REVIEW ARTICLE

# Actigraphy

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*Indian J Sleep Med 2007; 2.4, 116-121*

## Introduction

The gold standard for the evaluation of sleep is polysomnography (PSG) with a minimum of electroencephalographic (EEG), electrooculographic (EOG), and submentalis electromyographic (EMG) recordings. Other physiological variables are added depending on the patient's sleep complains (such as respiration, heart rate, tibialis muscle movement, oximetry). A PSG therefore allows for the collection of detailed information.

This information is very important for certain types of evaluations; however, the recording process may disturb a patient's sleep and often is very costly both to record and to score. In addition, the PSG typically provides data about sleep episodes during the time of recording, which often is 6 to 10 h. Because recordings are usually made during the major sleep period, little information is available about daytime (waking) or napping behavior. There are some instances in which it is not essential to know the specific stage of sleep or the status of the other physiological variables; only information on whether the person is awake or asleep is necessary.

New technological methods that are much less expensive than a PSG allow for 24-h recordings of activity from which wake and sleep can be scored. These devices are called actigraphs (or actimeters), and the usually record limb movement. Traditionally, the actigraphs are placed on a wrist, although sometimes activity from the leg is recorded. The data collected are displayed on a computer and are examined for activity versus inactivity and analyzed for wake versus sleep.

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## History

Wrist activity technology is based on the fact that during sleep, there is little movement, whereas during wakefulness, there is increased movement. Although activity monitors had been around for many years,[1] Kupfer et al.,[2] McPartland et al.,[3] Colburn et al.,[4] and Kripke et al.[5] were among the first to use activity to differentiate wake from sleep. The initial models were developed in the early 1970s by Kupfer and colleagues and were self- contained activity counters with integrated circuits and memory that provided off-line data retrieval.[2,3] Kripke and colleagues were among the first to publish reliability data on the use of wrist actigraphy for the assessment of sleep.[5-8] Several years later, other actigraphs were developed by Remond and Hegge[9] and Borbely.[10,11] The analog actigraphs were small but used telemetry or had to be attached to a medilog recorder and were scored by hand. The first digital actigraphs were about half of the size of a chalkboard eraser, and computer algorithms were written for automatic scoring of sleep and wake.

With the advent of microprocessors and miniaturization, most contemporary actigraphs have a movement detector (such as an accelerometer) and sufficient memory to record for long time periods. Newer models are the size of a wristwatch and collect digital data. Physical movement is generally sampled several times per second and stored in 1-min epochs, although sampling and epoch rates can be set by the clinician or investigator. The digitized data are then translated into a numeric representation and stored until downloaded to a computer. Computer algorithms have been written to automatically score wake and sleep and to provide the user with summary statistics. These computer algorithms generally supply information on total sleep time, percent of the time spent awake, number of awakenings, time between awakenings, and sleep on-set latency.[7] The only time the actigraph must be removed is during bathing or swimming (although some of the newer models are water resistant), thus allowing for nearly continuous 24-h recordings for several days or weeks.

The wrist actigraph may be particularly valuable for studying individuals who would have difficulty sleeping in a sleep laboratory or with the wires associated with traditional PSG, such as insomniacs, children, and the elderly with dementia. With actigraphy, patients are studied in their natural environment. In addition, the EEG in the elderly with dementia often makes it difficult to distinguish wake from sleep.[21] The use of actigraphy avoids both of these problems and enables the recording of sleep-wake activity in an easy, unobtrusive manner.

Some actigraphs record both activity and light exposure (for example, the Actillume by Ambulatory Monitoring, Inc., or the Actiwatch-L by Mini-Mitter Co., Inc.). Some devices also have the ability to record core body temperature, this allows both clinical and investigational studies of circadian rhythms in the home environment. Most actigraphs have event buttons that the subject can push when he or she turns out the lights or needs to note other events.

There still are many unknowns about how the environment affects activity recordings. Sadeh et al.[20] suggested that the bed surface (for example, a waterbed) and the presence of a bed partner may affect the activity signal. Additional research is needed in these areas.

## Application of Wrist Actigraphy

The American Sleep Disorders Association (ASDA) published recommendations on the use of actigraphy in the clinical assessment of sleep disorders.[23] Actigraphy is not recommended for the routine diagnosis of insomnia, sleep apnea, or periodic limb movements in sleep (PLMS).

## Specific Recommendations are as Follows:[56]

- Actigraphy is a valid technique to assist in determining sleep patterns in healthy adult populations and in patient suspected of certain sleep disorders.
- Actigraphy is indicated to assist in evaluating patients for ASPS, DSPS, and shift work sleep disorders as well as circadian rhythm disorders, including jet lag and non- 24hours 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 syndrome (OSAS). Compared with using time in bed, use of actigraphy combined with a validated method to monitor respiratory events may improve accuracy in determining the severity of obstructive sleep apnea.
- In patients with insomnia, including insomnia associated with depression, actigraphy is indicated as a method to characterize circadian rhythm patterns or sleep disturbances.
- In patients with complaints of hypersomnia, actigraphy is indicated as a method to determine circadian patterns and estimate average daily sleep time.
- Actigraphy is useful to evaluate treatment response in circadian rhythm disorders.
- Actigraphy is useful to evaluate treatment response in patient with inosomnia, including insomnia associated with depressive disorders.
- Actigraphy is useful to characterize and monitor sleep and circadian rhythm patterns and to document treatment outcome, in term of sleep patterns and circadian rhythms, in older community-dwelling adults, particularly when used in combination with other measures such as sleep diaries and/or caregiver observations.
- Actigraphy is indicated to characterize and monitor sleep and circadian rhythms, for older nursing home residents in whom traditional sleep monitoring using polysomnography can be difficult to perform and/ or interpret.
- Actigraphy is indicated to determine sleep patterns and to document treatment responses in healthy infants and children, in whom traditional sleep monitoring using polysomnography can be difficult to perform and/ or interpret, as well as special pediatric populations.

Few examples of the applications of wrist actigraphy in sleep medicine are described below.

## Insomnia

Researchers have examined the use of actigraphy in the study of insomnia. Although actigraphy cannot be used to determine the cause of insomnia, it can help in evaluation of the severity. In patients with insomnia, the most difficult distinctions for the actigraph to recognize are the transitions between sleep and wake and the ultra short sleep-wake cycles.

## Sleep Apnea

Aubert-Tulkens et. Al.[27] used wrist actigraphy to measure movement index and fragmentation index during sleep in patient with sleep apnea compared with control subjects. Those with sleep apnea had significantly higher movement and fragmentation indices.

Middlekoop et al.[28] conducted an epidemiological study of 116 subjects who reported snoring habitually, experienced excessive daytime sleepiness, and/or had a spousal report of respiratory cessations. Both wrist activity and respiration (oronasal thermistry) were recorded for one night in the subject's home. Results indicated that patients with an apnea index of more than five events per hour of sleep had higher movement and higher fragmentation indices than those with apnea index less than five. However, measures of activity failed to reliably predict who had sleep apnea.

Additional research is needed to determine whether actigraphy is a viable method for screening and for following treated patient with sleep apnea.

## Periodic Limb Movements in Sleep

PLMS is generally evaluated by measuring the EMG at the tibialis muscle. Kazenwadel et al.[29] found a high reliability between tibialis EMG and actigraphy for the number of leg movements per hour of sleep. Because PLMS can greatly vary from night to night, actigraphy gave a better assessment because multiple nights could be easily recorded.

## Treatment Effects

Pieta et al.[29]a used ankle actigraphy as well as an tibialis EMG to document leg movements in uremic patients being treated with pergolide. In a study of insomnia in older adults, Brooks et al.[15] used actigraphy to examine the treatment effects of sleep restriction therapy and found the actigraphy sufficiently sensitive to detect effects of therapy. The authors concluded that because actigraphy is less invasive and less expensive than PSG, it is a promising device for the assessment of treatment effects. In a critical evaluation of actigraphy, Chambers[30] also concluded that because actigraphy measures are reliable night to night, they are especially appropriate for assessing changes in sleep secondary to treatment. Others have used actigraphy to measure the treatment effects of nicotine replacement on sleep and daytime activity[31] and the effects of drugs on sleep.[32-34] These data suggest that actigraphy can be used as a screening device in some patients, before the more expensive PSG is ordered. It also may have a role in follow up.

## Circadian Rhythms

Actigraphy allows the study of rhythms occurring over many days; it therefore is well suited for the study of circadian rhythms and sleep-wake cycles in patient with cancer, as a preliminary step towards the advancement of chronotherapy. Studies have also been performed that examine the sleep schedules of adolescents,[36] shift workers,[37,38] in-flight crew,[39] and persons with jet lag.[32]

## Pediatrics

Sadeh[40] used wrist activity to study the treatment effects on the sleep patterns of 50 infants whose parents complained of sleep disturbances in their children. Objective activity recordings were compared with parental reports. Sadeh determined that most changes occurred during the first night of intervention. In addition, parental subjective reports significantly differed from objective actigraphy on quality of sleep, with parents reporting fewer awakenings during the night. The presence of objective measures allows for the evalution of activity during sleep that would otherwise be missed by observation alone.

## Elderly

At the other end of the age spectrum, actigraphy has been used to study sleep-wake patterns of the elderly. The elderly are particularly susceptible to sleep complaints secondary to circadian rhythm changes, sleep disordered breathing, PLMS, medical illness, and medication use.[41] Although some of these complaints may be examined in the laboratory, the elderly are often more set in their ways, need to stay home to take care of a spouse, or just find it more comfortable to sleep in their own beds.

Van Hilten et al.[42] examined the influence of age on nocturnal behavior in 100 healthy older adults who wore an activity monitor for 6 consecutive days and nights. The authors concluded that without illness, age itself has only marginal effects on nocturnal activity and immobility (that is, sleep and wake). This type of study could not have been done in the laboratory without an isolation unit, and even then it is unlikely that 100 subjects could have been studied. The only way this type of large-scale study could have been accomplished was with the use of actigraphy.

In the same group of subjects, van Hilten et al.[43] also examined the night-to-night variability and intra-subject variability of activity. Results indicated that there was no "first night effect", typical of laboratory sleep studies (data from the first night did not differ from that of subsequent nights and was rather stable from night to night). Similarly, Jean-Louis et al.[44] found no first night to effect with actigraphy in younger subjects. These results suggested that unlike the traditional laboratory studies, subjects do not need time to adapt to the activity monitor.

With the use of actigraphy, Ancoli-Israel and colleagues[45-47] have shown that sleep in nursing home patients is extremely fragmented, with most patients never sleeping for a full hour and never awake for a full hour throughout the 24-h day. These data led to ongoing studies of treatment to improve the sleep quality and quantity in this group of patients.

## Schizophrenia

Martin et al.[48, 49] studied the 24-h sleep wake patterns of 28 older patients with schizophrenia (mean age, 58 years). In general, the patients slept for only 67% of the night and napped for 9% of the day. Patients taking neuroleptic medication were significantly sleepier both at night and during the day. Wirz-Justice et al.[50] used actigraphy to examine the rest-activity cycle of a patient with schizophrenia. By recording wrist activity for 220 days, they were able to determine that under stable haloperidol treatment, the patient had an arrhythmic rest-activity cycle. When treatment was switched to clozapine, the circadian rhythmicity improved.

## Tricks of Trade

Actigraphs are traditionally placed on the wrist of the nondominant hand, but two groups of investigations have shown that either wrist can be used. Sadeh et al.[18] compared data from both wrists and found that although activity levels differed between the two hands, agreement rates with PSG were essentially the same for data collected from both hands. Chung et al.[54] reported similar results. In studies on infants, actigraphs have also been placed on the legs.[55]

Most actigraphs have bands that are similar to plastic watchbands. For individuals who are sensitive to such bands or who find it uncomfortable to wear them for long time periods, band made of terry cloth and Velcro can be sewed.

Patients wearing actigraphs should be asked to keep a actigraph log in which they note information about daily time to bed, time out of bed, and any unusual activity or times when the device is removed (such as for showers or swimming). This information is extremely helpful for editing and analyzing the data.

When data are collected in 1-min epochs, collected for more than 1 week, it is prudent to download data every week to minimize data loss. Battery levels should be checked when initializing the device and again during downloading. Batteries with levels of less than 90% of the original battery voltage should be discarded because they likely to fail. The battery life is approximately 30 days. In our laboratory, a battery log is kept that records the battery number, data activity monitor was initializing, and data the data were downloaded, total number of days the battery had been used, and starting and ending battery levels. With devices that also record light, it is extremely important that the light sensor not be covered by the person's sleeve. The sleeve can be tucked under the actigraph or pinned up to ensure it does not occlude the light sensor.

## Editing Actigraphy Data

Different software packages are available for scoring the rest-activity data and inferring sleep-wake. Because the experience of our laboratory is with the Actillume recorder. Data are editing on a computer screen with the use of daily sleep log. Time intervals during which the device is removed are automatically scored as sleep by the ACTION3 software program because there is no movement. If there is no information on the log about the activity during the time the device was removed, that time period should be scored as missing data.

Channels of information can also be added to the data. For example, interval channels with information about time in bed and time out of bed can be edited in, as can times of treatment intervals. An example is given to two 24-h periods with the activity data, sleep-wake scoring, and added interval channels.

## Summary

Wrist activity has the advantages of bring cost efficient, allowing the recording of sleep in natural environments, recording behavior that occurs during both the night and the day, and recording for long time periods. Although not a replacement for EEG or PSG recordings, there are times when actigraphy provides clear advantages for data collection. Actigraphy is particularly useful for studding individuals who cannot tolerate sleeping in the laboratory; for example, patients with complaints of insomnia, small children, or the elderly. Actigraphy is also becoming an important tool in follow-up studies and for examining efficacy in clinical outcome.

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