Utilizing Actigraphy Data and Multi-Dimensional Sleep Domains

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Objectives

• Brief overview of sleep actigraphy data collection in WHISPER

• Discuss how objective (actigraphic) sleep and circadian measures compliment subjective measures of sleep

• Sleep as a multi-dimensional exposure and approaches to analysis

• Opportunities
Actigraphy in WHISPER

- Gt9X Link Device
- 3 axis accelerometer
- Worn on non-dominant wrist for 4 days and 4 nights
- Participants keep a diary of sleep times, and watch removals
Key Sleep and Circadian Exposures from Actigraphy

• ‘Traditional’ night-time sleep-wake variables (averaged over all nights of recording):
  – Total sleep time (min)
  – Wake after sleep onset (min)
  – Sleep efficiency (%)
  – Sleep latency (min)

• Daytime Napping behavior

• Rest-activity rhythms (24 hour patterns):
  – Extended cosine model
  – Non-parametric methods
Poor Sleep Efficiency vs High Sleep Efficiency

Efficiency of 66.5%

Efficiency of 98.1%
Objective vs Subjective Sleep

• Poorly correlated, particularly in older adults
  – Correlation ~ 0.2 for night-time sleep duration based on data from the Study of Osteoporotic Fractures

• Associations with outcomes may differ
  – Subjective sleep tends to associate more strongly with depression and anxiety
  – Objective sleep more strongly related to some physical health outcomes

• Subjective and objective sleep may capture different information about health and well-being
Self-Reported 24-hour Sleep Duration and Risk of Mortality in Older Women

Total Self-reported Sleep Duration and Mortality

### Actigraphic Sleep Duration and Risk of Mortality in Older Women

<table>
<thead>
<tr>
<th></th>
<th>All-Cause</th>
<th>Cardiovascular</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SOF women</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>997</td>
<td>343</td>
</tr>
<tr>
<td><strong>Actigraphy TST</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \leq 5 ) hrs</td>
<td>1.80 (1.45, 2.23)</td>
<td>2.30 (1.61, 3.28)</td>
</tr>
<tr>
<td>( &gt;5 ) to ( \leq 7 ) hrs</td>
<td>1.02 (0.88, 1.19)</td>
<td>1.20 (0.92, 1.57)</td>
</tr>
<tr>
<td>( &gt;7 ) to ( \leq 8 ) hrs</td>
<td>1.00 (referent)</td>
<td>1.00 (referent)</td>
</tr>
<tr>
<td>( &gt;8 ) hrs</td>
<td>1.33 (1.10, 1.6)</td>
<td>1.43 (1.02, 2)</td>
</tr>
</tbody>
</table>
Actigraphic Correlates of Self-Reported Long Sleep in Older Men (MrOS Sleep Study)

- Actigraphic total sleep time (TST) and time-in-bed (TIB) predict long sleep duration (9 or more hours per night)
- In multivariate models including both TST and TIB:
  - TIB (per 30 min): OR=1.71 (95% CI 1.53-1.91)
  - TST (per 30 min): OR=1.03 (95% CI 0.94 – 1.11)

Patel et al. 2012; SLEEP 35(5)
Actigraphy for Studying Disruption of Circadian Rhythms in Aging

• Many biological processes follow ~24 hour pattern, including sleep-wake cycles

• Disrupted rhythms contribute to age-related outcomes including dementia, cardiovascular disease and mortality
  – Overall strength, timing, and regularity of rhythms are disrupted with aging

• Actigraphy is a convenient method to assess 24-hour patterns of activity
Changes in Sleep Timing in Different Age Groups

- **Delayed phase (teenagers)**: Sleepy – Go to bed; Wake up
- **Standard phase (younger adults)**: Sleepy – Go to bed; Wake up
- **Advanced phase (elderly)**: Sleepy; Go to bed; Wake up

Time of Day:
- 6PM to 9PM: Sleepy
- 9PM to 12AM: Go to bed
- 12AM to 3AM: Sleepy
- 3AM to 6AM: Wake up
- 6AM to 9AM: Wake up
- 9AM to NOON: Wake up for school; sleep is cut short

Modified from Ancoli-Israel, All I Want is a Good Night’s Sleep, Mosby, 1996
5-Parameter Extension of the Cosinor Model

- **Acrophase** ($\varphi$)
- **Mesor** ($\text{max}/2$)
- **Nadir** ($\text{min}$)
- **Period Length** ($\tau$)
- **Amplitude** ($\text{max}$)
Shifted rhythms

- **Late**: 9:05AM - 1:40AM
- **Mean**: 7:11AM - 11:18PM
- **Early**: 5:55AM - 10:07PM

Time of Day Peak:
- 1:30PM
- 2:40PM
- 3:50PM
5 year Risk of Dementia or MCI in Older Women

Dementia - MCI

<table>
<thead>
<tr>
<th>Time</th>
<th>Early</th>
<th>Mean</th>
<th>Late</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.2 (0.80 – 1.8)</td>
<td>1.0</td>
<td>1.8 (1.2 - 2.6)</td>
</tr>
</tbody>
</table>

Tranah et al. 2011, *Annals of Neurology*
5 year Cause-specific Mortality in Older Women

<table>
<thead>
<tr>
<th>Time</th>
<th>Stroke</th>
<th>Cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late</td>
<td>2.6 (1.1-6.3)</td>
<td>2.1 (1.1-4.2)</td>
</tr>
<tr>
<td>Mean</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Early</td>
<td>2.3 (0.95-5.4)</td>
<td>1.0 (0.42-2.6)</td>
</tr>
</tbody>
</table>

Activity Rhythms and Survival

Strong

Weak
Activity Rhythms and Survival

Sleep Health

- ‘Good sleep’ is essential to health
  - Can’t be defined based on a single measure of sleep (e.g. sleep duration)

- Sleep is multi-dimensional
  - Duration
  - Latency
  - Quality (fragmentation, etc)
  - Satisfaction
  - Sleepiness
  - Timing
  - Regularity

- Many older adults are disrupted in more than one domain of sleep
  - Domains are correlated
Subjective Sleep Health and Incident Depressive Symptoms in Older Women

<table>
<thead>
<tr>
<th>Sleep Health Score</th>
<th>Participants (%)</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>34.1</td>
<td>1.00 (reference)</td>
</tr>
<tr>
<td>1</td>
<td>33.2</td>
<td>1.46 (1.06 – 2.01)</td>
</tr>
<tr>
<td>2</td>
<td>21.1</td>
<td>1.95 (1.40 – 2.73)</td>
</tr>
<tr>
<td>3</td>
<td>8.5</td>
<td>1.99 (1.29 – 3.08)</td>
</tr>
<tr>
<td>4 or 5</td>
<td>3.1</td>
<td>3.16 (1.82 – 5.48)</td>
</tr>
</tbody>
</table>

Aggregate of ‘poor sleep’ across 5 subjective sleep domains:
- Satisfaction
- Sleepiness
- Timing
- Latency
- Duration

Furihata et al. 2017; SLEEP 40(3)
Selected Sleep Health Predictors

<table>
<thead>
<tr>
<th>SLEEP HEALTH DOMAINS</th>
<th>REPRESENTATIVE SLEEP HEALTH CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DURATION</td>
<td>Actigraphy Mean Total Sleep Time</td>
</tr>
<tr>
<td>TIMING</td>
<td>Actigraphy Mean Sleep Midpoint</td>
</tr>
<tr>
<td>CONTINUITY</td>
<td>Actigraphy Mean Wake After Sleep Onset</td>
</tr>
<tr>
<td>QUALITY</td>
<td>PSQI Sleep Quality Item</td>
</tr>
<tr>
<td>SLEEPINESS</td>
<td>Epworth Sleepiness Scale (ESS)</td>
</tr>
<tr>
<td>RHYTHMICITY</td>
<td>Pseudo-F (Fit of Cosine to Actigraphy )</td>
</tr>
<tr>
<td>REGULARITY</td>
<td>Actigraphy St. Dev. Wake Time</td>
</tr>
</tbody>
</table>

- Created categorical versions to indicate extreme sleep characteristics
- Computed number of extreme characteristics
- Random Survival Forest analysis

M. Wallace, Univ of Pittsburgh
Which Sleep Health Characteristics Predict Mortality in Older Men?

VIMP or Predictor Relative to VIMP of Age X 100

- Cognition
- CV
- 7 Sleep
- Sleep + # Extreme
- PASE
- Rhythmicity
- Depression
- Continuity
- # Extreme
- COPD
- SR Health
- Diabetes
- Duration
- BMI
- Stroke
- Education
- Pittsburgh
- NSAID
- Never Smoker
- Corticosteroids
- Timing
- Regulality
- Past Smoker
- White
- Hispanic
- Asian
- Current Smoker
- Sedatives
- Arthritis
- Philadelphia
- Sleepiness/Alertness
- African American
- Other Race
- Birmingham
- San Diego
- Portland
- Caffeine
- Sleep Quality
- Drinking
- Minneapolis
Opportunities in WHI

• WHISPER: Are sleep and circadian disruption related to cardiovascular disease, cancer and cognitive outcomes in older women?
• Sleep and circadian disruption and other age-related outcomes:
  – Falls and fractures
• Exploration of gender differences with MrOS cohort (analysis plans, ancillary studies)
• Wealth of objective and subjective sleep measures for analyses of multi-dimensional sleep health