a Level 3 study[59] testing the effects of bright light in a nursing home sample found significant improvements in sleep time and wake time within nocturnal sleep according to actigraphy which paralleled nursing staff ratings.

3.3.3 Actigraphy is indicated for delineating sleep patterns, and to document treatment responses in normal infants and children (in whom traditional sleep monitoring by polysomnography can be difficult to perform and/or interpret), and in special pediatric populations. (Guideline)

This recommendation is a modification of the recommendation from the previous practice parameter paper.[1] This recommendation is based on 23 additional studies identified in the current review that addressed the use of actigraphy in children. There were a total of five Level 2 studies (no studies were identified as Level 1, due to the absence of information regarding blinding, as described above), seven Level 3 studies, nine Level 4 studies, and two Level 5 studies of actigraphy in pediatric populations. These studies included a range of age groups (infant through adolescent), as well as a number of different medical, psychiatric, and sleep disordered diagnostic groups, and used a variety of reference standards.

In terms of age groups, the largest numbers of studies (10) were focused on infants (typically between 6 and 12 months). One Level 2 study[70] compared a parent-report infant sleep questionnaire (Brief Infant Sleep Questionnaire – BISQ) with actigraphy and daily sleep logs to assess correspondence between measures, as well as to determine differences between a control and clinical sample of infants referred to a sleep clinic. Significant but moderate correlations were found between BISQ and actigraphic measures of sleep onset latency (SOL) (r = 0.54, P <0.001) and night wakings (r = 0.42, P <0.0001), with nocturnal sleep duration showing lower agreement (r = 0.23, P <0.05). In contrast, the most robust correlations found between actigraphy measures and the reference standard (daily sleep logs) were found for SOL (r = 0.96, P <0.0001) and nocturnal TST (r = 0.87, P <0.0001), rather than night wakings (r = 0.49, P <0.0001). There were also some significant systematic differences between actigraphic and sleep log measures, with actigraphy providing lower estimates of sleep duration and higher estimates of night wakings compared to sleep diaries. Only one actigraphic measure, number of night wakings, had a unique contribution in discriminating between the control and clinical samples (F=6.29, P <0.05).

A different reference standard, direct observation of infant behavioral states, was used in a Level 2 study using actigraphy in assessing sleep-wake rhythm and sleep structure in healthy 1, 3, and 6 month old infants.[71] The overall agreement between measures in scoring sleep and wake was satisfactory (between 87% and 95%) after 3 months of age, but agreement was less than 73% at 1 month. Reliable actigraphic distinction, however, between active and quiet sleep could not be made in any of the three age groups.

Healthy term 6-8 week old infants were also the subjects in a Level 3 study[72] which assessed the effects of infant massage on the development of circadian rhythms by comparing actigraphy and salivary melatonin levels; peaks of period activity were delayed in the intervention group compared to controls. Another Level 3 study[73] which longitudinally assessed the relationship be-

tween light exposure, sleep patterns, and crying in healthy 6-12 week old infants found overall consistency between actigraphic measures of nocturnal activity and parental reports of sleep. A third Level 3 study documented some differences in activity-rest cycles but not in other sleep parameters during the first week of life in infants grouped according to delivery mode (planned C-section, emergency Caesarian section, and normal spontaneous vaginal delivery).[74] One Level 4b study[75] found some significant differences (i.e., increased variability ultradian cycles, diurnal sleep duration) in actigraphically derived activity-rest behaviors between healthy pre-term and full-term infants, while another[76] Level 4b study used actigraphy to characterize inter-individual variability in activity-rest behavior and differences in sleep duration between pre- and full-term infants. Actigraphy was also used in a Level 4b study[77] to document a significant increase in nocturnal activity counts associated with rapid ascent to moderate altitudes in a groups of infants and young children (4-33 months), and in another Level 4b study[78] which examined the development of circadian rhythms in newborns by comparing sleep-wake patterns longitudinally in newborns and their mothers at 3, 6, 9, and 12 weeks. A Level 5 study[19] used actigraphy to determine sleeping position and measure sleep-wake patterns in healthy 34-42 week old infants. Finally, a Level 3 study[79] assessing differences in sleep patterns in *parents* of newborns, found that mothers had less actigraphically documented sleep at night and more during the day compared to fathers, that breastfeeding was associated with more WASO, and that working mothers had an average 6-7 minutes less sleep in 24 hours than nonworking mothers.

Older children and adolescents were subjects in several other studies. A Level 4b study[80] which assessed the ability of measures of emotional intensity (maternal rating, vagal functioning) to predict actigraphically determined sleep problems in healthy school-aged children, found that increased emotional intensity was correlated with reduced nocturnal sleep and increased night activity. A Level 2 study[81] examined the validity of a self-report adolescent sleep survey by comparing retrospective self-report estimates of sleep patterns (TST, bedtime, and waketime on weekends and weekdays) with sleep parameters measured by both actigraphy and sleep logs over a subsequent week. Survey-estimated school-night total sleep times and wake times did not differ from diary and actigraphy measures, although survey bedtimes were slightly earlier. On weekends, survey-reported sleep duration was about 30 minutes longer than estimated by sleep diaries (t = 4.26, P <0.001) and actigraphy (t = 5.25, P <0.001), and wake times were about 55 minutes longer. Overall, school- and weekend-night survey variables were significantly correlated with both diary and actigraphy variables, but the strength of the associations were consistently greater for school-night variables than for corresponding weekend-night variables. However, it should be noted that there was no attempt to directly compare actigraphy and the reference standard sleep log variables in this study; in fact, it was noted in the Methods section that the procedure ("Sadeh algorithm") used to analyze actigraphy "relies heavily upon the concurrent behavioral self-report obtained by the sleep diaries," and thus the two measures would be expected to be highly correlated.

Actigraphic measures of sleep were also used in studies of several pediatric patient populations with chronic medical conditions. One was a Level 2 study that primarily assessed the relationship between sleep disturbance and pulmonary function in a group of children with cystic fibrosis (CF) but also compared actigraphy

to parent- and self-report data in this population.[82] There was a significant correlation between sleep duration (the only parameter reported) as measured by actigraphy with sleep period reported by parents (r = 0.79, P<0.0001) and by children (r = 0.71, P <0.0001) in the control group, but not in the CF group (r = 0.29, P = 0.06; r = 0.18, P = 0.2, respectively). A Level 3 study[83] used actigraphy to confirm sleep instability, frequent microarousals, and increased daytime napping in a group of children with Smith-Magenis syndrome (a genetic syndrome frequently characterized by self-injury and sleep disturbances). Actigraphy was also used to measure sleep disturbance in a Level 4b study[84] of blind adolescents with and without optic nerve disease, which documented that greater wake time instability was associated with optic nerve disease.

In studies of children with psychiatric disorders, one Level 3 study[85] used actigraphy to study sleep patterns in children with ADHD with and without sleep problems compared to controls, and found significantly delayed sleep onset and offset in children with ADHD and insomnia, suggesting a circadian rhythm abnormality. A Level 4b[86] intervention study used actigraphy to document treatment response (decrease in mean nocturnal activity) to melatonin and rebound sleep disturbance following discontinuation in children with Asperger syndrome. Another Level 4b[35] study, which used actigraphy to evaluate locomotor activity and circadian rest-activity cycles in children with major depression compared to controls, found significant differences related to gender and age but not group assignment. Finally, a retrospective chart review (Level 5 study)[87] of children with ADHD referred to a sleep center showed a high incidence (94%) of sleep onset delay and high night-to-night variability in sleep patterns in the small percentage (16%) of subjects for whom actigraphy data was available.

There were also several studies which used actigraphy to assess sleep in children with sleep disorders. Agreement between periodic limb movement during sleep scored by actigraphy and those detected with anterior tibialis EMG was assessed in a Level 2 study of ninety-nine 4- to 12-year-old children.[88] It was concluded that this actigraphic measurement of PLMs in children was not sufficiently accurate to permit use in clinical settings. Specifically, actigraphy tended to overestimate PLMs compared to EMG, and, although the application of a correction factor based on average number of EMG-derived movement during arousals improved agreement between measures somewhat, different correction factors were required for each of the different diagnostic groups (SDB, primary snoring/normal, and periodic limb movement disorder), limiting its utility as a diagnostic measure. One Level 4b study[31] of adolescents with SDB found sleep duration was significantly negatively correlated with C-reactive protein, body mass index, and AHI.

Finally, one Level 2 study[89] compared actigraph placement (waist vs nondominant wrist) in estimating sleep duration in school-aged children. Although diurnal activity was lower with waist placement, the overall minute-by-minute agreement of sleep-wake states between placement sites was 92.5% (range 82.3%–97.7%), and nocturnal agreement was 95.6%. None of the mean sleep estimates (sleep duration, sleep latency, sleep percentage, sleep efficiency) were significantly affected by placement site, although there were some inter-individual differences in agreement (sleep duration and latency). Another Level 3 study[90] assessing compliance with imposed sleep schedules in the home setting in school-aged children demonstrated significant differences in actigraphically measured sleep according to condition.

4. RECOMMENDATIONS FOR FUTURE RESEARCH

4.1

Additional research is needed which compares results from different actigraphy devices and the variety of algorithms used to evaluate actigraphy data in order to further establish standards of actigraphy technology. Well designed studies using actigraphy should describe the device and the analysis algorithms used.

4.2

There is need for additional study addressing the reliability and validity of actigraphy compared to reference standards, such as polysomnography, and the circadian rhythms of basic physiologic functions, such as temperature, cortisol, and melatonin levels.

4.3

Further research is needed to establish standards for setting start and stop times of the sleep and wake periods when using actigraphy, including techniques such as event markers or sleep diaries, and other methods in the study of populations where these techniques may not be valid (e.g., dementia patients, nursing home setting). For example, difficulty in establishing a standard for setting start time is likely one factor contributing to the difficulty in correlating certain sleep variables (especially sleep onset latency) measured by actigraphy with findings from PSG.

4.4

Well-designed studies should include technical details related to the administration and scoring of actigraphy. In much of the existing literature, there is an inadequate description of whether visual inspection of data is performed, how missing data is handled, and other important decisions made in the analysis of actigraphy data. More research is needed to assess the reliability of actigraphy under various clinical circumstances, and to determine what parameters may be used to assess the quality of actigraphic data.

4.5

Further work is needed to clarify the relative and unique contributions of actigraphy, polysomnography and sleep logs in the diagnosis of sleep disorders and measurement of treatment effects. For example, besides estimates of wake and sleep times, there are various other data generated by commercially available analysis software, such as fragmentation index and movement index, for which clinical correlates are not well described.

4.6

The use of actigraphy in hypersomnia populations, especially as an adjunct to the Multiple Sleep Latency Test, should be tested to establish an evidence-based recommendation for the use of actigraphy in the clinical evaluation and management of hypersomnia.

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