Wearable Sleep Trackers in Occupational Health Psychology

A critical review and illustrative case studies (Part 1)

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16th Conference

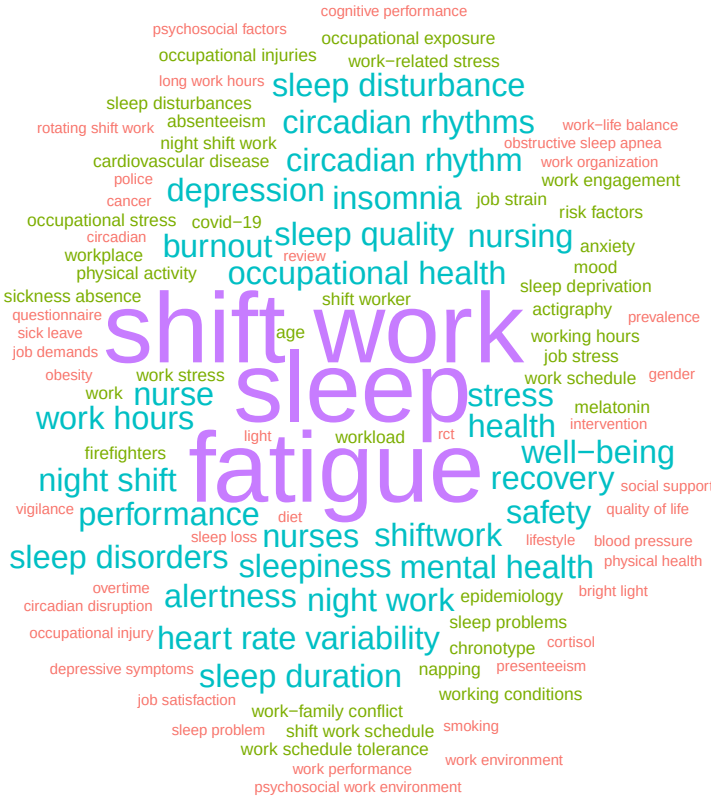
European Academy of Occupational Health Psychology

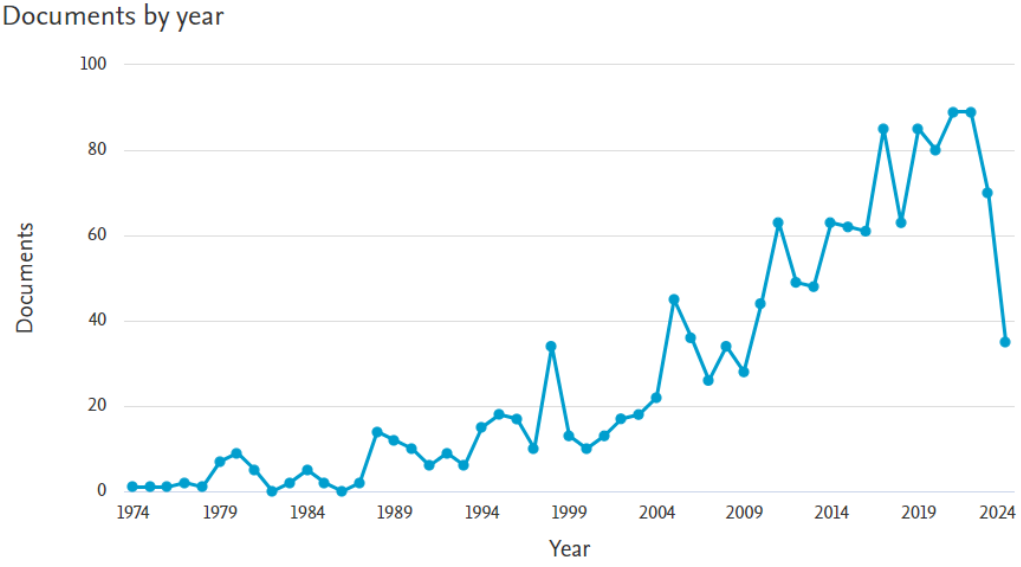
Granada, June 5-7 2024

Symposium: *Sleep research trends in occupational health psychology*

The importance of sleep in OHP research

Increasing use of sleep measures to investigate how psychosocial conditions such as job demands and shift work impact on **sleep/wake patterns & circadian rhythms** and how sleep, in turn, impact on work-related health, safety, and performance.





Scopus search of `"work" AND "sleep"` in WOP journals between 1970 and 2024 ($N = 1447$)

Sleep measurement in OHP

Primarily based on **retrospective self-reports**
How is your sleep quality, in general?

Recent increase in the use of **sleep diaries**
How was your sleep last night?

Rarely measured through **objective techniques** →

Evolution of ambulatory sleep assessment (ASA) techniques


Portable PSG


Actigraphy

Multi-sensor


Consumer tech

Is it time to include wearable sleep trackers in the applied psychologists' toolbox?

The Spanish Journal of Psychology (2024), **27**, e8, 1–5
doi:10.1017/SJP.2024.8

Review Article

Is it Time to Include Wearable Sleep Trackers in the Applied Psychologists' Toolbox?

Luca Menghini[1,2], Cristian Balducci[3] and Massimiliano de Zambotti[4,5]

Critical review of state-of-the-art wearable ASA in ~~applied psychology~~ occupational health psychology research and professional practice.

Portable PSG & holters

Polysomnography (PSG)
= multichannel recording of cortical, muscular, and eye-movement activity into 30-sec epochs

Portable PSG
= home-based PSG recording

Holters
= portable electrocardiograph (ECG) monitoring devices

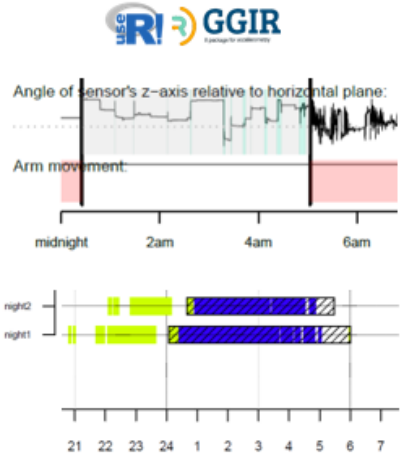
Challenges

- Equipment costs
- Unsuitable for long-term recording (obtrusiveness)
- Technical expertise required
- Poorly used in OHP

Holter Monitor

Actigraphy

Standard actigraphy
= piezoelectic sensors quantifying body movements ('activities') and defining *sleep as the absence of motion*

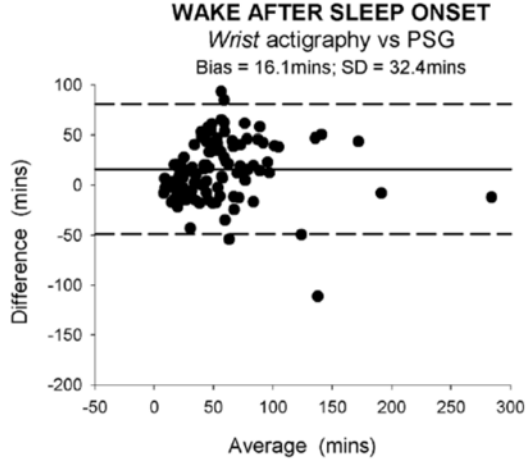


Accepted alternative to PSG in clinical & research non-laboratory settings

Validated against PSG
e.g., Cole–Kripke and Sadeh algorithms

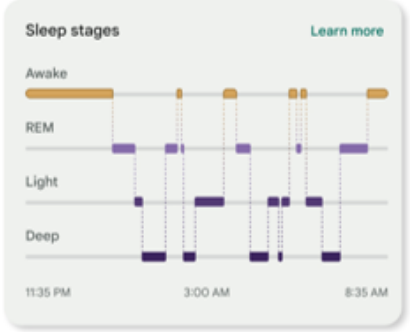
Challenges

- Equipment costs
- Proprietary algorithms (black box)
- Technical expertise required
- Low specificity (unable to detect motionless wake)



Slater et al (2015)

Consumer-grade wearables



Smartwatches and other wearable sensors with sleep tracking features

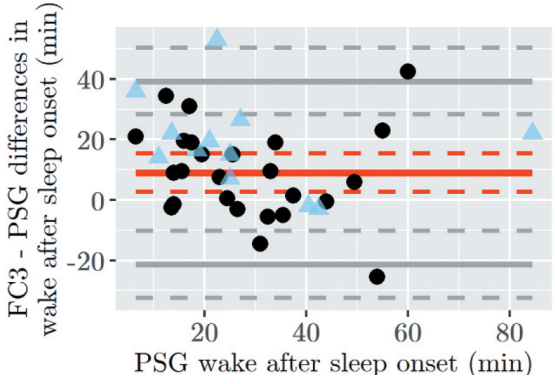
More acceptable & accessible (lower costs, better design, less expertise needed)

Consumer-oriented features (e.g., battery and memory capacity) → large scale

Multi-sensor features integrating acceleration and cardiac activity (PPG)
→ sleep staging?
→ better accuracy?

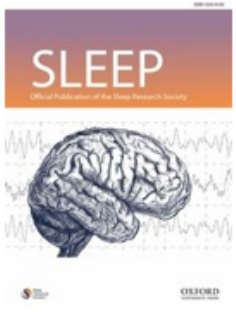
Challenges

- Mostly not validated
- Proprietary algorithms (black box)
- Limited access to raw data (low reproducibility)
- Consumer-oriented updates (e.g., firmware version)



Menghini et al (2021)

Towards rigorous evaluation of ASA performance



A standardized framework for testing the performance of sleep-tracking technology: step-by-step guidelines and open-source code

Luca Menghini[1,2,*], Nicola Cellini[2,3,4,5], Aimee Goldstone[1], Fiona C. Baker[1,6], Massimiliano de Zambotti[1]

Rigorous performance evaluation (previously, "validation") for informed use of new technologies for sleep health measurement

Massimiliano de Zambotti, PhD • Luca Menghini, PhD • Michael A. Grandner, PhD • ... Ying Zhang, PhD
Meredith L. Wallace, PhD • Orfeu M. Buxton, PhD • Show all authors

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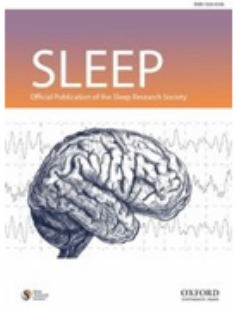


Review

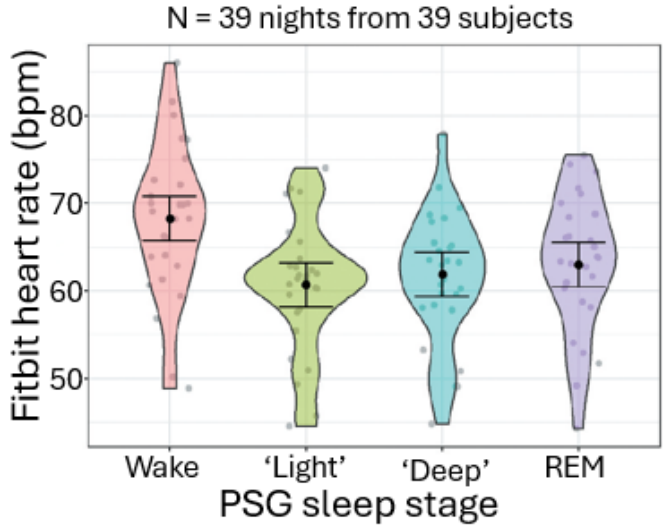
State of the science and recommendations for using wearable technology in sleep and circadian research

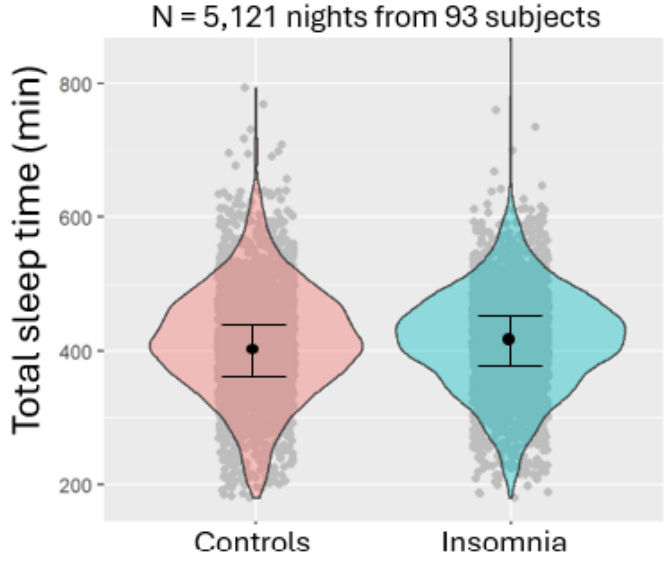
Massimiliano de Zambotti[1,2,*,†], Cathy Goldstein[3,†], Jesse Cook[4], Luca Menghini[5], Marco Altini[6], Philip Cheng[7], Rebecca Robillard[8,9]

Beyond sleep tracking

2^{nd} generation research-grade & consumer devices

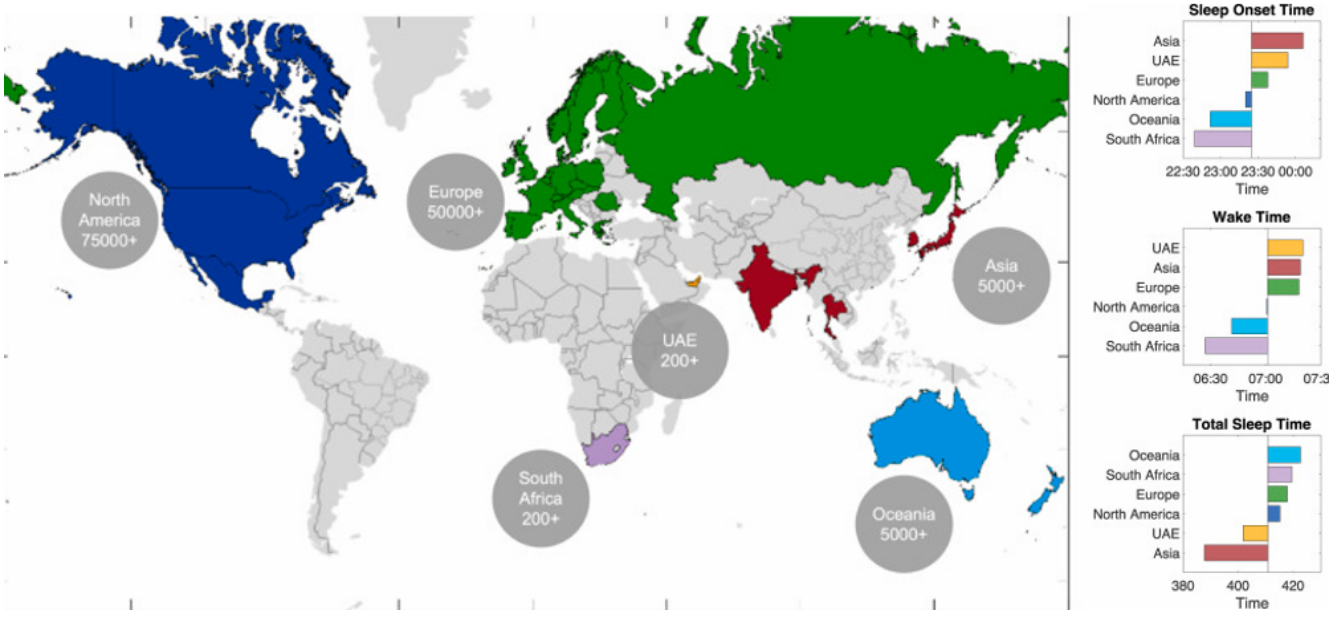
- Optimized wake detection + sleep staging
- Optical detection of night-time cardiac activity and heart rate variability (HRV) analysis
- Cloud-based research services
- Integrated with experience sampling methods (ESM)
  - Needed for accurate analysis (lights-off/on)
  - **Sleep discrepancies** (e.g., paradoxical insomnia objetive vs. subjective)





Menghini et al. (2021; 2023)

Opportunities for OHP research & pratice



Willoughby et al (2023)

50+ million night's sleep from ~220,000 Oura ring users in 35 countries (~242 nights/person)

- Towards **longer-term & larger-scale studies**
- Towards more **reproducible multi-source research** on work-related sleep antecedents & consequences
- Towards **ecological momentary interventions** improving employee health and well-being (e.g., EWP) and reducing work-related injuries (e.g., drivers)

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Challenges for OHP reseaerch & practice

- Work-in-progress validity
  varies across devices, populations, and applications
- Getting familiar with device features
  e.g., memory & battery capacity (at least 1-2 weeks), cost, sensors, connectivity, device performance
- Black box & data format
  Use raw data when available, otherwise use the maximum available resolution (e.g., 1-min)
- Participant burden, compliance, & missing data
- Acceptability & privacy

The Nation.

ACTIVISM / MARCH 12, 2018

The West Virginia Teachers Strike Shows That Winning Big Requires Creating a Crisis

The strikers won all five of their demands by shutting down every public school in the state.

board. Later that year, the board proposed the implementation of Go365, an app that requires workers to wear devices like FitBit that submit tracking data. Workers that refused would face increased health-care costs. Peters notes, "It was a complete, total invasion of our privacy."

Moore & Piwek (2017). Regulating wellbeing in the brave new quantified workplace. *Employee Relations, 39*(3). https://doi.org/10.1108/ER-06-2016-0126

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References (1/3)

Wearable sleep tracking capabilities & performance

- de Zambotti, Menghini, Grandner, Redline, Zhang, Wallace, & Buxton (2022) Rigorous performance evaluation (previously, "validation") for informed use of new technologies for sleep health measurement. *Sleep Health, 8*(3), 263-269.
- de Zambotti, Goldstein, Cook, Menghini, Altini, Cheng, & Robillard (2023) State of the science and recommendations for using wearable technology in sleep and circadian research. *Sleep*, zsad325.
- Menghini, Cellini, Goldstone, Baker, & de Zambotti (2021) A standardized framework for testing the performance of sleep-tracking technology: step-by-step guidelines and open-source code. *Sleep, 44(2)*, zsaa170.
- de Zambotti, Cellini, Menghini, Sarlo, & Baker (2020) Sensors capabilities, performance, and use of consumer sleep technology. *Sleep medicine clinics, 15*(1), 1-30.
- de Zambotti, Cellini, Goldstone, Colrain, & Baker (2019) Wearable sleep technology in clinical and research settings. *Medicine and science in sports and exercise, 51*(7), 1538.

References (2/3)

Representative studies using sleep trackers in OHP

Portable PSG

- Åkerstedt, Lekander, Peterson, Kecklund, & Axelsson (2014) Sleep polysomnography and reported stress across 6 weeks. *Industrial Health, 52*(1), 36–42.
- Barnes, Ghumman, & Scott (2013) Sleep and organizational citizenship behavior: The mediating role of job satisfaction. *Journal of Occupational Health Psychology, 18*(1), 16.

Actigraphy

- Dorrian, Baulk, & Dawson (2011) Work hours, workload, sleep and fatigue in Australian Rail Industry employees. *Applied Ergonomics, 42*(2), 202–209.
- Sianoja, Crain, Hammer, Bodner, Brockwood, LoPresti, & Shea (2020) The relationship between leadership support and employee sleep. *Journal of occupational health psychology, 25*(3), 187.

Consumer sleep trackers

- von Gall, Muth, & Angerer (2023) Sleep duration on workdays is correlated with subjective workload and subjective impact of high workload on sleep in young healthy adults. *Brain Sciences, 13*(5).

References (3/3)

Other relevant studies

- Menghini, Yuksel, Prouty, Baker, King, & de Zambotti (2023) Wearable and mobile technology to characterize daily patterns of sleep, stress, presleep worry, and mood in adolescent insomnia. *Sleep health, 9*(1), 108-116.
- Menghini, Yuksel, Goldstone, Baker, & de Zambotti (2021) Performance of Fitbit Charge 3 against polysomnography in measuring sleep in adolescent boys and girls. *Chronobiology international, 38*(7), 1010-1022.
- Slater, Botsis, Walsh, King, Straker, & Eastwood (2015) Assessing sleep using hip and wrist actigraphy. *Sleep and Biological Rhythms, 13*, 172-180.
- Rezaie, Fobian, McCall, & Khazaie (2018) Paradoxical insomnia and subjective–objective sleep discrepancy: A review. *Sleep medicine reviews, 40*, 196-202.
- Willoughby, Alikhani, Karsikas, Chua, & Chee (2023) Country differences in nocturnal sleep variability: Observations from a large-scale, long-term sleep wearable study. *Sleep medicine, 110*, 155-165.

Thank you!

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R code available from https://luca-menghini.github.io/pResentations