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]

[1]Università di Trento (Italy); [2]Università degli Studi di Padova (Italy); [3]Alma Mater Studiorum - Università di Bologna (Italy); [4]SRI International (USA); [5]Lisa Health Inc. (USA)

Abstract

Wearable sleep trackers are increasingly used in applied psychology. Particularly, the recent boom in the fitness tracking industry has resulted in a number of relatively inexpensive consumer-oriented devices that further enlarge the potential applications of ambulatory sleep monitoring. While being largely positioned as wellness tools, wearable sleep trackers could be considered useful health devices supported by a growing number of independent peer-reviewed studies evaluating their accuracy. The inclusion of sensors that monitor cardiorespiratory physiology, diurnal activity data, and other environmental signals allows for a comprehensive and multidimensional approach to sleep health and its impact on psychological well-being. Moreover, the increasingly common combination of wearable trackers and experience sampling methods has the potential to uncover within-individual processes linking sleep to daily experiences, behaviors, and other psychosocial factors. Here, we provide a concise overview of the state-of-the-art, challenges, and opportunities of using wearable sleep-tracking technology in applied psychology. Specifically, we review key device profiles, capabilities, and limitations. By providing representative examples, we highlight how scholars and practitioners can fully exploit the potential of wearable sleep trackers while being aware of the most critical pitfalls characterizing these devices. Overall, consumer wearable sleep trackers are increasingly recognized as a valuable method to investigate, assess, and improve sleep health. Incorporating such devices in research and professional practice might significantly improve the quantity and quality of the collected information while opening the possibility of involving large samples over representative time periods. However, a rigorous and informed approach to their use is necessary.

Keywords: applied psychology; sleep assessment; sleep health; wearable sleep trackers; wearable technology

(Received: 15 October 2023; revised: 04 January 2024; accepted: 08 February 2024)

In applied psychology, ambulatory sleep assessment is increasingly used to investigate how psychosocial conditions such as shift work, work-home crossover/spillover, and socioeconomic status impact on sleep/wake patterns and circadian rhythms (e.g., Baek et al., 2020; Barber et al., 2017; Etindele Sosso et al., 2021; Feng et al., 2021; Zhang et al., 2023). While self-reports have traditionally dominated the field, with consequent limitations in terms of reliability, adherence to long-term monitoring, and ability to capture multifaceted sleep features, the recent advancements in wearable technology have open up new avenues for expanding the horizons of applied psychology research and practice. Increasingly accessible, user-friendly, and multi-functional devices allow for unprecedented large-scale and extensive long-term monitoring of sleep patterns and related physiology (Baron et al., 2018; de Zambotti et al., 2020). Yet, while such devices are ideal methods for monitoring sleep in free-living conditions, their use implies numerous challenges that need to be considered to fully exploit their potential.

Here, we review selected works highlighting the main advantages and pitfalls of using wearable sleep trackers in applied psychology. Building from a limited number of recent studies that we selected among representative applications of ambulatory sleep assessment in applied psychology, we aim at answering the question: "Is it time to include wearable sleep trackers in the applied psychologists' toolbox?" We conducted a narrative review aiming at highlighting the potential of novel vs. older wearable sleep technology to be used in applied psychology research and practice. After introducing the relevance of ambulatory assessment and sleep monitoring in the field, we briefly review key device profiles and what we consider the main opportunities and challenges of integrating these methods in the applied psychologist' toolbox.

Ambulatory Biobehavioral Assessment in Applied Psychology

Ambulatory assessment in free-living conditions has drawn the attention of applied psychologists since the first half of the 20th century (see Klumb et al., 2009). For instance, early applications focused on the effects of unemployment on daily life, everyday communication flows, and other problems in fields such as

Corresponding author: Correspondence concerning this article should be addressed to Luca Menghini. Università degli Studi di Padova. Dipartimento di Psicologia Generale. Via Venezia, 8. 35132 Padova (Italy). Email: luca.menghini@unipd.it

Cite this article: Menghini, L., Balducci, C., & de Zambotti, M. (2024). Is it Time to Include Wearable Sleep Trackers in the Applied Psychologists' Toolbox? *The Spanish Journal of Psychology* **27**, e8, 1–5. https://doi.org/10.1017/SJP.2024.8

industry, business, and education (e.g., Hinrichs, 1964; Jahoda, 1992; Münsterberg, 1913). Particularly, biobehavioral monitoring has been employed by applied psychologists since World War II and increasingly used since the 1980s (Akinola, 2010; Boucsein & Backs, 2000; Ganster et al., 2018), with recent trends including cardiovascular load assessment, stress and creativity at work, and the promotion of worker sleep quality (e.g., Akinola et al., 2019; Dias et al., 2023; Zhang et al., 2023).

Sleep as a Key Biobehavioral Factor in Applied Psychology

In a recent diary study conducted with 101 supervisor-subordinate dyads over five working days, Tariq et al. (2020) reported a spillover effect of supervisors' poor sleep on next-day abusive supervisory behavior, which in turn showed a crossover effect on subordinates' sleep quality. Sleep is a fundamental aspect of individual functioning and health that is connected to virtually all psychological processes (Buysse, 2014; Grandner, 2017). It is also a highly complex phenomenon manifesting at multiple levels (physiological, behavioral, subjective) that do not always take the same direction. For instance, paradoxical insomnia has been described as a prevalent condition where individuals perceive sleep disturbances that are not corroborated by objective methods (Rezaie et al., 2018). Moreover, sleep manifests as a dynamic multidimensional process whose temporal fluctuations (e.g., timing, quality, efficiency, and regularity over time) are critical to capture its health and psychosocial correlates (Buysse, 2018).

Ambulatory Sleep Assessment

Ambulatory sleep assessment originated with the first applications of sleep diaries and portable polysomnography (PSG) (Schulz, 2022; van de Water et al., 2011), and the first attempts to monitor sleep/wake patterns with small-sized devices attached to the human body, dating back to the 1970s (Foster et al., 1972; Kupfer et al., 1972). While such pioneering applications drove outstanding progress in sleep research, sleep tracking has become mainstream only in recent years thanks to the push of the wearable industry targeting the consumer market (Kolla et al., 2016).

Portable Polysomnography

PSG is the recognized gold-standard for measuring sleep and diagnosing sleep disorders. It implies the multichannel recording of cortical, muscular, and eye-movement activity into 30-second epochs to be manually expert scored based on international norms (Kryger et al., 2005). While PSG is largely restricted to laboratory settings, ambulatory PSG has the advantage of reaching participants' home and reducing the burden of laboratory testing. However, even portable PSG devices can be poorly suitable for long-term monitoring due to equipment size, obtrusiveness, and still relatively high costs (van de Water et al., 2011). Moreover, the required technical expertise is a great obstacle for its utilization in fields such as applied psychology, which only counts a few PSG-based studies (e.g., Åkerstedt et al., 2014).

Actigraphy

As the accepted alternative to PSG in non-laboratory settings, actigraphy uses piezoelectric sensors to quantify body movements (acceleration or 'activities') and characterize sleep/wake patterns by defining sleep as the absence of motion (Kripke et al., 1978; Sadeh et al., 1994). Most actigraphy devices (e.g., Philips Actiwatch) are wrist-based and have been repeatedly tested to evaluate their accuracy in estimating PSG-like sleep parameters such as total sleep time (TST), sleep onset latency (SOL), and wake after sleep onset (WASO) (see Sadeh, 2011). The reduced size and obtrusiveness of wrist-worn devices are key determinants of their suitability for long-term monitoring and their widespread use in applied psychology. For instance, Etindele Sosso et al. (2021) recently reviewed 19 actigraphy-based studies on social inequities, reporting shorter TST and longer SOL for individuals with lower socioeconomic status. Actigraphy is also widely used in occupational health psychology, where the detrimental effects of job demands and related perseverative cognitions on sleep duration and quality have been repeatedly reported (e.g., Dorrian et al., 2011; Melo et al., 2021; von Gall et al., 2023). Yet, while being overall simpler than PSG, the use of actigraphy still requires technical expertise and relatively high research budgets. This, together with its frequently highlighted limitation in wake detection (i.e., low sensitivity to motionless wake), are among the main limitations of this technique (Sadeh, 2011; Scott et al., 2019).

Consumer-Grade Wearable Sleep Trackers

In the present days, encountering relatives, friends, and even strangers wearing smart watches, armbands, or clothing to monitor their steps, heart rate, and sleep cycles has become increasingly common. The consumer wearable industry is indeed bringing the most recent innovations in ambulatory sleep assessment. The possibility of monitoring sleep passively, continuously, and unobtrusively through simple objects of everyday usage (chest, wristband, rings, etc.) opened the way to a new era of sleep research characterized by longer-term and larger-scale research designs (e.g., Clark et al., 2021; Stucky et al., 2021). For instance, Willoughby et al. (2023) were able to investigate sleep differences (e.g., duration, timing, variability, and social jetlag) across 35 countries by accessing and analyzing over 50 million night's sleep data from over 200,000 unique Oura Ring users (242 nights per user, on average). Consumer-oriented features such as higher memory capacity and longer battery life, together with their lower costs and required expertise, make these devices ideal for such extensive data collections, providing unprecedented knowledge on the numerous factors (e.g., geographical, cultural, environmental) affecting sleep.

Beyond Sleep Tracking

An important advancement in the newer-generation sleep trackers (both research- and consumer-grade) is the integration of additional sensors enabling the quantification of sleep macrostructure (staging), 24h activity, and cardio-respiratory function (see de Zambotti et al., 2020). The most popular of these additional sensors is photoplethysmography (PPG), which uses infrared or LED light to estimate heart rate and heart rate variability (HRV) from peripheral blood volume pulse fluctuations. Due to the expected changes in cardiac activity between wake and sleep, and across sleep stages, such feature has been suggested to improve sleep classification accuracy (Chinoy et al., 2021; Haghayegh et al., 2019) while providing estimates of time in 'light', 'deep', and rapid-eye-movement (REM) sleep (e.g., Wulterkens et al., 2021).

https://doi.org/10.1017/SJP.2024.8 Published online by Cambridge University Press

Wearable Sleep Trackers in Applied Psychology

From the overview reported above, it is evident that wearable sleep trackers imply several potential advantages for the advancement of applied psychology research and practice. Yet, due to the novel and rapidly evolving nature of such technologies, we believe that providing specific recommendations on their use in the field is somehow premature. While some more general recommendations have been recently provided by de Zambotti et al. (2023), here we summarize what we consider the main opportunities and challenges of using these devices in applied psychology.

Opportunities for Applied Psychologists

The main advantage of wearable sleep tackers for applied psychologists is disposing of multi-source measurements that mitigate common method bias (Eatough et al., 2016) and allow considering specific sleep profiles such as paradoxical insomnia (Rezaie et al., 2018). On the one hand, experience sampling methods (ESM) are the ideal tools to contextualize objective sleep data with complementary information on behaviors, experiences, and environmental factors immediately preceding or following sleep episodes. ESM are well-established in applied psychology (Beal, 2015; Ohly et al., 2010) and increasingly implemented within dedicated or third-party mobile applications (Pejovic et al., 2016). For instance, by using Fitbit Charge 3 devices and the SurveySparrow mobile app, we were able to continuously track sleep parameters (e.g., TST, sleep stages, cardiac activity) over two months from a sample of 93 adolescents, and to analyze their within-individual relationships with pre-sleep stress, worry, and mood (Menghini et al., 2023).

On the other hand, while the reduced costs of consumer-grade devices can increase the scalability of sleep monitoring, the passive nature of wearable recording (not requiring any action from the user) is a key feature to extend assessment durations beyond what can be usually done with ESM (e.g., multiple weeks, months, and even years). Moreover, several wearables can be synchronized with cloud services (e.g., Empatica Health Monitoring Platform), third-party platforms (e.g., Small Steps Labs Fitabase), and dedicated SDKs/APIs to allow researchers and practitioners accessing more granular sensor data (sometimes including raw data) from multiple devices. Although consumer-grade wearables are not optimized for being used in research settings, several solutions can be adopted to adapt these devices for specific research goals.

From the practitioner side, it is worth mentioning that wearable sleep trackers can also be useful to implement ecological momentary interventions (Balaskas et al., 2021; Nahum-Shani et al., 2018) and to assess the impact of psychological interventions such as counseling and psychotherapy (Chellappa & Aeschbach, 2022). For instance, Torres and Zhang (2021) implemented an employee wellness program where 30 hotel managers tracked their diurnal activity and sleep patterns over 14 days using Fitbit Charge 2 devices, showing positive outcomes such as reduced caloric intake and increased work engagement. This and other applications such as improving work efficiency and reduce work-related injuries (see Khakurel et al., 2017) highlight the great potential of using wearable sleep trackers in applied psychology research and practice.

Challenges for Applied Psychologists

Despite such promising opportunities, wearable sleep trackers pose several challenges that should be carefully considered. First, their validity is uncertain and can vary across different devices and populations, with method comparison studies being increasingly needed as these technologies evolve (Benedetti et al., 2023; Depner et al., 2020; Menghini, Cellini, et al., 2021). The term 'performance evaluation' has been recently proposed instead of 'validation' precisely because the continuous update of device features prevents the research community from definitely establishing their validity (de Zambotti et al., 2022). Depending on the research focus (e.g., overnight composite indicators vs. within-night changes in sleep macrostructure or physiology), the device output should demonstrate adequate agreement with reference (e.g., PSG-based) measurements before being applied to a specific population (for an overview on how to interpret performance evaluation metrics, see Menghini, Cellini, et al., 2021). For instance, we recently evaluated Fitbit Charge 3 performance in a sample of 39 adolescents that simultaneously undertook laboratory-based PSG recording (Menghini, Yuksel, et al., 2021). Our results indicated systematic underestimations of TST by 11 ± 15.6 minutes, with no substantial differences between healthy sleepers and participants with insomnia symptomatology. Whether such discrepancies are excessively large for a specific utilization of the device is something that researchers and practitioners should think about before integrating a wearable tracker in their monitoring protocols.

Second, the black-box nature of proprietary and undisclosed algorithms is regarded with suspicion by the scientific community. While this applies to both research-grade (including actigraphy) and consumer-grade devices, the use of consumer technology for diagnosing and treating sleep problems has been discouraged so far (Khosla et al., 2018). Again, it is the researcher/practitioner's responsibility to search for available evidence justifying the use of a given device to record specific sleep parameters in a specific population. Third, raw data (e.g., epoch-by-epoch sleep classifications, light, acceleration, and PPG signal) can be only accessed from a minority of devices, constraining the derivable range of output parameters, and threatening the reproducibility of the measurement procedures (Baron et al., 2018; de Zambotti et al., 2020). While we recommend relying on data exported at the maximum possible resolution (e.g., minute-level heart rate), being able to inspect data quality and identify unreliable observations is a necessary skill to ascertain the validity of the collected measures. More generally, the large number of features to be considered (size, cost, battery life, memory capacity, range of sensors, available evidence on device performance, etc.) can pose great challenges to applied psychologists approaching these methods for the first time. In the state of science review recently requested by the Sleep Research Society (de Zambotti et al., 2023), we systematically address these and other issues while providing some guidance on how to evaluate, choose, and use these new methods.

Further challenges are common to intensive longitudinal designs not involving wearables, such as dealing with participant burden and missing data. For instance, missing wearable data can be due to device malfunctioning or lack of participant compliance (e.g., participants not wearing the device). As in other ambulatory assessment techniques, it is important to keep in touch with participants/clients to monitor their adherence with the research protocol and the occurrence of technical errors. Finally, adopting wearable trackers in applied settings might pose ethical and privacy concerns related to the potential misuse of individual sensitive information (Akinola, 2010; Moore & Piwek, 2017). Using anonymized user accounts and removing personal and identifying information are among the fundamental practices that should be considered to prevent unethical uses of these technologies.

Conclusions

Wearable sleep trackers are increasingly considered as valuable tools to objectively measure sleep in an ecologically valid, large-scale, and temporally extensive way. This opportunity should not be missed by applied psychologists to improve the quantity and quality of the data collected in both research and professional practice. Overall, the increasing intuitiveness and automaticity of wearable sleep tracking (particularly in the consumer-oriented space) can strongly facilitate the inclusion of these methods in the applied psychologist's toolbox. Yet, a degree of awareness on the methodological pitfalls of using wearable trackers and interpreting their output is highly recommended. Here, we concisely summarized some of the opportunities and challenges of using wearable sleep trackers in applied psychology, and we provided key references to master the use of wearable sleep monitoring.

Conflicts of interest. MdZ has received research funding unrelated to this work from Noctrix Health Inc. and Verily Life Science LLC. MdZ is a co-founder and Chief Scientific Officer at Lisa Health Inc., and has ownership of shares in Lisa Health Inc.

Data sharing. Not applicable.

Authorship credit. Luca Menghini played a lead role in conceptualization, investigation, methodology, writing–original draft, writing–review & editing; Cristian Balducci played a supporting role in conceptualization and writing–review & editing; Massimiliano de Zambotti played a supporting role in conceptualization, investigation, methodology, writing–original draft, writing–review & editing.

References

Åkerstedt, T., Lekander, M., Peterson, H., Kecklund, G., & Axelsson, J. (2014). Sleep polysomnography and reported stress across 6 weeks. *Industrial Health*, **52**(1), 36–42. https://doi.org/10.2486/indhealth.2013-0169

Akinola, M. (2010). Measuring the pulse of an organization: Integrating physiological measures into the organizational scholar's toolbox. *Research in Organizational Behavior*, **30**(C), 203–223. https://doi.org/10.1016/j.riob.2010.09.003

Akinola, M., Kapadia, C., Lu, J. G., & Mason, M. F. (2019). Incorporating physiology into creativity research and practice: The effects of bodily stress responses on creativity in organizations. *Academy of Management Perspectives*, **33**(2), 163–184. https://doi.org/10.5465/amp.2017.0094

Baek, J., Han, K., & Choi-Kwon, S. (2020). Sleep diary- and actigraphy-derived sleep parameters of 8-hour fast-rotating shift work nurses: A prospective descriptive study. *International Journal of Nursing Studies*, **112**, Article 103719. https://doi.org/10.1016/j.ijnurstu.2020.103719

Balaskas, A., Schueller, S. M., Cox, A. L., & Doherty, G. (2021). Ecological momentary interventions for mental health: A scoping review. *PLOS ONE*, **16** (3), Article e0248152. https://doi.org/10.1371/journal.pone.0248152

Barber, L. K., Taylor, S. G., Burton, J. P., & Bailey, S. F. (2017). A self-regulatory perspective of work-to-home undermining spillover/crossover: Examining the roles of sleep and exercise. *Journal of Applied Psychology*, **102**(5), 753–763. https://doi.org/10.1037/apl0000196

Baron, K. G., Duffecy, J., Berendsen, M. A., Cheung Mason, I., Lattie, E. G., & Manalo, N. C. (2018). Feeling validated yet? A scoping review of the use of consumer-targeted wearable and mobile technology to measure and improve sleep. *Sleep Medicine Reviews*, **40**, 151–159. https://doi.org/10.1016/j.smrv.2017.12.002

Beal, D. J. (2015). ESM 2.0: State of the art and future potential of experience sampling methods in organizational research. *Annual Review of Organizational Psychology and Organizational Behavior*, **2**(1), 383–407. https://doi.org/10.1146/annurev-orgpsych-032414-111335

Benedetti, D., Menghini, L., Vallat, R., Mallett, R., Kiss, O., Faraguna, U., Baker, F. C., & de Zambotti, M. (2023). Call to action: An open-source pipeline for standardized performance evaluation of sleep-tracking technology. *Sleep*, **46**(2), Article zsac304. https://doi.org/10.1093/sleep/zsac304

Boucsein, W., & Backs, R. W. (2000). Engineering psychophysiology as a discipline: Historical and theoretical aspects. In R. W. Backs & W. Boucsein (Eds.), *Engineering psychophysiology: Issues and applications* (pp. 3–30). Lawrence Erlbaum Associates Publishers.

Buysse, D. J. (2014). Sleep health: Can we define it? Does it matter? *Sleep*, **37**(1), 9–17. https://doi.org/10.5665/sleep.3298

Buysse, D. J. (2018). Multidimensional sleep health: A conceptual overview. *Innovation in Aging*, **2**(suppl_1), Article 595. https://doi.org/10.1093/geroni/igy023.2210

Chellappa, S. L., & Aeschbach, D. (2022). Sleep and anxiety: From mechanisms to interventions. *Sleep Medicine Reviews*, **61**, Article 101583. https://doi.org/10.1016/j.smrv.2021.101583

Chinoy, E. D., Cuellar, J. A., Huwa, K. E., Jameson, J. T., Watson, C. H., Bessman, S. C., Hirsch, D. A., Cooper, A. D., Drummond, S. P. A., & Markwald, R. R. (2021). Performance of seven consumer sleep-tracking devices compared with polysomnography. *Sleep*, **44**(5), Article zsaa291. https://doi.org/10.1093/sleep/zsaa291

Clark, I., Stucky, B., Azza, Y., Schwab, P., Müller, S., Weibel, D., Button, D., Karlen, W., Seifritz, E., Kleim, B., & Landolt, H.-P. (2021). Diurnal variations in multi-sensor wearable-derived sleep characteristics in morning- and evening-type shift workers under naturalistic conditions. *Chronobiology International*, **38**(12), 1702–1713. https://doi.org/10.1080/07420528.2021.1941074

de Zambotti, M., Cellini, N., Menghini, L., Sarlo, M., & Baker, F. C. (2020). Sensors capabilities, performance, and use of consumer sleep technology. *Sleep Medicine Clinics*, **15**(1), Article zsad325. https://doi.org/10.1016/j.jsmc.2019.11.003

de Zambotti, M., Goldstein, C., Cook, J., Menghini, L., Altini, M., Cheng, P., & Robillard, R. (2023). State of the science and recommendations for using wearable technology in sleep and circadian research. *Sleep*. Advance online publication. Article zsad325. https://doi.org/10.1093/sleep/zsad325

de Zambotti, M., Menghini, L., Grandner, M. A., Redline, S., Zhang, Y., Wallace, M. L., & Buxton, O. M. (2022). Rigorous performance evaluation (previously, "validation") for informed use of new technologies for sleep health measurement. *Sleep Health*, **8**(3), 263–269. https://doi.org/10.1016/j.sleh.2022.02.006

Depner, C. M., Cheng, P. C., Devine, J. K., Khosla, S., de Zambotti, M., Robillard, R., Vakulin, A., & Drummond, S. P. A. (2020). Wearable technologies for developing sleep and circadian biomarkers: A summary of workshop discussions. *Sleep*, **43**(2), Article zsz254. https://doi.org/10.1093/sleep/zsz254

Dias, M., Silva, L., Folgado, D., Nunes, M. L., Cepeda, C., Cheetham, M., & Gamboa, H. (2023). Cardiovascular load assessment in the workplace: A systematic review. *International Journal of Industrial Ergonomics*, **96**, Article 103476. https://doi.org/10.1016/j.ergon.2023.103476

Dorrian, J., Baulk, S. D., & Dawson, D. (2011). Work hours, workload, sleep and fatigue in Australian Rail Industry employees. *Applied Ergonomics*, **42**(2), 202–209. https://doi.org/10.1016/j.apergo.2010.06.009

Eatough, E., Shockley, K., & Yu, P. (2016). A review of ambulatory health data collection methods for employee experience sampling research. *Applied Psychology*, **65**(2), 322–354. https://doi.org/10.1111/apps.12068

Etindele Sosso, F. A., Holmes, S. D., & Weinstein, A. A. (2021). Influence of socioeconomic status on objective sleep measurement: A systematic review and meta-analysis of actigraphy studies. *Sleep Health*, **7**(4), 417–428. https://doi.org/10.1016/j.sleh.2021.05.005

Feng, T., Booth, B. M., Baldwin-Rodríguez, B., Osorno, F., & Narayanan, S. (2021). A multimodal analysis of physical activity, sleep, and work shift in nurses with wearable sensor data. *Scientific Reports*, **11**(1), Article 8693. https://doi.org/10.1038/s41598-021-87029-w

Foster, F. G., Kupfer, D., Weiss, G., Lipponen, V., McPartland, R., & Delgado, J. (1972). Mobility recording and cycle research in neuropsychiatry. *Journal of Interdisciplinary Cycle Research*, **3**(1), 61–72. https://doi.org/10.1080/09291017209359298

Ganster, D. C., Crain, T. L., & Brossoit, R. M. (2018). Physiological measurement in the organizational sciences: A review and recommendations for future use. *Annual Review of Organizational Psychology and Organizational Behavior*, **5**(1), 267–293. https://doi.org/10.1146/annurev-orgpsych-032117-104613

Grandner, M. A. (2017). Sleep, health, and society. *Sleep Medicine Clinics*, **12**(1), 1–22. https://doi.org/10.1016/j.jsmc.2016.10.012

Haghayegh, S., **Khoshnevis, S.**, **Smolensky, M. H.**, **Diller, K. R.**, & **Castriotta, R. J.** (2019). Accuracy of wristband Fitbit models in assessing sleep: Systematic review and meta-analysis. *Journal of Medical Internet Research*, **21**(11), Article e16273. https://doi.org/10.2196/16273

Hinrichs, J. R. (1964). Communications activity of industrial research personnel. *Personnel Psychology*, **17**(2), 193–206. https://doi.org/10.1111/j.1744-6570.1964.tb00061.x

Jahoda, M. (1992). Reflections on Marienthal and after. *Journal of Occupational and Organizational Psychology*, **65**(4), 355–358. https://doi.org/10.1111/j.2044-8325.1992.tb00511.x

Khakurel, J., **Pöysä, S.**, & **Porras, J.** (2017). The use of wearable devices in the workplace - A systematic literature review. In O. Akan, P. Bellavista, J. Cao, G. Coulson, F. Dressler, D. Ferrari, M. Gerla, H. Kobayashi, S. Palazzo, S. Sahni, X. Shen, M. Stan, J. Xiaohua, & A. Y. Zomaya (Eds.), *Lecture notes of the institute for computer sciences, social-informatics and telecommunications engineering, LNICST: Vol.* 195 *LNICST* (pp. 284–294). https://doi.org/10.1007/978-3-319-61949-1_30

Khosla, S., **Deak, M. C.**, **Gault, D.**, **Goldstein, C. A.**, **Hwang, D.**, **Kwon, Y.**, **O'Hearn, D.**, **Schutte-Rodin, S.**, **Yurcheshen, M.**, **Rosen, I. M.**, **Kirsch, D. B.**, **Chervin, R. D.**, **Carden, K. A.**, **Ramar, K.**, **Aurora, R. N.**, **Kristo, D. A.**, **Malhotra, R. K.**, **Martin, J. L.**, **Olson, E. J.**, … **Rowley, J. A.** (2018). Consumer sleep technology: An American Academy of Sleep Medicine position statement. *Journal of Clinical Sleep Medicine*, **14**(5), 877–880. https://doi.org/10.5664/jcsm.7128

Klumb, P., **Elfering, A.**, & **Herre, C.** (2009). Ambulatory assessment in industrial/organizational psychology. *European Psychologist*, **14**.

Kolla, B. P., **Mansukhani, S.**, & **Mansukhani, M. P.** (2016). Consumer sleep tracking devices: A review of mechanisms, validity and utility. *Expert Review of Medical Devices*, **13**(5), 497–506. https://doi.org/10.1586/17434440.2016.1171708

Kripke, D. F., **Mullaney, D. J.**, **Messin, S.**, & **Wyborney, V. G.** (1978). Wrist actigraphic measures of sleep and rhythms. *Electroencephalography and Clinical Neurophysiology*, **44**(5), 674–676. https://doi.org/10.1016/0013-4694(78)90133-5

Kryger, M. H., **Roth, T.**, & **Dement, W. C.** (2005). *Principles and practice of sleep medicine* (5th ed.). Elsevier. https://doi.org/10.1016/B0-7216-0797-7/X5001-0

Kupfer, D. J., **Detre, T. P.**, **Foster, G.**, **Tucker, G. J.**, & **Delgado, J.** (1972). The application of delgado's telemetric mobility recorder for human studies. *Behavioral Biology*, **7**(4), 585–590. https://doi.org/10.1016/S0091-6773(72)80220-7

Melo, J. M., **Campanini, M. Z.**, **Souza, S. C. S.**, **Andrade, S. M.**, **Durán González, A.**, **Jiménez-López, E.**, & **Mesas, A. E.** (2021). Work-related rumination and worry at bedtime are associated with worse sleep indicators in schoolteachers: A study based on actigraphy and sleep diaries. *Sleep Medicine*, **80**, 113–117. https://doi.org/10.1016/j.sleep.2021.01.055

Menghini, L., **Cellini, N.**, **Goldstone, A.**, **Baker, F. C.**, & **de Zambotti, M.** (2021). A standardized framework for testing the performance of sleep-tracking technology: Step-by-step guidelines and open-source code. *Sleep*, **44**(2), Article zsaa170. https://doi.org/10.1093/sleep/zsaa170

Menghini, L., **Yuksel, D.**, **Goldstone, A.**, **Baker, F. C.**, & **de Zambotti, M.** (2021). Performance of Fitbit Charge 3 against polysomnography in measuring sleep in adolescent boys and girls. *Chronobiology International*, **38**(7), 1010–1022. https://doi.org/10.1080/07420528.2021.1903481

Menghini, L., **Yuksel, D.**, **Prouty, D.**, **Baker, F. C.**, **King, C.**, & **de Zambotti, M.** (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. https://doi.org/10.1016/j.sleh.2022.11.006

Moore, P., & **Piwek, L.** (2017). Regulating wellbeing in the brave new quantified workplace. *Employee Relations*, **39**(3), 308–316. http://doi.org/10.1108/ER-06-2016-0126

Münsterberg, H. (1913). *Psychology and industrial efficiency*. Mifflin and Company. http://doi.org/10.1037/10855-000

Nahum-Shani, I., **Smith, S. N.**, **Spring, B. J.**, **Collins, L. M.**, **Witkiewitz, K.**, **Tewari, A.**, & **Murphy, S. A.** (2018). Just-in-time adaptive interventions (JITAIs) in mobile health: Key components and design principles for ongoing health behavior support. *Annals of Behavioral Medicine*, **52**(6), 446–462. https://doi.org/10.1007/s12160-016-9830-8

Ohly, S., **Sonnentag, S.**, **Niessen, C.**, & **Zapf, D.** (2010). Diary studies in organizational research. *Journal of Personnel Psychology*, **9**(2), 79–93. https://doi.org/10.1027/1866-5888/a000009

Pejovic, V., **Lathia, N.**, **Mascolo, C.**, & **Musolesi, M.** (2016). Mobile-based experience sampling for behaviour research. In M. Tkalčič, B. De Carolis, M. De Gemmis, A. Odić, & A. Košir (Eds.), *Emotions and personality in personalized services: Models, evaluation and applications* (pp. 141–161). Springer. https://doi.org/10.1007/978-3-319-31413-6_8

Rezaie, L., **Fobian, A. D.**, **McCall, W. V.**, & **Khazaie, H.** (2018). Paradoxical insomnia and subjective–objective sleep discrepancy: A review. *Sleep Medicine Reviews*, **40**, 196–202. https://doi.org/10.1016/j.smrv.2018.01.002

Sadeh, A. (2011). The role and validity of actigraphy in sleep medicine: An update. *Sleep Medicine Reviews*, **15**, 259–267. https://doi.org/10.1016/j.smrv.2010.10.001

Sadeh, A., **Sharkey, M.**, & **Carskadon, M. A.** (1994). Activity-based sleep-wake identification: An empirical test of methodological issues. *Sleep*, **17**(3), 201–207. https://doi.org/10.1093/sleep/17.3.201

Schulz, H. (2022). The history of sleep research and sleep medicine in Europe. *Journal of Sleep Research*, **31**(4), Article e3602. https://doi.org/10.1111/jsr.13602

Scott, H., **Lack, L.**, & **Lovato, N.** (2019). A systematic review of the accuracy of sleep wearable devices for estimating sleep onset. *Sleep Medicine Reviews*, **49**, Article 101227. https://doi.org/10.1016/J.SMRV.2019.101227

Stucky, B., **Clark, I.**, **Azza, Y.**, **Karlen, W.**, **Achermann, P.**, **Kleim, B.**, & **Landolt, H.-P.** (2021). Validation of Fitbit Charge 2 sleep and heart rate estimates against polysomnographic measures in shift workers: Naturalistic study. *Journal of Medical Internet Research*, **23**(10), Article e26476. https://doi.org/10.2196/26476

Tariq, H., **Weng, Q. D.**, **Garavan, T. N.**, **Obaid, A.**, & **Hassan, W.** (2020). Another sleepless night: Does a leader's poor sleep lead to subordinate's poor sleep? A spillover/crossover perspective. *Journal of Sleep Research*, **29**(1), Article e12904. https://doi.org/10.1111/jsr.12904

Torres, E. N., & **Zhang, T.** (2021). The impact of wearable devices on employee wellness programs: A study of hotel industry workers. *International Journal of Hospitality Management*, **93**, Article 102769. https://doi.org/10.1016/j.ijhm.2020.102769

van de Water, A. T. M., **Holmes, A.**, & **Hurley, D. A.** (2011). Objective measurements of sleep for non-laboratory settings as alternatives to polysomnography - A systematic review. *Journal of Sleep Research*, **20**, 183–200. https://doi.org/10.1111/j.1365-2869.2009.00814.x

von Gall, C., **Muth, T.**, & **Angerer, P.** (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), Article 818. https://doi.org/10.3390/brainsci13050818

Willoughby, A. R., **Alikhani, I.**, **Karsikas, M.**, **Chua, X. Y.**, & **Chee, M. W. L.** (2023). Country differences in nocturnal sleep variability: Observations from a large-scale, long-term sleep wearable study. *Sleep Medicine*, **110**, 155–165. https://doi.org/10.1016/j.sleep.2023.08.010

Wulterkens, B. M., **Fonseca, P.**, **Hermans, L. W. A.**, **Ross, M.**, **Cerny, A.**, **Anderer, P.**, **Long, X.**, **van Dijk, J. P.**, **Vandenbussche, N.**, **Pillen, S.**, **van Gilst, M. M.**, & **Overeem, S.** (2021). It is all in the wrist: Wearable sleep staging in a clinical population versus reference polysomnography. *Nature and Science of Sleep*, *Volume* **13**, 885–897. https://doi.org/10.2147/NSS.S306808

Zhang, Y., **Murphy, J.**, **Lammers-van der Holst, H. M.**, **Barger, L. K.**, **Lai, Y-J.**, & **Duffy, J. F.** (2023). Interventions to improve the sleep of nurses: A systematic review. *Research in Nursing & Health*, **46**(5), 462–484. https://doi.org/10.1002/nur.22337