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Article

Bibliometric Analysis of Research Hotspots and Trends in Non-Contact Sleep Monitoring

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Abstract: Objective: To explore the current status and developmental trends in non-contact sleep monitoring, providing references for future research. **Methods:** A bibliometric analysis was conducted by retrieving literature related to non-contact sleep monitoring from the Web of Science database, covering records from its inception to December 2024. CiteSpace and Bibliometrix software were employed to perform visual analyses of annual publication trends, geographic distributions, institutional contributions, author collaborations, high-frequency keywords, and burst keywords. These analyses aimed to elucidate research landscapes, hotspots, and emerging directions, with corresponding visual maps generated. **Results:** A total of 625 articles were analyzed. Current research primarily focuses on the prevention and monitoring of sleep apnea syndrome and the development of Internet of Things (IoT) -based sleep monitoring systems. **Conclusion:** Non-contact sensing technologies for sleep monitoring have gained significant research momentum in recent years. Future studies in this field are expected to emphasize interdisciplinary integration and technological innovation. Further exploration of the clinical diagnostic potential and health management applications of non-contact sleep monitoring technologies is recommended, with an emphasis on advancing intelligent and precision-oriented developments.

Keywords: non-contact; sleep monitoring; bibliometric analysis; CiteSpace

1. Introduction

1.1. Background

Polysomnography (PSG), the gold standard in sleep medicine, enables sleep staging and pathological analysis by synchronously collecting multidimensional physiological parameters including electroencephalography, electrooculography, electromyography, and respiratory cycles [1]. However, this technology faces two critical

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limitations due to its reliance on contact-based devices such as surface electrodes and piezoelectric sensors: First, the complexity of hardware systems and dependence on laboratory environments result in prohibitively high costs, rendering it unsuitable for routine home-based monitoring [2]; Second, contact sensors may induce skin irritation or motion artifacts, potentially disrupting natural sleep states and compromising the objectivity of physiological signal acquisition [3]. Recent breakthroughs in sensing technologies, biosignal processing algorithms, and IoT infrastructure have enabled non-contact sleep monitoring systems to achieve non-invasive detection of respiratory rate, heart rate variability, and body movement patterns through radar beams, infrared thermography, and video analysis. These advancements demonstrate significant potential for improving user compliance and data reliability.

1.2. Research Problem and Aim

Bibliometrics, a research domain employing statistical and mathematical methods to analyze academic publications, provides critical insights through quantitative assessment of publication patterns, trends, and relationships. It aids in identifying research hotspots, evolutionary trajectories, and key contributors within scholarly fields [4]. To systematically delineate the intellectual landscape of this domain, this study utilizes CiteSpace and Bibliometrix tools to conduct a bibliometric analysis and visualization of the knowledge base, research hotspots, and developmental trends in non-contact sleep monitoring technologies. Our objectives are threefold: (1) to identify technical bottlenecks, (2) to propose optimization pathways for clinical and health management applications, and (3) to provide theoretical foundations for building intelligent, precision-oriented sleep health ecosystems.

2. Materials and Methods

2.1. Data Sources and Retrieval Strategy

This study utilized the Web of Science (WOS) Core Collection as the primary data source. The search query was formulated as follows:

"TS = (((“sleep monitoring” OR “sleep tracking” OR “sleep assessment” OR “sleep measurement” OR “sleep analysis” OR “sleep detection” OR “sleep surveillance” OR “sleep quality” OR “sleep patterns” OR “sleep evaluation” OR “sleep disorders” OR “sleep technology” OR “sleep health” OR “sleep apnea detection” OR “sleep study”)) AND (“contactless” OR “non-contact” OR “touchless” OR “non-invasive” OR “remote” OR “unattended” OR “automated” OR “radar” OR “Infrared” OR “Bio-signal” OR “Ambient”))”.

The search timeframe spanned from the database’s inception to 31 December 2024. CiteSpace and Bibliometrix software were employed to perform metric and similarity analyses of bibliographic data, generating visual knowledge maps to systematically delineate the intellectual structure of this field.

2.2. Inclusion and Exclusion Criteria

The inclusion criteria were defined as follows: (1) journal articles, (2) studies focused on research hotspots and trends in non-contact sleep monitoring, and (3) publications written in English. The exclusion criteria comprised (1) non-English publications, retracted works, or non-article types (e. g., reviews, editorials, conference abstracts), (2) content irrelevant to non-contact sleep monitoring themes, (3) duplicate records, and (4) incomplete metadata (e.g., missing abstracts or author affiliations). These criteria ensured methodological consistency and thematic alignment in the literature selection process.

2.3. Data Analysis Methods

Bibliometric analysis and visualization were performed using CiteSpace (version 6.3.1) and Bibliometrix (version 4.1.2). For keyword clustering and co-occurrence analysis in CiteSpace, keyword-based nodes were generated with parameter configurations including a g-index (k = 15), Top N = 50, and Top N% = 10%, while retaining default settings for other variables. Collaboration network analysis, conducted via Bibliometrix, focused on mapping author collaboration patterns to highlight key contributors in the field [5,6]. This integrated approach aimed to systematically identify emerging trends and collaborative frameworks within non-contact sleep monitoring research.

3. Results

3.1. Literature Search Results

A total of 2619 articles were initially retrieved, with 625 articles ultimately included after screening. The publication timeframe spanned from 2006 to 2024, and the literature screening process is illustrated in Figure 1.

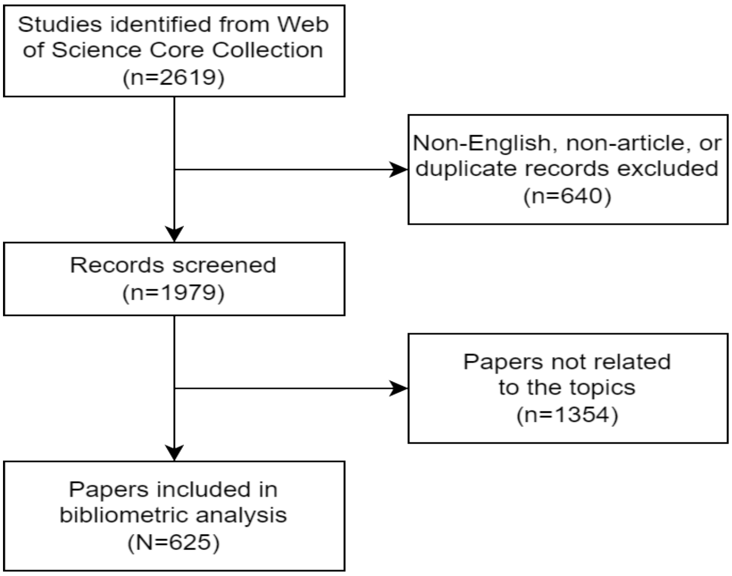

Figure 1. Flowchart of literature selection.

3.2. Annual Publication Trends

The annual publication volume in non-contact sleep monitoring research exhibited a significant upward trajectory (Figure 2). Linear regression analysis (red line) revealed a strong positive correlation between publication count and time ($R^2 = 0.87$), while a locally weighted scatterplot smoothing (LOWESS) curve (green line) further validated this trend. During the initial phase (2006–2016), publications remained sparse, growing slowly from 5 articles in 2006 to a peak of 25 articles in 2014, followed by minor fluctuations at relatively low levels. However, a rapid growth phase began in 2017, with annual publications surging from 33 articles in 2017 to 92 articles in 2024. Despite minor fluctuations (e.g., a slight decline in 2022), the overall trend demonstrates robust growth.

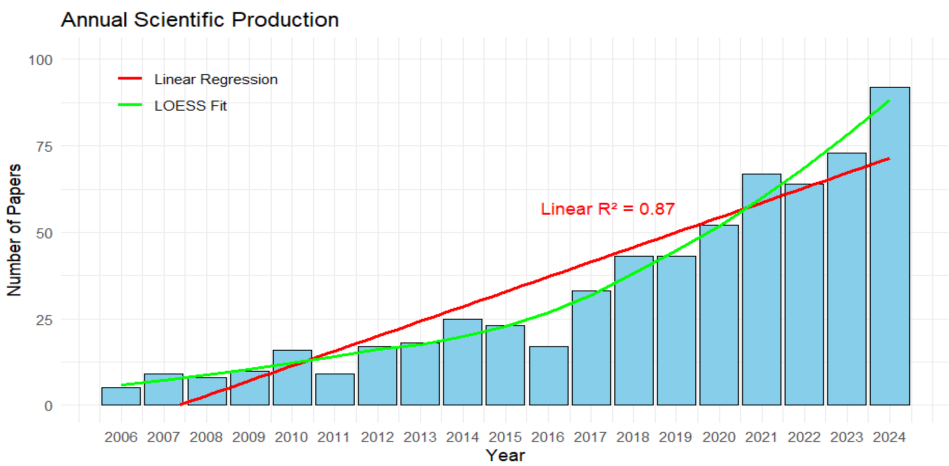

Figure 2. Annual distribution of publications on non-contact sleep monitoring.

3.3. Author Collaboration Analysis

Collaboration networks were analyzed using Bibliometrix, revealing participation from 3199 authors across the 625 articles, with an average of 5.76 co-authors per article. The visualized collaboration network (Figure 3) highlights a "high cohesion, low coupling" pattern, where researchers primarily collaborate within tightly-knit groups, with limited inter-group interactions.

To quantify collaboration intensity, the co-authorship rate was calculated as:

$\text{Co}-\text{authorship rate} = \dfrac{\text{Number of co}-\text{authored articles}}{\text{Total articles}} \times 100\% = 98.56\% \left(\dfrac{519}{625}\right)$. This underscores the prevalence of collaborative research in this field [7].

The most prolific authors in the field were identified as Zhang H (7 articles), Li SH (6 articles), Redline S (6 articles), Hong H (5 articles), and Overeem S (5 articles). Table 1 summarizes co-authorship network statistics for these researchers, including their fractionalized contributions—a metric reflecting individual leadership roles in collaborative studies [8]. Notably, Redline S and Hong H demonstrated contrasting collaborative dynamics, with fractionalized article contributions quantified at 0.75 and 0.92, respectively. These metrics reflect variations in their roles within multi-author studies, underscoring differences in leadership or collaborative engagement across research teams.

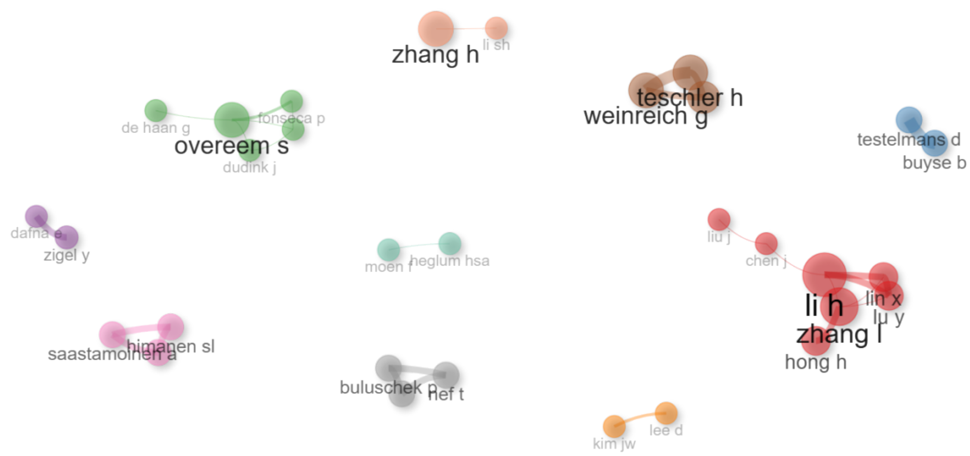

Figure 3. Co-authorship network of researchers in non-contact sleep monitoring.

Table 1. Co-authorship network statistics for non-contact sleep monitoring research.

Authors	Articles	Articles Fractionalized
REDLINE, SUSAN	6 (0.96%)	0.75
HONG, HONG	5 (0.8%)	0.92
ACHARYA, U. RAJENDRA	4 (0.64%)	0.87
BUYSE, BERTIEN	4 (0.64%)	0.53
DIJK, DERK-JAN	4 (0.64%)	0.65

3.4. Keyword Co-Occurrence Analysis

High-frequency keywords reflect core research themes. Using CiteSpace, a keyword co-occurrence map was generated (Figure 4). The top 10 keywords by frequency included "sleep apnea", "actigraphy", and "validation" (Table 2), indicating these topics dominate current research. Betweenness centrality (ranging 0 – 1) identifies pivotal nodes in the network. Nodes with centrality >0.1 are considered influential [9]. The top keywords by centrality were: "apnea" (0.14), "validation" (0.13), "system" (0.12), "diagnosis" (0.11), and "obstructive sleep apnea" (0.08). This underscores a research focus on "sleep apnea detection" and "validation of monitoring technologies".

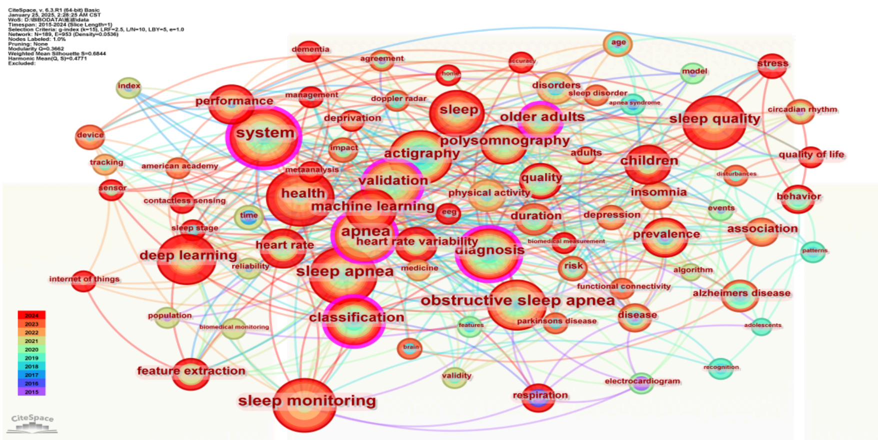

Figure 4. Keyword co-occurrence map for non-contact sleep monitoring research.

Table 2. Top 10 keywords in non-contact sleep monitoring research.

Rank	Keyword	Frequency	Centrality
1	sleep apnea	44 (%)	0.08
2	apnea	42	0.14
3	sleep monitoring	39	0.05
4	system	36	0.12
5	obstructive sleep apnea	34	0.08
6	health	33	0.04
7	sleep quality	33	0.06
8	actigraphy	32	0.1
9	diagnosis	32	0.11
10	validation	30	0.13

3.5. Keyword Cluster Analysis

The keyword clustering map (Figure 5) shows that the research topics in the field of non-contact sleep monitoring can be divided into several major clusters, including “Sleep apnea”, “Sleep monitoring”, “Internet of things”, etc. Among them, “Sleep apnea”, as the core cluster, highlights its status as a research hotspot at present. “IOT” and “mhealth” reflect the important trend of technological integration, providing key support for the application of non-contact sleep monitoring. In addition, clusters such as “Functional near – infared spectroscopy” reflect the focus of emerging sensor technologies. Overall, this reveals the interdisciplinary research characteristics and application potential of this field.

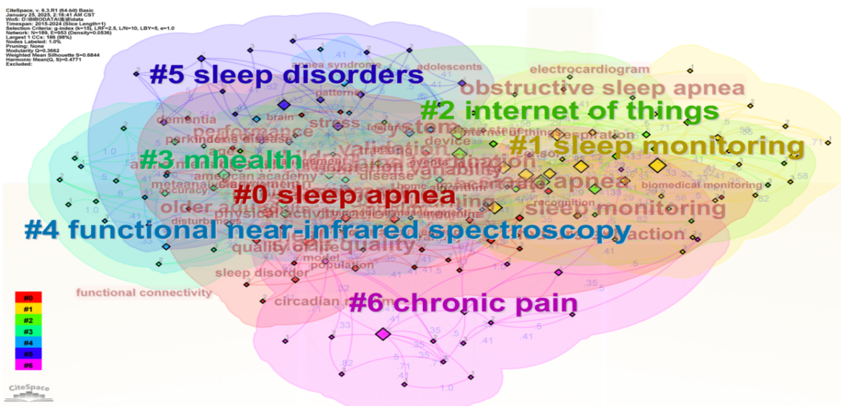

Figure 5. Keyword clustering map for non-contact sleep monitoring research.

4. Discussion

4.1. General Information

This research field has demonstrated sustained growth, with annual literature output showing a significant upward trend. This developmental trajectory exhibits a strong positive correlation with iterative innovations in key technologies such as multimodal sensing, deep learning algorithms, and IoT architectures. Based on current technological evolution trends, non-contact sleep monitoring systems hold promising application prospects in clinical diagnostics and personalized health management.

Notably, among the 625 analyzed publications, a total of 3199 researchers were involved. Bibliometric analysis reveals that a core group of highly productive authors has yet to emerge: the top five contributors (Zhang H, Li SH, Redline S, Hong H, and Overeem S) have a maximum output of only seven publications each. Less than 10% of authors have published two or more papers, while approximately 90.6% have contributed only a single publication, indicating a pronounced fragmentation of research efforts in this domain.

Such structural characteristics may exert dual impacts on disciplinary advancement. First, the lack of stable academic leadership within the research community limits sustained progress in addressing critical scientific challenges. Second, methodological fragmentation risks hindering the establishment of systematic theoretical frameworks and technical standardization. To address these issues, interdisciplinary research consortia and enhanced longitudinal funding mechanisms are recommended to cultivate internationally influential core research teams.

4.2. Research Hotspots and Frontiers

Keyword co-occurrence and clustering analyses have identified three primary research directions in non-contact sleep monitoring: (1) intelligent recognition of sleep disorders, (2) IoT-driven home monitoring system development, and (3) innovative applications of mobile health (mHealth) technologies, reflecting a trend toward technological convergence and scenario expansion.

In sleep disorder monitoring, high-frequency keywords such as “obstructive sleep apnea” (frequency: 34) and “validation” (centrality: 0.13) indicate a shift toward clinical validation. The synergistic use of multimodal sensors has emerged as a critical breakthrough, enabling precise differentiation of apnea subtypes through depth video and audio feature learning [10]. However, most existing studies remain confined to algorithm validation in laboratory settings, with non-contact systems still exhibiting limitations in sample size, accuracy, and consistency—key areas for future optimization [11].

The integration of IoT technologies has redefined the spatial-temporal boundaries of sleep monitoring. Cluster #2 (“Internet of Things”) and the high-frequency keyword “system” (frequency: 36) highlight advancements in distributed sensor networks. Current research integrates piezoelectric sensing, ambient light detection, and cloud-based analytics to evolve monitoring systems from single-function devices to multiparameter platforms. For instance, under-bed pressure acquisition systems employ magnetic induction for data collection, while synchronized environmental parameter monitoring (e. g., temperature and humidity) enables novel explorations of sleep-environment interactions [12]. Nevertheless, interoperability barriers persist due to the absence of standardized cross-device communication protocols.

The universalization of mHealth technologies underscores a transition toward real-world applications. Cluster #3 (“mHealth”) and the keyword “sleep quality” (frequency: 33) reveal that multimodal systems combining accelerometers and acoustic signals have achieved preliminary sleep stage classification and snore event detection [13]. However, non-contact devices remain vulnerable to background noise, motion artifacts, and electromagnetic interference. For example, environmental complexity, patient movement, posture changes, and multi-target suppression can compromise signal accuracy—a critical bottleneck for clinical adoption [14]. Additionally, the lack of cross-platform data standardization protocols challenges the comparability of results across devices.

4.3. Strengths and Limitations

This study pioneers the systematic mapping of the non-contact sleep monitoring domain through bibliometric methods, offering three key strengths: (1) cross-verification using CiteSpace and Bibliometrix enhances the objectivity of hotspot identification; (2) comprehensive temporal coverage (database inception to 2024) captures technological evolution trajectories; and (3) quantitative analysis of 625 publications overcomes the subjectivity inherent in traditional reviews, providing robust data-driven insights.

However, limitations must be acknowledged. First, reliance solely on the Web of Science Core Collection may introduce database bias. Second, the exclusion of non-English publications risks underestimating regional innovations, particularly from non-English-speaking countries. Third, bibliometric methods exhibit inherent delays in identifying emerging terminologies, such as “generative AI for signal enhancement,” which have yet to form distinct clusters. Future studies should integrate patent analysis and expert interviews to construct a more holistic technology foresight framework.

4.4. Conclusions

Non-contact sleep monitoring technology is transitioning from laboratory validation to clinical practice. Our bibliometric analysis reveals a progressive research framework characterized by “technology-driven innovation, clinical validation, and health management integration,” with three defining trends: (1) multi-modal sensor fusion (e. g., radar, piezoelectric, and acoustic synergy), (2) intelligent data analytics (increasing adoption of deep learning algorithms), and (3) broadened application ecosystems (from hospitals to communities and households). Future research priorities include establishing standardized cross-device data protocols, conducting multicenter trials to validate generalizability, and developing ethical frameworks for data privacy. Through multidisciplinary collaboration, non-contact monitoring may overcome the “gold-standard substitution dilemma” and achieve broader clinical adoption.

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Author Contributions

Conceptualization, H.S.; writing—original draft preparation and writing—review and editing, J.Q., J.K., Y.C., Y. S., K. B., L. F., W. Y., D. Y., J. Z. and S. C. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

References

1 Marouf M, Vukomanovic G, Saranovac L, *et al*. Multi-Purpose ECG Telemetry System. *Biomedical Engineering Online* 2017; **16**: 80. https://doi.org/10.1186/s12938-017-0371-6.

2 Lund HG, Rybarczyk BD, Perrin PB, *et al.* The Discrepancy Between Subjective and Objective Measures of Sleep in Older Adults Receiving CBT for Comorbid Insomnia. *Journal of Clinical Psychology* 2013; **69**: 1108–1120. https://doi.org/10.1002/jclp.21938.

3 Li W, Gao J. Automatic Sleep Staging by a Hybrid Model Based on Deep 1D-ResNet-SE and LSTM with Single-Channel Raw EEG Signals. *PeerJ Computer Science* 2023; **9**: e1561.

4 Broadus RN. Toward a Definition of ‘Bibliometrics’. *Scientometrics* 1987; **12**: 373–379. https://doi.org/10.1007/BF02016680.

5 Chen C. CiteSpace II: Detecting and Visualizing Emerging Trends and Transient Patterns in Scientific Literature. *Journal of the American Society for Information Science and Technology* 2006; **57**: 359–377.

6 Aria M, Cuccurullo C. Bibliometrix: An R-Tool for Comprehensive Science Mapping Analysis. *Journal of Informetrics* 2017; **11**: 959–975. https://doi.org/10.1016/j.joi.2017.08.007.

7 Gauffriau M, Larsen PO. Counting Methods Are Decisive for Rankings Based on Publication and Citation Studies. *Scientometrics* 2007; **71**: 239–262.

8 Abramo G, D’Angelo CA, Rosati F. The Importance of Accounting for the Number of Co-Authors and Their Order When Assessing Research Performance at the Individual Level in the Life Sciences. *Journal of Informetrics* 2013; **7**: 198–208.

9 Huang Z, Ling BWK. Joint Ensemble Empirical Mode Decomposition and Tunable Q Factor Wavelet Transform Based Sleep Stage Classifications. *Biomedical Signal Processing and Control* 2022; **77**: 103760.

10 Yang C, Cheung G, Stankovic V, *et al.* Sleep Apnea Detection via Depth Video and Audio Feature Learning. *IEEE Transactions on Multimedia* 2017; **19**: 822–835. https://doi.org/10.1109/TMM.2016.2626969.

11 Tran VP, Al-Jumaily AA, Islam SMS. Doppler Radar-Based Non-Contact Health Monitoring for Obstructive Sleep Apnea Diagnosis: A Comprehensive Review. *Big Data and Cognitive Computing* 2019; **3**: 3. https://doi.org/10.3390/bdcc3010003.

12 Mahdavi H, Rosell-Ferrer J. In-Bed Vital Signs Monitoring System Based on Unobtrusive Magnetic Induction Method with a Concentric Planar Gradiometer. *Physiological Measurement* 2017; **38**: 1226–1241. https://doi.org/10.1088/1361-6579/aa6a09.

13 Rossi M, Sala D, Bovio D, *et al.* Sleep-See-Through: Explainable Deep Learning for Sleep Event Detection and Quantification from Wearable Somnography. *IEEE Journal of Biomedical and Health Informatics* 2023; **27**: 3129–3140. https://doi.org/10.1109/JBHI.2023.3267087.

14 Boiko A, Martínez Madrid N, Seepold R. Contactless Technologies, Sensors, and Systems for Cardiac and Respiratory Measurement during Sleep: A Systematic Review. *Sensors* 2023; **23**: 5038. https://doi.org/10.3390/s23115038.