



Research article

Potential vicious cycle between postoperative pain and sleep disorders: A bibliometric analysis

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ABSTRACT

Background: Surgical pain affects postoperative sleep quality, and they jointly form a vicious cycle of mutual influence. The cycle of postoperative pain and sleep disorders could lead to delirium, cardiovascular disease, and hyperalgesia, which significantly affect patients' postoperative recovery. Thus, exploring this phenomenon is of great importance for surgical patients, and warrants further investigation.

Objective: By employing bibliometric methods, this study systematically analyzes the publications on postoperative pain-sleep disorders, identifies research trends and field dynamics, and ultimately provides insights for further progress in this research area.

Methods: In this study, we searched the Web of Science database for studies on postoperative pain and sleep disorders from 2013 to 2023, and analyzed the number of publications, journals, authors, institutions, country regions, and keywords by utilizing CiteSpace, VOSviewer, and Bibliometrix.

Results: The 1894 retrieved publications showed a trend of increasing number of publications and correlations between postoperative pain and sleep disorders from 2013 to 2023. The top countries for publications included the USA, China, etc., establishing a global collaborative network centered around the USA, China, and Europe. The top institutions for publications included University of California System, Harvard University, etc. The top authors include Christine Miaskowski, Steven M. Paul, Qiuling Shi, etc. These publications involved multiple disciplines including surgery, neurology, and anesthesiology, and various research funds including NIH, HHS, NSFC, etc. The top journals for publications included the European Archives of Oto-Rhino-Laryngology, etc. Keywords that appear most frequently in this field include "pain", "surgery", "quality of life", "sleep", "depression", and "outcomes". The thematic map indicated that the hot topics in this area include obstructive sleep apnea, tonsillectomy, children, pain, quality of life, and sleep. The undeveloped topics with research potential included postoperative pain, analgesia and dexmedetomidine, breast cancer, fatigue, and lung cancer.

Conclusion: The increased number of publications and correlations between postoperative pain and sleep disorders, and the collaborative network across the USA, China, and Europe indicate a

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growing global interest in this area. This study also provides valuable insights into the trend of hot topics and frontiers and shows that this is an evolving and dynamic research area.

1. Introduction

Recent advances in Enhanced Recovery After Surgery (ERAS) protocols have underscored the critical importance of managing postoperative pain and sleep disturbance in optimizing surgical recovery [1]. ERAS protocols, which are designed to accelerate postoperative recovery and improve patient outcomes, emphasize multimodal analgesia and strategies to minimize sleep disorders as crucial components of postoperative care [2]. Despite significant strides in understanding these factors individually, the intricate interplay between postoperative pain and sleep disturbance, as well as their collective impact on recovery, remains underexplored. This oversight is particularly concerning, given that up to 80 % of patients report moderate to severe postoperative pain, accompanied by significant disruptions in postoperative sleep architecture [3,4]. Such conditions not only prolong hospital stays but also precipitate long-term postoperative complications, such as chronic pain, cardiovascular issues, and immune dysfunction [5]. Furthermore, impaired sleep and unresolved pain can negatively impact mental health, leading to increased anxiety, depression, and overall decreased quality of life [6]. These factors collectively impair recovery efficiency, highlighting the urgent need for an integrated approach to postoperative management that concurrently addresses both pain and sleep disturbances.

The complex bidirectional relationship between postoperative pain and sleep disorder underscores the necessity for a comprehensive understanding. Postoperative pain can worsen sleep quality, potentially causing sleep interruptions [7]. Conversely, pain-induced sleep deprivation can exacerbate pain perception, negatively affecting pain management and the efficacy of analgesics, thereby creating a vicious cycle of sleep disturbances [8,9]. In light of these findings, the integration of pain and sleep disorder management into postoperative care is crucial, advocating a holistic treatment strategy. This strategy not only improves the quality of rehabilitation but also accelerates patient recovery and alleviates psychological distress [10]. Postoperative pain and sleep disorders have been recognized in contemporary medical practice as pivotal determinants of patient recovery and overall health [11]. Although the individual effects of these factors on recovery have been extensively studied, the combined effects and implications for treatment strategies require further investigation.

This gap highlights the urgent need to examine the current landscape and emerging trends in research on postoperative pain and sleep disorders. Bibliometrics, the study of measuring and analyzing scientific literature, provides valuable insights into the evolution of research topics, collaboration networks, and the impact of scientific work [12]. By employing scientometric methods and visual analytics, including scientific knowledge mapping, this study aims to describe trends and distributions of publications within the field, including their impact and citation patterns. This bibliometrics facilitates the exploration of development patterns and identification of research hotspots, shedding light on the leading research teams and institutions, the allocation of medical resources, and the broader social phenomena associated with postoperative pain and sleep disorders. Utilizing bibliometric analysis tools such as CiteSpace, VOSviewer, and Bibliometrix, we conduct a comprehensive review of the impact and trajectories of sleep research in the postoperative context. Moreover, this study aims to delineate dominant research themes and directions, map evolutionary dynamics and boundaries of the field, and provide insights for future research endeavors.

2. Method

2.1. Data collection and retrieval strategy

We searched the literature from the Web of Science Core Collection (WOSCC) with the strategy formula (TS = (Surgery OR Operative OR Surgical OR Postsurgical OR Postoperative OR Post-surgical OR Post-operative)) AND TS = (Sleep OR Sleep apnea OR Insomnia OR Hypersomnia OR Narcolepsy OR Sleep quality OR Sleep quantity OR Sleep duration OR Circadian rhythm) AND TS = (pain OR NRS OR VAS OR "Numeric rating scale" OR "Visual analogue scale") for the period from January 1, 2013 to December 31, 2023. Language type was not restricted and literature type was restricted to articles. A total of 2237 papers were obtained. After removing 344 non-article publications, 1893 papers were included. The following bibliometric information was collected: year of publication, country, journal, number of citations, authors, funding, disciplines, institutions, and topics. Retrieval work was performed in the same week to avoid variations due to daily updates. As all data were secondary and did not contain personal information, consent was deemed unnecessary.

2.2. Bibliometric analysis

The publication characteristics were reviewed online from the WOSCC database, including publication data, institutional and author collaboration, disciplines and funds, journals, and keywords. The data were then transferred into Microsoft Excel 2019 (Redmond, Washington) for organization and tabulation or for visualization analysis through bibliometric analysis software, including: 1) CiteSpace software Basic version 6.2.R4 (Chaomei Chen, Philadelphia, PA, USA) [13], 2) VOSviewer version 1.6.9 (The Centre for Science and Technology Studies, CWTS, Leiden, The Netherlands) [14], and 3) Bibliometrix (R version 3.5.6) [15].

CiteSpace, a freely available Java application, was employed in this study to provide dynamic visualizations that reflect the evolution of bibliometric networks over time. Specifically, CiteSpace was used to visualize a co-occurrence network for Keywords Plus

analysis.

VOSviewer, a bibliometric tool that focuses on visualizing bibliometric networks using distance-based techniques, was utilized in this study for the following purposes: 1) exploring collaborative networks among authors and their affiliated institutions through a co-authorship network; and 2) illustrating associations between countries through a co-occurrence network. Additionally, it was also used to visualize the citations per article in different journals and their co-occurrence network.

Bibliometrix, an R package explicitly designed for quantitative research in scientometrics, was employed in this study to carry out the following tasks: 1) summarizing publication and citation counts for bibliometric analysis on global maps; 2) identifying annual trend topics based on top keywords/terms; and 3) visualizing the thematic map of keyword analysis; 4) identifying keyword clustering and visually map its temporal progression.

3. Results

3.1. Analysis of publication data

After conducting an extensive search and filtering process within the WOS database, a total of 1893 publications focusing on postoperative pain and sleep disorders from 2013 to 2023 were identified. As depicted in Fig. 1a, the publications exhibited a steady and significant growth trend in publication volume. From 2013 to 2018, the number of publications remained relatively consistent. However, starting in 2019, there was a notable increase in publication volume, peaking at 270 publications in 2022, which represents an 80 % increase compared to 2018. This surge suggests that the high prevalence of research on postoperative pain and sleep disorders, as well as their intercirculation and adverse effects on postoperative recovery, has attracted unprecedented attention. These researches have supported the advancement of day surgery and postoperative recovery through enhanced recovery programs and other

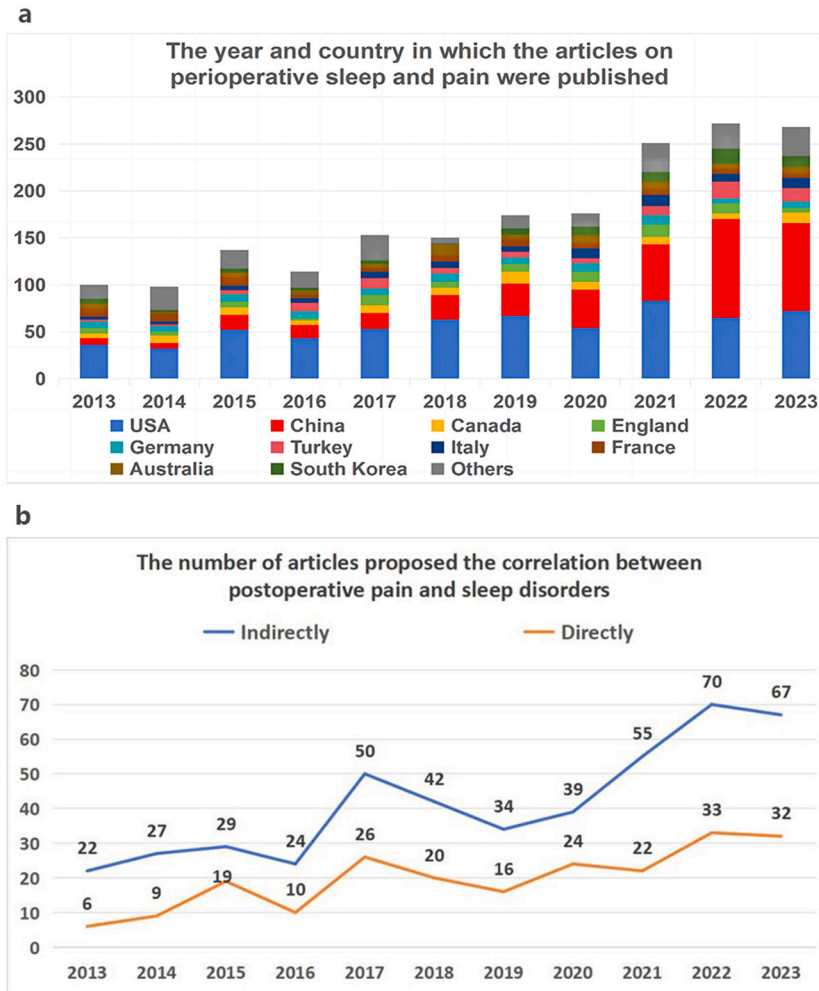


Fig. 1. (a) The year and country in which the articles on postoperative pain-sleep disorders were published. (b) Number of articles per year that directly/indirectly confirm the association between postoperative pain and sleep disorders.

innovative care models [16].

To further clarify the recent focus on the association between postoperative pain and sleep disorders, we meticulously reviewed the abstracts of 1893 articles. This involved a sentence-by-sentence analysis to identify the number of articles in each year that directly or indirectly studied the correlation between postoperative pain and sleep disorders. “Direct evidence” refers to articles that explicitly and directly address the correlation between postoperative pain and sleep disorders in the results section or abstract. “Indirect evidence” encompasses studies that observed both conditions and reported improvements in one following intervention in the other, even if the correlation was not explicitly stated. As depicted in Fig. 1b, the results show a consistent annual increase in the number of articles providing direct and indirect evidence of the correlation between perioperative pain and sleep disorders from 2013 to 2023. In 2013, there were 6 articles that directly studied the correlation between postoperative pain and sleep disorders, 22 articles that indirectly studied the correlation. By 2023, these numbers had increased to 32 and 67, respectively, indicating an increase of 433 % and 205 %.

For publication country, Table 1 illustrates that the USA accounts for 620 articles (32.75 % of the total) and China accounts for 420 papers (22.19 %). This is followed by Canada, 88 (4.65 %); Turkey, 87 (4.60 %); England, 83 (4.38 %); Germany, 83 (4.38 %); Italy, 78 (4.12 %); South Korea, 71 (3.75 %); France, 69 (3.65 %); and Australia, 67 (3.54 %). Fig. 2a was generated by collecting publication output and co-citation data from the WoS database. This data was then imported into VOSviewer, which created the figure based on the collected information. The statistical analysis section involved computing the publication counts and co-citation relationships for each country/region, which allowed for a detailed examination of global research collaboration patterns, highlighting key research hubs and their interconnections. This analysis facilitated an evaluation of the extent of academic collaboration on a global scale. It illustrates 36 hubs and 259 connections, indicating widespread interest and research on postoperative pain-sleep disorders around the world. The prominence of each nation is depicted by the size of its respective circle, and the proximity of two circles approximately reflects their co-citation links.

A clustering analysis based on co-citation relationships reveals that the principal research nations in this field are divided into three clusters: the most substantial and interconnected cluster (green) includes the USA, China, Canada, and Italy, etc. followed by a cluster (blue) that comprises the United Kingdom, Germany, France, and Australia, among others; and a third cluster (red) involving Turkey, Denmark, Sweden, and the Netherlands, among others. As shown in Fig. 2b, these interconnected researchers have gradually established a relatively dense global collaborative network centered around the USA, China, and Europe. The stabilization of this network has deepened research, and accumulated expertise, swiftly responded rapidly to new challenges and needs, and facilitated the development and promotion of international standards.

3.2. Analysis of institutional and author collaboration

We analyzed the 20 most prolific corresponding authors and their affiliated institutions and ranked them by number of publications. Table 2 lists the leading institutions contributing to research on postoperative pain and sleep disorders, with the University of California System, Harvard University, and the Pennsylvania Commonwealth System among the most prominent. Fig. 3, generated by importing information from WoS regarding major research institutions in this field into VOSviewer for visualization, illustrates the collaborative network among different institutions in the field of postoperative pain and sleep disorders. In this visualization, the principal research institutions in the field are divided into three clusters: the first, centered on the Mayo Clinic (total link strength: 91), the University of California System (69), and the University of Pittsburgh (66), consists mainly of primarily consisting of the USA research institutions (red cluster). The second, centered on Shanghai Jiao Tong University (18), Zhejiang University (12), and Anhui Medical University (10), predominantly comprises Chinese research institutions (blue cluster). The third, centered on the University of Copenhagen (31), Sichuan University (19), and Capital Medical University (18), highlights a more internationally diverse assembly (green cluster). Table 3 shows that Christine Miaskowski (University of California, USA) has the most publications (22 publications and 522 citations), followed by Steven M. Paul (20, Weill Cornell Medical College, USA), Qiuling Shi (Chongqing Medical University, China), Henrik Kehlet (University of Copenhagen, Denmark), Jon D. Levine (University of Michigan, USA), etc. The collaboration between these authors is visualized in Fig. 4, which is generated by importing information from the WoS on individual publication output and co-citation relationships in this field into VOSviewer for visualization. This observation indicates that, despite the increasing globalization of the field, there still exists a geographical specificity in research. Studies by authors from the same country tend to exhibit greater similarities and co-citation relationships. For example, the majority of American authors are concentrated in the red cluster, forming a cluster centered around Christine Miaskowski (total link strength: 92), Steven M. Paul (89), and Jon D. Levine (58). Authors of Chinese nationality are predominantly found in the green and light blue clusters, with their research focus on Qiuling Shi (36), Wei Dai (33), and Xin Wei (33). European authors are located in the dark blue, yellow, and purple clusters, centered on Henrik Kehlet (70), Lisa Goudman (39), and Bengt Linderoth (38).

3.3. Analysis of disciplines and funds

We conducted a comprehensive analysis of journal disciplines encompassing the articles on postoperative pain and sleep disorders from 2013 to 2023. Our findings highlight that the disciplines contributing most significantly to this body of literature are surgery (comprising 305 articles, 14 % of the total), clinical neurology (290, 13 %), anesthesiology (253, 11 %), otorhinolaryngology (199, 9 %), medicine general internal (185, 8 %), etc. (Fig. 5). This diversity underscores the multifaceted interest that postoperative pain and sleep disorders have attracted across different medical specialties.

In addition, an examination of the funding agencies most frequently acknowledged in these articles revealed a diverse international funding base (Table 4). The foremost contributors are predominantly from the United States, with agencies like the Department of

Table 1

The year and country in which the articles on postoperative pain-sleep disorders were published.

	USA	China	Canada	Turkey	England	Germany	Italy	South Korea	France	Australia	Other	Total	Indirectly	Directly
2013	36	7	5	2	6	7	3	5	9	5	15	100	22	6
2014	32	6	8	2	4	6	3	2	8	2	25	98	27	9
2015	52	16	8	4	6	8	5	4	9	5	20	137	29	19
2016	43	14	5	9	2	8	5	3	3	5	17	114	24	10
2017	53	17	8	11	11	7	7	4	4	4	27	153	50	26
2018	63	26	8	6	6	9	7	1	6	12	6	150	42	20
2019	67	34	13	6	8	7	6	6	7	6	14	174	34	16
2020	54	41	8	5	11	9	11	9	6	8	14	176	39	24
2021	83	60	8	10	13	10	12	10	6	8	32	251	55	22
2022	65	105	6	18	11	5	8	16	6	5	27	272	70	33
2023	72	94	11	14	5	7	11	11	5	7	31	268	67	32
Total	620	420	88	87	83	83	78	71	69	67	227	1893	459	217

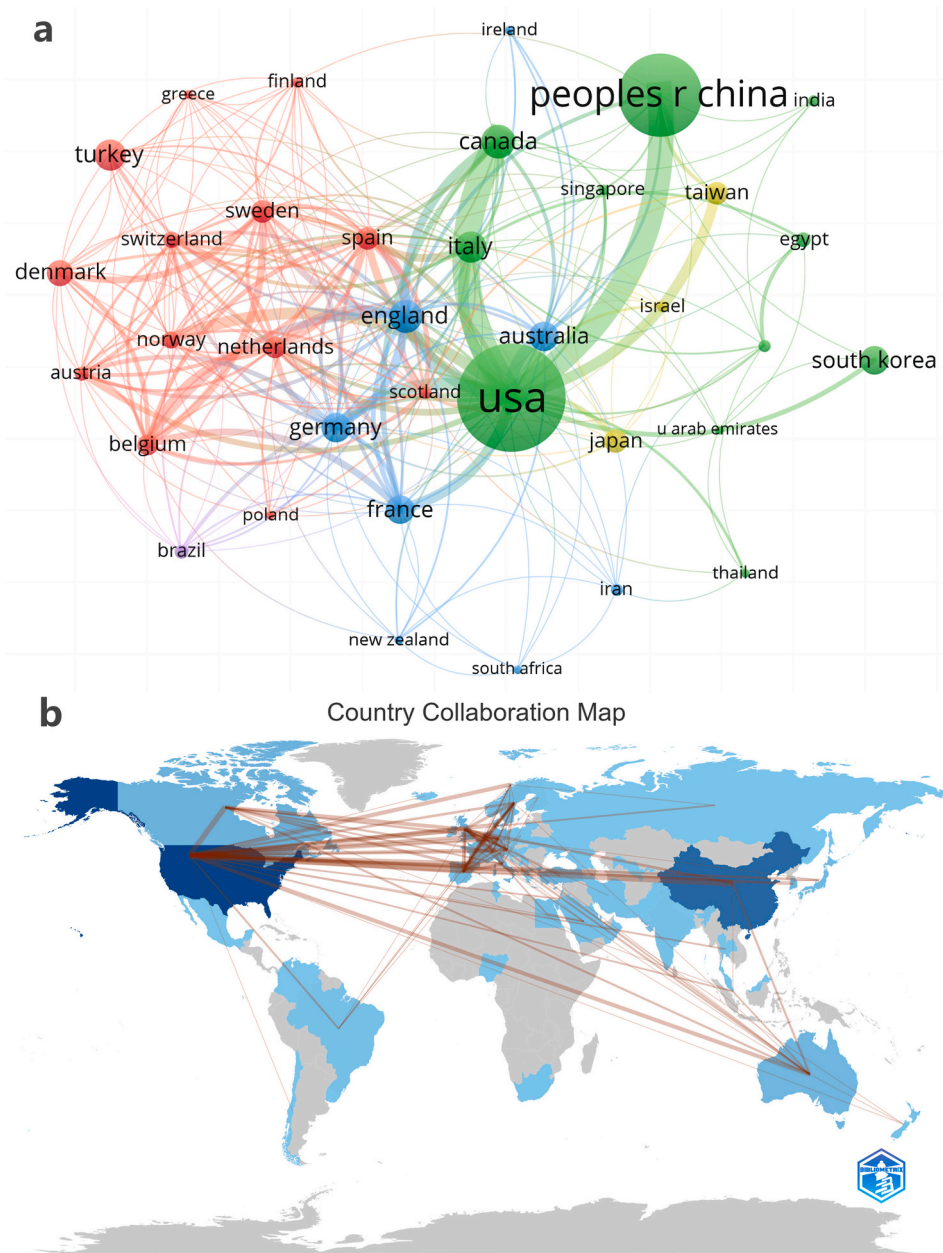


Fig. 2. (a) The country contact map for co-published articles. (b) Distribution of postoperative pain-sleep disorders in the world map.

Health and Human Services (117 grants) and the National Institutes of Health (116 grants) leading the way, followed by the National Natural Science Foundation of China (89 grants). This concentrated investment by American and Chinese agencies underlines their important role in advancing research in this clinical area.

4. Analysis of journals

In our subsequent analysis, we analyzed the leading journals that published articles on postoperative pain and sleep disorders (Table 5). Among these journals, the European Archives of Oto-Rhino-Laryngology emerged as the most prolific, with 34 articles averaging 11.9 citations each. This was followed by Medicine (29, 6.9 citations), Anesthesia & Analgesia (25, 34.6 citations), Laryngoscope (24, 16.2 citations), BMJ Open (23, 5.6 citations), etc. Notably, Anesthesia & Analgesia, Otolaryngology-Head and Neck Surgery, and Neuromodulation have top citations per article with 34.6, 33.3 and 28.0 respectively. Fig. 6 illustrates a visual representation of the publication output in relevant fields for each journal, where the color gradient from blue to yellow indicates the

Table 2
Top 10 institutions in terms of number of articles issued.

Rank number	Institutions	Record Count
1	University of California System	75
2	Harvard University	53
3	University of California San Francisco	46
4	Pennsylvania Commonwealth System of Higher Education Pshe	45
5	University of Copenhagen	41
6	Harvard Medical School	38
7	Johns Hopkins University	36
8	University of Michigan	34
9	University of Michigan System	34
10	University of Pittsburgh	33
11	Mayo Clinic	32
12	Sichuan University	29
13	Stanford University	29
14	Rigs Hospitalet	28
15	Capital Medical University	27
16	Duke University	27
17	University System of Ohio	27
18	University of Texas System	26
19	University of Toronto	25
20	Assistance Publique Hopitaux Paris Aphp	23

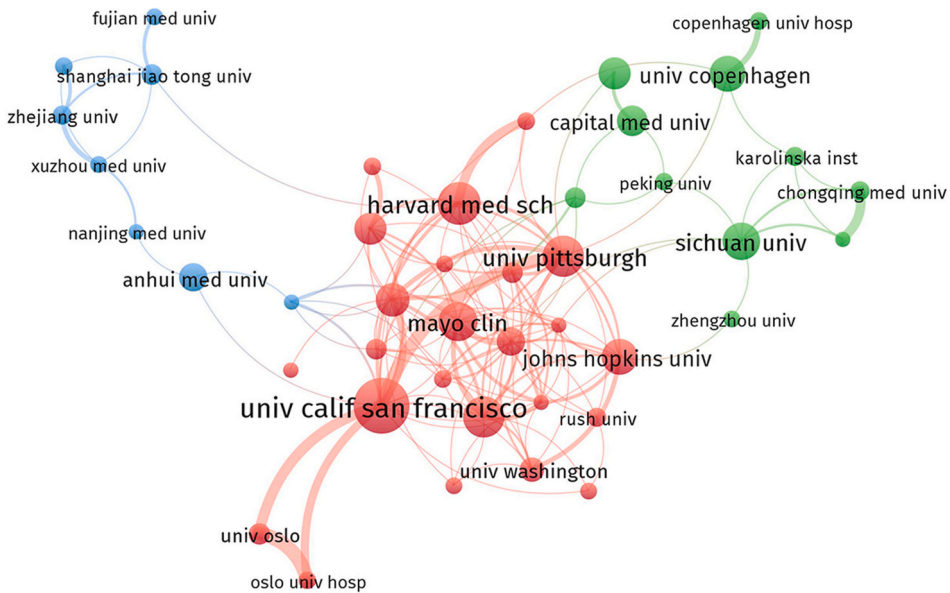


Fig. 3. Institution collaboration chart. The dot size represents the number of papers issued by the institution, and different colors represent different clusters.

average number of citations. It can be observed that the highest co-citation frequencies occur between "Otolaryngology-Head and Neck Surgery" and "International Journal of Pediatrics", "European Archives of Oto-Rhino-Laryngology" and "International Journal of Pediatrics", as well as between "European Archives of Oto-Rhino-Laryngology" and "International Journal of Pediatrics".

Analysis of Keywords.

4.1. Keyword co-occurrence analysis

Table 6 shows the keywords with the highest frequency, with "pain" (491 occurrences) leading the list, followed by "surgery" (386), "management" (212), "quality of life" (197), "sleep" (183), "depression" (153), "outcomes" (145), "children" (138), "quality of life" (137), etc. As depicted in Fig. 7, the data are segmented into annual time slices in a highly structured network with clearly delineated research clusters (modularity (Q) value = 0.7806), the Silhouette coefficient (S) = 0.9144 indicates the robustness of the clustering. These metrics show a significant increase in articles with "pain" as a keyword in recent years, especially after 2021, with associated

Table 3
Top 10 authors for the publications and citations.

Rank number	Author	Publications	Citations
1	Christine Miaskowski	22	522
2	Steven M. Paul	20	490
3	Qiuling Shi	14	142
4	Henrik Kehlet	13	162
5	Jon D. Levine	12	444
6	Wei Dai	10	54
7	Yvette P. Conley	9	59
8	Xing Wei	9	54
9	Bruce Cooper	8	257
10	Lisa Goudman	8	85
11	Anners Lerdal	8	93
12	Qiang Li	8	54
13	Maarten Moens	8	85
14	Tone Rustoen	8	158
15	Laura B. Dunn	7	189
16	Nicholas A. Giordano	7	9
17	Krista B. Highland	7	4
18	George A. C. Murrell	7	74
19	Brian J. Neuman	7	142
20	Richard L. Skolasky	7	142

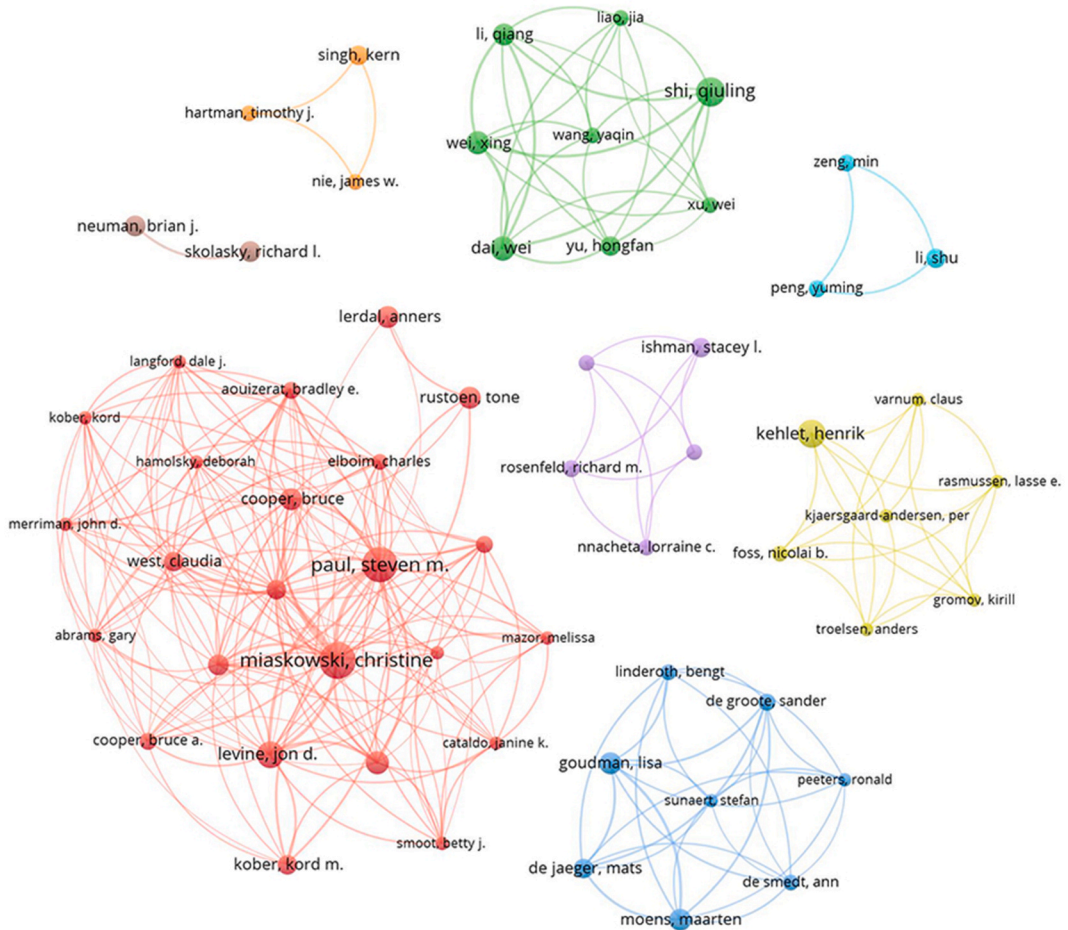


Fig. 4. Author collaboration chart. The size of the dot represents the publication volume of authors, and the color represents different clusters.

The proportion of articles published in different disciplines

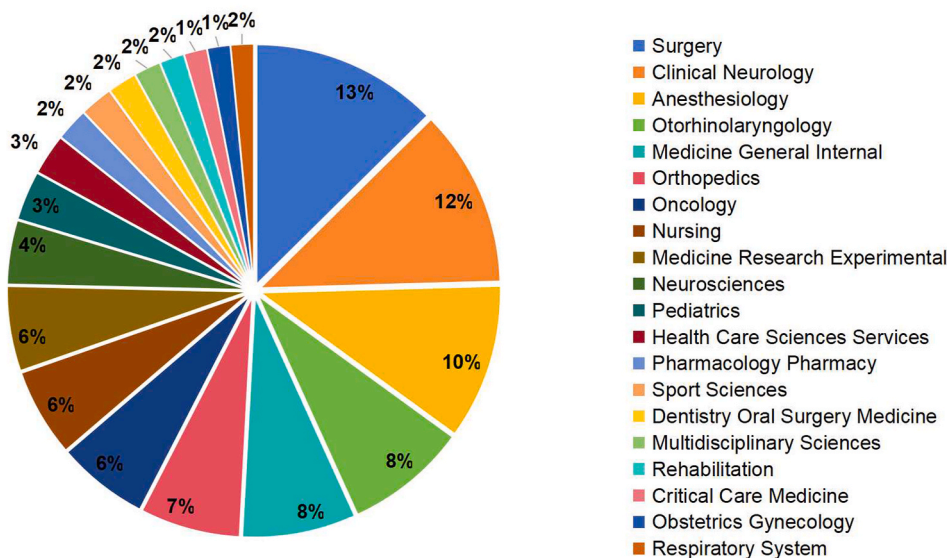


Fig. 5. The proportion of articles published in different disciplines.

Table 4
Top 10 funding agencies by publications.

Rank number	Funding agencies	Number of publications	Proportion
1	United States Department of Health Human Services	117	6.181
2	National Institutes of Health	116	6.128
3	National Natural Science Foundation of China	89	4.702
4	NIH National Cancer Institute	30	1.585
5	Pfizer	15	0.792
6	Medtronic	12	0.634
7	Canadian Institutes of Health Research	11	0.581
8	NIH National Center for Research Resources	11	0.581
9	NIH National Institute of Nursing Research	11	0.581
10	National Health and Medical Research Council of Australia	10	0.528

Table 5
Top 10 journals by publications.

Rank number	Source	Documents	Citations	Average citations per article
1	European Archives of Oto-Rhino-Laryngology	34	430	12.65
2	Medicine	30	221	7.37
3	BMJ Open	26	144	5.54
4	Laryngoscope	26	405	15.58
5	Anesthesia and Analgesia	25	965	38.60
6	Journal of Pain Research	24	310	12.92
7	Trials	24	112	4.67
8	International Journal of Pediatric Otorhinolaryngology	23	265	11.52
9	PLOS ONE	23	438	19.04
10	BMC Anesthesiology	22	261	11.86
11	Journal of Arthroplasty	21	290	13.81
12	Otolaryngology-Head and Neck Surgery	21	769	36.62
13	Journal of Clinical Medicine	20	48	2.40
14	Neuromodulation	20	610	30.50
15	International Journal of Clinical and Experimental Medicine	19	21	1.11
16	Pain Practice	19	186	9.79
17	Obesity Surgery	17	340	20.00
18	Supportive Care in Cancer	17	213	12.53
19	Journal of Perianesthesia Nursing	16	62	3.88
20	Pain Management Nursing	16	111	6.94

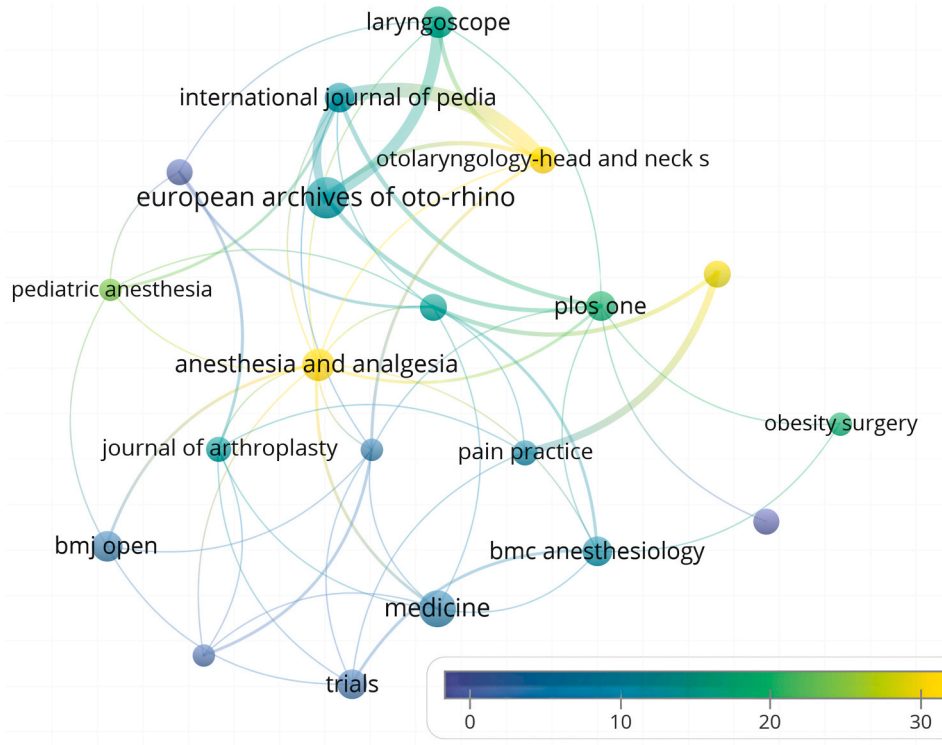


Fig. 6. The average citations per article in different disciplines. The color gradient from blue to yellow signifies the average citation count.

Table 6
Top 10 keywords by occurrences.

Rank number	Keyword	Occurrences
1	pain	491
2	surgery	386
3	postoperative pain	230
4	management	212
5	quality-of-life	197
6	sleep	183
7	depression	153
8	outcomes	145
9	children	138
10	quality of life	137
11	anxiety	135
12	prevalence	124
13	analgesia	120
14	obstructive sleep-apnea	118
15	impact	113
16	anesthesia	110
17	tonsillectomy	109
18	sleep quality	108
19	efficacy	107
20	quality	106

neighboring nodes including "fatigue", "depression" and "tonsillectomy". Articles with "surgery" as a keyword have shown no significant fluctuations, maintaining around 30 publications per year, with neighboring nodes such as "multimodal analgesia", "morphine" and "anxiety". Articles focusing on "postoperative pain" spiked in 2015, with other years maintaining around 15 publications per year, with neighboring nodes including "nerve injury", "neuropathic pain" and "randomized controlled trials".

4.2. Research topic trend analysis

Fig. 8a tracks the prominence of key topics from 2013 to 2023, with the duration of each topic's prevalence marked by the blue line.

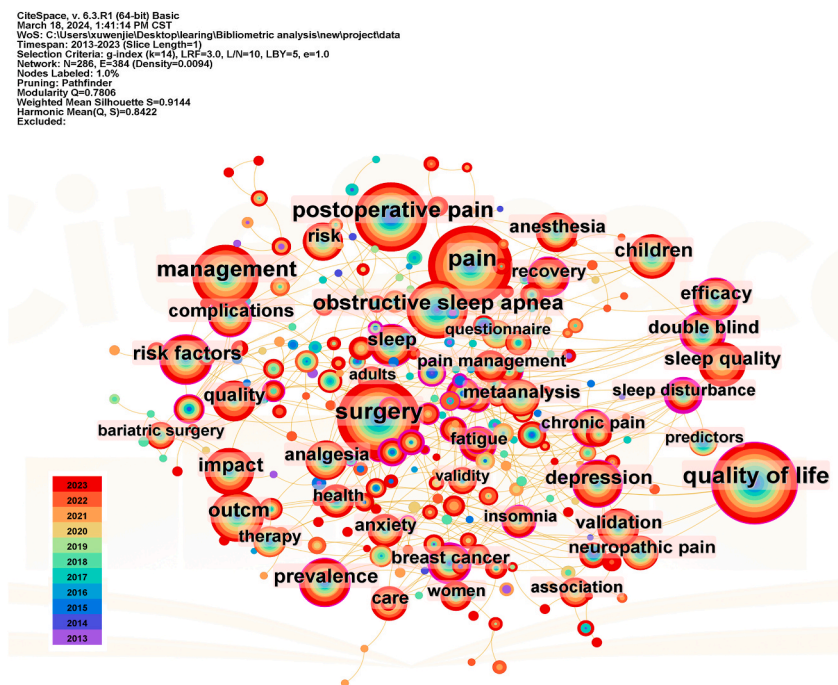


Fig. 7. Keyword co-occurrence knowledge map. The size of the dot represents the frequency of the keyword, and the color represents the publication of the keyword in different years.

The frequency of topic mentions is visually represented by the size of the circles. The high-frequency topic “pain” appeared from 2017 to 2022, “surgery” from 2016 to 2021, “postoperative pain” from 2015 to 2021, “management” from 2017 to 2022, “quality of life” from 2016 to 2022, and “impact” from 2017 to 2022. Interestingly, we found that the hotspots in the past decade also included specific surgeries including “volumetric tissue reduction” (2014), “abdominal surgery” (2015), “pediatric tonsillectomy” (2015), “adenoidectomy” (2016), and drugs including “morphine” (2017) and “ketamine” (2022). The recent hotspots included “version”, “information” and “repair”.

Fig. 8b shows the thematic progression in perioperative pain and sleep disorder research. Three distinct phases were categorized by keyword evolution: 2013–2017, 2018–2020, and 2021–2023. During 2013–2017, the major themes included “pain”, “obstructive sleep apnea”, “treatment”, “postoperative pain”, “spinal cord stimulation”, “bispectral index”, “obesity” and “postoperative analgesia.” During 2018–2020, new thematic keywords comprised “quality of life”, “sleep quality”, “breast cancer”, “delirium”, “tonsillectomy”, “patient-reported outcomes”, “patient satisfaction”, “one-lung ventilation”, “actigraphy”, “naloxone”, “chronic postsurgical pain”, “adolescent”, “hip fracture” and “Roux-en-Y gastric bypass”, highlighting a gradual specialization within the field and the distinction of specific surgical procedures as research foci. From 2021 to 2023, new thematic keywords were added including “failed back surgery syndrome”, “general anesthesia”, “colorectal cancer”, “neuropathic pain”, “bariatric surgery”, “dexmedetomidine”, “inflammation”, “lung cancer”, “coblation”, “total knee arthroplasty” and “functional recovery”. It is notable that “inflammation” is the only term that involves mechanism. As research on the association between postoperative pain and sleep disorders deepens, inflammation is increasingly recognized as the mechanism most involved in the vicious cycle, indicating that inflammation could be a potential link between postoperative pain and sleep disorders. In addition, “spinal cord stimulation” is involved in the first two periods and is considered to be related to “failed back surgery syndrome” in the third period. This is a treatment for chronic pain, which also improves the quality of sleep by sending electrical signals to the spinal cord. This suggests that the spinal cord may be involved in the correlation between postoperative pain and sleep disorders.

Fig. 9 shows the degree of development(density) and relevance (centrality) of the identified topics (keywords), which have been categorized into four quadrants. The hot topics located in the upper right quadrant (motor themes), included “obstructive sleep apnea”, “tonsillectomy”, “children”, “pain”, “quality of life” and “sleep”. Topics located in the upper left quadrant (niche themes) were strongly developed but still with a marginal position in the domain, including “general anesthesia”, “propofol”, “sevoflurane”, and other 5 keywords. The peripheral topics located in the lower left quadrant (emerging themes) included “spinal cord stimulation”, “failed back surgery syndrome”, “back pain” and other 3 keywords. Topics located in the lower right quadrant (basic themes) included post-operative “pain”, “analgesia” and “dexmedetomidine”, “breast cancer”, “fatigue” and “lung cancer”, which presents untapped research potential in this field.

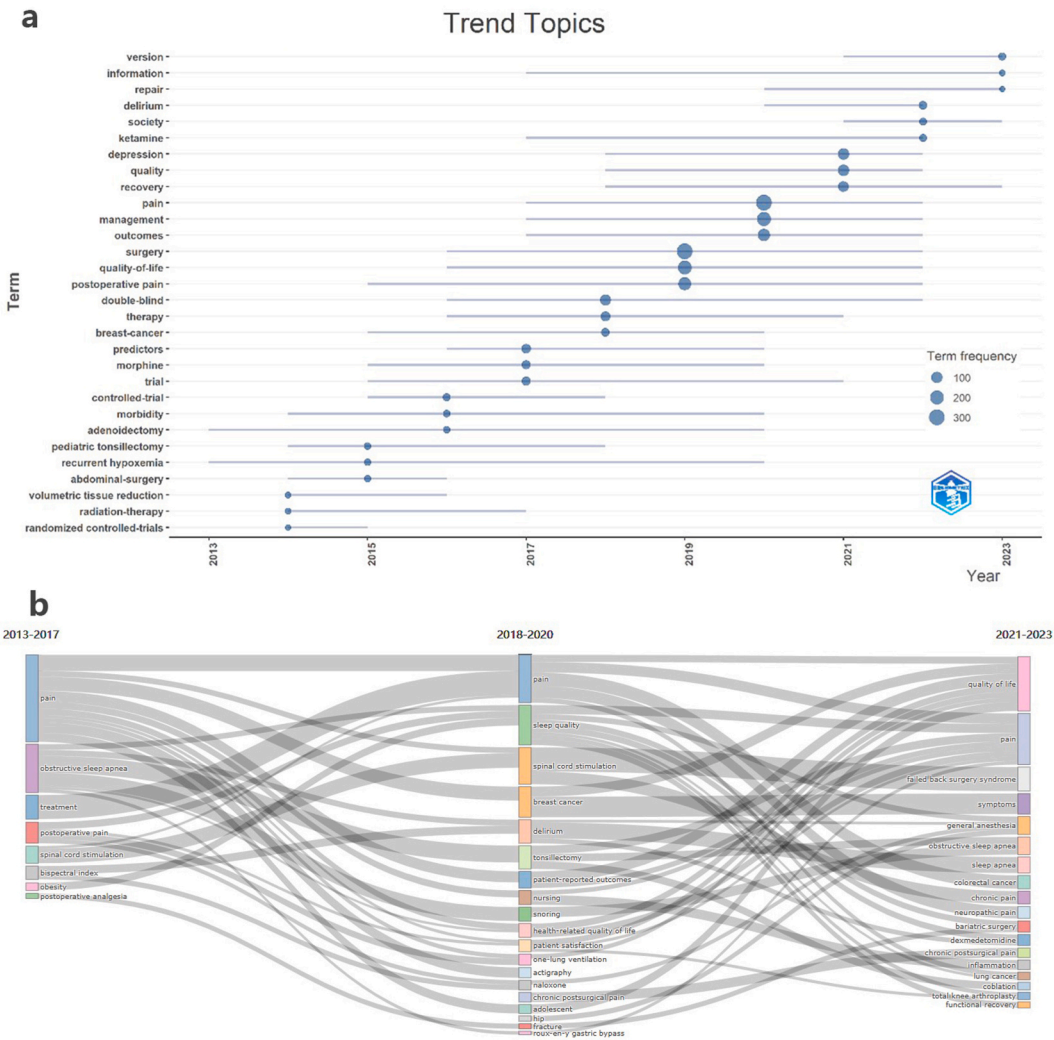


Fig. 8. (a) Trend topics of keywords in postoperative pain-sleep disorders. (b) Thematic evolution of the three stages in the field of postoperative pain-sleep field.

5. Discussion

The bidirectional relationship between pain and sleep in the context of postoperative care, as revealed by our bibliometric analysis, highlights a critical area of patient recovery and holistic healing that requires further attention. This study maps the evolving landscape of research on postoperative pain and sleep disorders, highlighting the increasing recognition of their intertwined nature and the need for integrated management approaches in clinical practice. By examining the contributions and trends across authors, institutions, and countries, we have identified a positive upward trend in scholarly engagement, reflecting a broader shift towards addressing these intertwined issues as central to improving patient outcomes. This bibliometric analysis was conducted to reveal the current status and development trends of postoperative pain-sleep disorders studies in terms of authors, institutions, journals, countries, documents, and keywords. The literature in this field has been continuously increasing, indicating a rapid development and an overall positive upward trend. Possible reasons include: 1) With the global population aging, the co-occurrence of postoperative pain-sleep disorders has been increasingly recognized. This has led to a growing concern among healthcare professionals and researchers due to the associated risks, such as cardiovascular events and postoperative delirium [17]. 2) In recent years, comfort-oriented care has gained widespread popularity worldwide. Concepts such as ERAS and patient-centered care have become new trends in medical development [18]. The vicious cycle of post-operative pain and sleep disorders, as a significant factor contributing to decreased patient satisfaction, has naturally become a crucial aspect that needs to be addressed [19].

From the country contact map for co-published articles (Fig. 2), we can observe a more accurate representation of research disparities and geographical distribution in the field of postoperative pain and sleep disorders studies across the USA, Europe, and China. Over the past decade, the USA has maintained a relatively stable publication output, leading with a significant margin of 620 articles

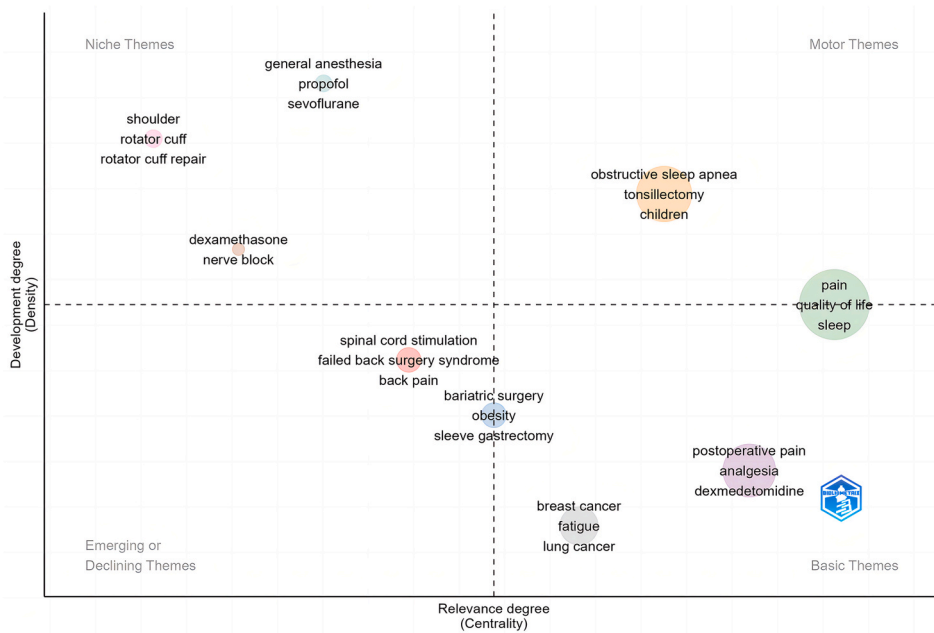


Fig. 9. Thematic map of keywords in postoperative pain-sleep disorders.

with the highest influence in the field. China has shown a noticeable increase in publication output, with a fifteen-fold increase from 2013 to 2022 (7–105), due to the comprehensive establishment of a healthcare service system with Chinese characteristics, focusing on postoperative comfort-oriented care [20]. The increasing frequency of academic exchanges between countries and regions has fostered a positive and continuous development in the field of postoperative pain and sleep disorders. Such exchanges and collaborations enhance the advancement of research and practice related to sleep during the postoperative period. The sharing of ideas, methods, and findings among researchers from different countries and regions has contributed to the improvement of postoperative pain-sleep disorders studies.

5.1. The hotspots for postoperative pain-sleep disorders study

In bibliometrics, keywords serve as indicators of the core themes of publications and the development of hot topics [21], the frequency and changes in keywords can also reflect the trends and dynamics of research areas [22]. Through keyword analysis, it can be seen that not only neuropathic headache, chronic pain, depression, and other complications caused by postoperative pain are important factors leading to sleep disorders, but also drugs used for the treatment of postoperative pain (such as morphine, ketamine) will also lead to sleep disorders. The possible mechanisms include: 1) Opioid-mediated central nervous system inhibition disrupts the normal sleep cycle, leading to alterations in sleep structure [23]. 2) High doses or prolonged use of opioids can induce sleep-related breathing disorders, particularly in patients with obstructive sleep apnea syndrome [24]. Furthermore, there is a body of research positing that significant sleep deficits may attenuate the efficacy of central pain modulation pathways, resulting in increased pain perception. This modulation is thought to be associated with neuroimmune modulatory processes, neural pathways, and endocrine system activities [25]. Additionally, the stress response triggered by sleep disorder may provoke dysfunction within the hypothalamic-pituitary-adrenal axis, subsequently diminishing the anti-inflammatory effects of cortisol [26]. Such lesions may lead to a decreased pain threshold, impede postoperative recuperation, and foster the development of chronic, recurrent pain syndromes. These results also indicate that the focus on sleep disorders has shifted from reduced sleep duration and sleep deprivation to circadian rhythm disorders and a decline in sleep quality. This change indicates that the prevalence of sleep disorders might be higher than anticipated and could have a greater impact. The keywords "obesity", "children", and "women", frequently appearing and centrally positioned in the research literature, are also considered to be predisposing factors that could lead to heightened pain sensitivity. These factors are indicators of increased vulnerability to pain sensitization [27–29].

In recent years, the variation of keywords also indicates ongoing innovation and reform in the treatment of postoperative pain and sleep disorders. On one hand, non-pharmacological interventions, such as preoperative music therapy and the application of anesthesia outpatient clinics, have been shown to potentially ameliorate preoperative anxiety and stress [30,31]. On other hand, non-opioid medications, such as melatonin and dexmedetomidine, have emerged as alternatives to reduce the use of opioids while improving pain and sleep management [32,33]. These keywords burst detection are useful methods to understand the evolving dynamics of postoperative pain-sleep disorder studies, reflecting a shift from these issues as separate entities to integrating them into a cohesive whole. This evolution also highlights a growing focus on the link between postoperative sleep disorders, pain sensitization, and the occurrence of postoperative neuroinflammation [34,35]. Consequently, therapeutic interventions are increasingly being

associated with the mitigation of neuroinflammatory responses. This action helps to suppress postoperative stress-induced reactive neuroinflammation, thereby alleviating pain sensitization. This transition in research focus underscores the importance of understanding the relationship between sleep, pain, and neuroinflammation in the postoperative context and the potential for integrated therapeutic strategies.

The current research hotspots in this field mainly include "obstructive sleep apnea", "tonsillectomy", and "children", all of which are recognized as risk factors associated with postoperative pain and sleep disorders. However, as research has progressed, the high incidence rates of breast cancer and lung cancer have gradually attracted researchers' attention. Furthermore, dexmedetomidine is likely to become a focus of future research efforts owing to its beneficial effects on postoperative pain and sleep disorders. In addition, with the widespread use of ERAS, topics related to "postoperative analgesia" and improving patients' postoperative mental state are emerging as areas of interest [36].

There are several limitations in this study. Firstly, it is essential to note that the WOSCC retrieval data is limited to the articles indexed in the WOS database. Although the WOS database is considered one of the most reliable databases for bibliometric studies, there is still a possibility of missing certain articles [37]. Secondly, bibliometric analysis may not fully reflect the most current trends. For instance, some high-quality articles published recently may not yet have accumulated a high number of citations, but their citation count is likely to increase in the future. Thirdly, we did not further analyze the types of publications, whether they are articles, reviews, or other types. Although the analyze of keywords, including double-blind and controlled trials, suggest that clinical research in this field has been increasing in recent years, further classification of publications may help analyze the issue from different perspectives, particularly to guide changes in management strategies. Finally, the association between postoperative pain and sleep disorders, which is mainly based on big data literature and keyword transition analysis, needs further substantiated by more convincing clinical studies and animal experiments. This approach is essential to deepen our understanding and provide empirical evidence for the observed correlations, thereby enhancing the validity and applicability of the findings in clinical practice.

6. Conclusion

The increasing number of publications on postoperative pain and sleep disorders, with a significant increase in cross-study articles, underscores a growing interest in this theme. Current research hotspots revolve around "obstructive sleep apnea", "tonsillectomy", "children", indicating potential avenues for new research directions. Moreover, the aspects of "breast cancer", "lung cancer", "dexmedetomidine", and "fatigue" represent untapped research potential in this field. In summary, this study uses visual analysis to predict future research trends in postoperative sleep disorders, providing valuable insights into the frontiers and hotspots of the field.

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Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Data availability statement

All data generated or analyzed during this study are included in this published article and its additional information files. The dataset generated and analyzed during the current study is available from the corresponding author upon reasonable request.

CRedit authorship contribution statement

Wenjie Xu: Writing – original draft, Software, Data curation, Conceptualization. **Yuxiang Zheng:** Formal analysis, Conceptualization. **Zizheng Suo:** Visualization, Software. **Yafan Yang:** Visualization, Data curation. **Jing Yang:** Visualization, Data curation.

Qing Wang: Visualization, Data curation. **Bowen Zhou:** Writing – review & editing, Formal analysis, Conceptualization. **Cheng Ni:** Writing – review & editing, Supervision, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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