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Actigraphy: Validity, Reliability, and Clinical Utility

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Conflict of Interest Disclosures for Speakers

1. I do not have any relationships with any entities producing, marketing, re-selling, or distributing health care goods or services consumed by, or used on, patients, OR

2. I have the following relationships with entities producing, marketing, re-selling, or distributing health care goods or services consumed by, or used on, patients:

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3. The material presented in this lecture has no relationship with any of these potential conflicts, OR

4. This talk presents material that is related to one or more of these potential conflicts, and the following objective references are provided as support for this lecture:

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Objectives

• Describe the basic technology underlying actigraphy.
• Provide an overview of the reliability and validity of actigraphy in detection of sleep and wake, in normal and abnormal populations.
• Discuss the clinical utility of actigraphy in evaluation of sleep disorders.
Basic technology of actigraphy

• Measures frequency, duration, and intensity of physical activity.
• Movement is a vector sum of movement in 3 directions (side to side, head to toe, up and down).
• Components
  • Piezoelectric accelerometer
  • -pass filter (filters everything except the 2-3 Hz band)
  • Timer
  • Memory
  • Interface
Basic technology of accelerometer

- Measures rate of change of velocity (i.e., “g-force”).
- Piezoelectric component converts the mechanical motion into an electrical signal.

![Diagram of accelerometer components]

- When pressure is placed on the spring, the piezoelectric material is compressed.
- When acceleration occurs, the pressure changes on the piezoelectric material release energy, generating a voltage.
Many current uses for actigraphy

- Sleep/circadian patterns
- Activity monitoring in obesity research
- Scratching behavior in children with atopic dermatitis
- Movement in ADHD research
- Safety monitoring in the elderly
- Sprint speeds in football and soccer
- Tonic-clonic seizure detection
- Gait analysis and tremor in Parkinson’s Disease
- Fetal movement
Examples of actigraphy devices

Prices range from about $400-$3,000 depending on features (memory, +/- light sensor, interfaces, etc.)
Accelerometer placement

- Wrist
- Leg
- Hip
- Waist
- Jaw
- Ankle
- Toe
CPT codes

- 95803: actigraph testing, recording, analysis, interpretation, and report (72 hours-14 consecutive days)
- 95803-26: actigraph data interpretation and report only
- 95803-TC: actigraph testing without interpretation and report
Background concepts

• Reliability (consistency, precision):
  • Do different actigraphy devices, placements, etc., agree with each other?

• Validity (meaningfulness):
  • Does actigraphy measure what we are intending to measure (sleep, movement, PLMs, etc.)?

• Sensitivity:
  • What is the agreement between minutes of sleep scored by actigraphy vs. PSG?

• Specificity:
  • What is the agreement between minutes of wake scored by actigraphy vs. PSG?
Reliability and Validity

1) Which target best describes actigraphy?
2) What are we really aiming at?
   • Quality of sleep?
   • Quantity of sleep?
   • Consistency of sleep?
   • Pattern of sleep across time?
Why is it important to understand reliability in actigraphy?

- Reliability is necessary but not sufficient to establish validity.
- The ability to obtain multiple samples over time improves test reliability by reducing the probability of sampling error caused by night-to-night variability.
- Actigraphy may be reliable in one demographic, condition, or severity but not in another.
Sensitivity and specificity applied to actigraphy

• Sensitivity = “true positive”
  *If the person is really sleeping, does the actigraph indicate sleep?*

• Specificity = “true negative”
  *If the person is not sleeping, does the actigraph indicate wake?*

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<th>PSG sleep</th>
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<td>Actigraph</td>
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<td>sleep</td>
<td>true positive</td>
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<td>Actigraph</td>
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<td>wake</td>
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Sensitivity = \( \frac{\text{true positives}}{\text{true positives} + \text{false negatives}} \)

Specificity = \( \frac{\text{true negatives}}{\text{false positives} + \text{true negatives}} \)
Sensitivity and specificity characteristics of actigraphy

- Actigraphy generally has
  - High sensitivity (sleep detection): 90-97%
  - Low specificity (wake detection): 25-60%

What is the question?

- Is it more important to know if the person is asleep in bed (sensitivity) or if they are awake in bed (specificity)?

Analogy:
- Is it more important to detect the number of people in a pool who are swimming well or to detect the ones who are struggling?
- If you intervene with a swimmer who seems to be struggling but is really OK, will it cause harm, incur costs, or distract you from helping someone who is drowning?
Understanding actigraphy specificity and sensitivity

- Assuming 90% sleep efficiency, if all epochs are scored as sleep, the sensitivity of actigraphy will be 100% and specificity will be 0%.
- If the device is less able to detect small movements, test specificity is reduced.
- If the device is more able to detect small movement, test sensitivity is reduced.
- More severely disordered sleep results in less diagnostic utility for actigraphy, particularly in insomnia\(^1\).

Scoring algorithms

• Most are based on a combination of linear compilations (of predefined windows) of activity levels and various logical decisions (smoothing, decision trees, neural networks)¹.

• Use of the “high sensitivity” setting does not appear to improve detection of wake (55% wake detection)².

• Minutes of immobility for determination of sleep onset vary across age and specific device³.

Actigraphy example
Validity data on sleep apps

• Consumer devices lack objective evidence to support claims\(^1\).
• Sleep Time\(^{\text{tm}}\) app for iPhone was similar to actigraphy in detecting sleep (86% sensitivity) but appears to have no correlation with sleep efficiency or other sleep parameters\(^2\).

Validity data on commercially available devices

- The Fitbit Ultra (sensitive setting) demonstrated reasonable specificity (.79) but inadequate sensitivity/accuracy (.70), overestimating sleep time.
- Similar to actigraphy, the Fitbit Ultra (normal mode) demonstrated good sensitivity (.86) but poor specificity (.52).¹

Comparing actigraphy, caregiver observations, and self-report

- Caregivers overestimate sleep time in both the elderly\(^1\) and infants\(^2\).
- Actigraphy may be more accurate than sleep diaries for individuals with depression\(^3\) and PTSD\(^4\).

Reliability data

- Comparison of the AMI and Phillips devices demonstrated poor agreement, with >1 hr differences between devices in both WASO and TST\(^1\).
- When compared to PSG, accuracy is better for wrist placement than hip-based measurement\(^2\).

Clinical utility of actigraphy in insomnia

- Advantage of actigraphy is the ability to document patterns across many days.
- Since clinical interventions are usually based on an extended period of time, actigraphy may be a good fit for the evaluation of interventions for insomnia.
- Actigraphy typically underestimates wake, but sleep diaries over-estimate wake in insomnia patients.
- Accuracy of actigraphy declines as sleep efficiency declines\(^1\).

Clinical utility of actigraphy in hypersomnias

• May be helpful in determining average daily sleep time and stability during the week prior to evaluation with PSG and MSLT\(^1\).

Clinical utility of actigraphy in SDB

• May slightly improve accuracy of AHI in HSAT, although the improvement is minor\(^1\).
• When compared to patients with insomnia or even normals, actigraphy may have a higher correlation with WASO in untreated OSA patients vs. OSA patients without other comorbid sleep disorders\(^2\).

Clinical utility of actigraphy in shift work and circadian rhythm sleep disorders

- Potential use for evaluating time in bed and relationship to safety measures\(^1\).
- Ability of actigraphy to evaluate patterns of rest and activity is also useful in evaluation of circadian rhythm disorders\(^2\).

Clinical utility of actigraphy in PLMD

- Agreement between PSG and two different actigraphy devices attached to both legs is poor (+/- 30/hr)\(^1\).
- Detection of PLMs improves when sensor is moved to the ankle or base of the big toe\(^2\).

Conclusions

• Actigraphy underestimates SOL and WASO in comparison to PSG.
• Poorer sleep is associated with poorer accuracy of actigraphy, therefore clinical utility for diagnosis of many sleep disorders is limited.
• Actigraphy data do not correlate well with measures of sleep quality.
Conclusions

• Actigraphy is particularly useful in documenting patterns across many days, and in the evaluation of interventions for circadian rhythm disorders and insomnia.
• Actigraphy, subjective sleep descriptions, and PSG all measure aspects of sleep.
Questions?