



Relevance of sleep for wellness: New trends in using artificial intelligence and machine learning

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Abstract

Sleep and well-being have been intricately linked, and sleep hygiene is paramount for developing mental well-being and resilience. Although widespread, sleep disorders require elaborate polysomnography laboratory and patient-stay with sleep in unfamiliar environments. Current technologies have allowed various devices to diagnose sleep disorders at home. However, these devices are in various validation stages, with many already receiving approvals from competent authorities. This has captured vast patient-related physiologic data for advanced analytics using artificial intelligence through machine and deep learning applications. This is expected to be integrated with patients' Electronic Health Records and provide individualized prescriptive therapy for sleep disorders in the future.

Key Words: Sleep initiation and maintenance disorders; Sleep apnea; Obstructive; Machine learning; Artificial intelligence; Algorithms

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Core Tip: Quality sleep is one of the major determinants of wellness. Insomnia and other sleep disorders are widespread in the society. Increasingly, technology is being used to diagnose sleep disorders through wearable devices and consumer technologies. This has allowed sleep disorders to be diagnosed at home rather than at polysomnography labs. With the advent of artificial intelligence, including machine and deep learning, sleep disorder diagnosis has become highly dynamic based on multiple inputs and complex algorithms analyzing huge quantum of metadata. Similarly, therapy is also becoming highly patient-specific due to available digital tools. However, the ever-expanding knowledge needs further validation to establish patient-centric care.

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INTRODUCTION

The duration and quality of sleep remarkably impact our wellness and health. Quality sleep rejuvenates emotion, body functions, metabolism, memory, and learning[1]. Optimum human functioning has been recently associated with attributes like resilience, an “individual’s ability to successfully adapt in life despite social disadvantage or other highly adverse conditions”[2]. Resilience is a complex interplay of environmental, psychosocial, genetic, and biological factors. Quality sleep is important in developing resilience and improves mental health and wellness[2,3].

While insomnia affects one-third of the global population, excessive sleepiness varies from 4% to 26% and obstructive sleep apnea (OSA) prevails in 2%-4%[3]. While impaired mental health leading to poor sleep has been traditionally implied[4,5], subsequent evidence shows that impaired sleep adversely impacts wellness[6].

THE RELEVANCE OF SLEEP FOR WELLNESS

Instead of being a medical concept, wellness is a “holistic and comprehensive multidimensional concept,”[7] representing a continuum of health as defined by the World Health Organization as a “state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity,”[8] to an individual’s overall lifestyle and behavior[7] to ensure a balanced and fulfilling life.

While exercise is widely recognized as “medicine” for a healthy life, nutrition and sleep are the other prerequisites[9]. Insomnia or shorter duration of sleep has been associated with reduced happiness levels[10] and weight gain caused by increased food intake due to an imbalance between hunger (ghrelin) and satiety (leptin)[11]. Decreased sleep time and quality have also shown temporal association with various metabolic diseases like diabetes and cardiovascular diseases [11]. Sleep disorders also increase the risk of accidents and hospitalization[12].

Poor sleep health affects the immune system, resulting in long-term impact on infectious and inflammatory disease risks[13]. It also amplifies malignancy development and major depression[14]. Meanwhile, quality sleep restores the immune system, specifically the adaptive and innate immunity. Hence, accurately diagnosing sleep disorders and creating patient-specific management are the keys to sleep hygiene and wellness.

USE OF TECHNOLOGY FOR DIAGNOSIS OF SLEEP DISORDERS

With increasing consumer sleep technology (CST) capabilities, sleep disorder diagnosis and management are enhanced [15]. A continuous feedback loop mechanism is expected to deliver individualized care with enabled wearables and therapeutic devices, like CSTs. Currently, these have been integrated into wearables, sleeping mattresses, clothing, and sleep environments to provide insights into sleep hygiene, quality, and schedule[16]. These devices are at various stages of validation and approval by the United States Food and Drug Administration (FDA), with some even receiving FDA clearance. Although sufficient literature uses actigraph triaxial accelerometers to assess sleep[17,18], data generated through accelerometers and mobile devices needs further reinforcement[16]. Although a study comparing the validity of six wearable devices for assessing sleep validates the “field-based assessment of the timing and duration of sleep,” the assessment of specific stages of sleep must still be improved[19].

All these devices are compared against the traditional gold standard of laboratory-based polysomnography (PSG), which integrates data derived from electroencephalography, electrooculography, electromyography for neural activity along with electrocardiographic, blood oxygen saturation, and respiratory patterns[20].

A systematic review showed that the digital clinical tools to screen or diagnose OSA demonstrated an excellent discriminating capability, with the best tools reaching an area under the curve of > 0.99[21]. Of the 41 studies covered in the systematic review (Table 1), 11 (27%) used bed/mattress sensors, 10 (24%) used wearables, 7 (17%) used smartphones, 5 (12%) used nasal airflow sensors, and 8 (20%) could not be classified into either of these[21].

USE OF TECHNOLOGY TO MANAGE SLEEP DISORDERS: THE ROLE OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Information and communication technologies aided cognitive-behavioral therapy, Audiovisual Stimulation, Music Video Intervention, and Gight (Innovative Automated Guiding Light) has been used to treat insomnia. It improved sleep-related outcomes and other wellness metrics, such as depression, quality of life, and physical activity[22]. An initial literature proved the efficacy of therapy for sleep disorders through mobile apps. However, its performance and

Table 1 Use of technology for diagnosis of sleep disorders[23]

Type of sensor	Number of studies	Percentage	Sample size	AUC ¹	Evidence
Bed/mattress sensors	11	27%	10-366	AUC: 0.94-1.00	Strong
Wearables	10	24%	20-404	AUC: 0.80-1.00	Strong
Smartphones	7	17%	15-620	AUC: 0.61-0.95	Moderate to strong
Nasal airflow sensors	5	12%	5-288	AUC: 0.77-0.91	Moderate to strong
Other digital tools (could not be classified)	8	20%	10-359	AUC: 0.85-1.00	Strong

¹Area under curve measures discrimination power of the predictive classification model. AUC: Area under curve.

standardized care delivery must be further validated[23].

Cognitive-behavioral therapy for insomnia remains the first-line treatment for insomnia. However, technology enabling “machine learning (ML)-assisted clinical decision support” can scale and disseminate sustainable care to areas with a scarce supply of skilled physicians[24].

As already discussed, PSG remains the gold standard to detect sleep disorders and physiological records must clinch a diagnosis. Due to the elaborate set-up required and the unnatural environment of a sleep laboratory, research has always tried to analyze physiologic signals from a myriad of devices and use artificial intelligence (AI) to assign meaning to the derived data. Since 2018, using multiple ML and deep learning (DL) algorithms to the metadata acquired from millions of devices, technology has been providing us key insights into simple diagnostic modalities (through complex data analytics) and patient-specific therapy guidelines to drive patient-centric care[25]. DL provides increased resilience to the algorithms derived as it requires several data for testing and training[25]. However, recent interest has been drawn to DL and ML hybrid models for sleep disorder detection through integrated devices.

Future research would also focus on integrating AI with Electronic Health Records to alert caregivers proactively. Integrating data acquired through wearables can allow ML and DL algorithms to provide key insights for driving sleep hygiene and moving from predictive diagnostics to prescriptive therapy[26].

CONCLUSION

Sleep quality is intricately related to an individual’s wellness, including productivity and contribution to society. Although widespread, sleep disorders are often underdiagnosed and inappropriately treated. Technologies massively transformed sleep disorder diagnosis and management. With this, wearable devices might soon replace the PSG to detect sleep dysfunction. Voluminous data generated from millions of devices are now using AI, ML, and DL to provide us with deep insights into sleep physiology and suggest targeted therapy.

FOOTNOTES

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