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Global Research Trends on Sleep Quality in Chronic Kidney Disease: A Comprehensive Bibliometric and SWOT Analysis

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ABSTRACT

Background: Sleep disturbances are increasingly recognized as clinically significant complications across all stages of chronic kidney disease (CKD), yet the global research landscape remains heterogeneous and insufficiently mapped. This study provides a comprehensive bibliometric and SWOT analysis to evaluate worldwide research trends, thematic structures, and strategic gaps in the literature on sleep quality in CKD.

Materials and Methods: A bibliometric search of the Web of Science Core Collection (1 January 2020–10 February 2023) identified 149 publications addressing sleep quality in CKD. VOSviewer was used to visualize keyword co-occurrence patterns, authorship and country collaboration networks, and thematic clusters. Temporal publication trends were assessed through linear regression. A SWOT framework was applied to contextualize strengths, weaknesses, opportunities, and threats within the research field.

Results: Four major clusters were identified: hemodialysis–psychosocial burden, chronic renal failure–sleep quality, pre-dialysis sleep disorders, and estimated glomerular filtration rate–sleep disturbance. Hemodialysis-centered research formed the densest and most cited cluster, whereas early-stage CKD and objective sleep assessments (e.g., polysomnography, actigraphy) were notably underrepresented. Country-level mapping revealed substantial geographic variability, with China, the United States, and Türkiye leading in output, while Canada, Italy, and Sweden demonstrated high collaboration strength. Forecasting models showed a sustained upward trajectory in global publication volume through 2030. SWOT analysis highlighted a well-established but unevenly distributed research base, methodological variability, and clear opportunities for standardized, longitudinal, and mechanistic studies.

Conclusion: Global research activity on sleep quality in CKD is expanding, yet critical gaps persist—particularly in early CKD populations, objective sleep measurement, and multinational collaboration. Addressing these limitations will be essential for developing robust evidence frameworks and improving clinical management of sleep disturbances across the CKD continuum.

Keywords: Chronic kidney disease, sleep quality, hemodialysis, bibliometric analysis, SWOT analysis

Introduction

Chronic kidney disease (CKD) is defined by a sustained reduction in glomerular filtration rate (GFR) or other markers of kidney damage persisting for at least three months and represents a major global public health challenge, with prevalence estimates ranging from 8.5% to 9.8% worldwide.[1-3] As renal function declines, patients experience a wide spectrum of systemic complications that contribute to substantial morbidity,

mortality, and healthcare burden.[2,3] Among these complications, sleep disturbances have emerged as highly prevalent yet frequently underrecognized contributors to impaired quality of life and adverse clinical outcomes in the CKD population.[4–7]

Sleep disorders occur across all stages of CKD, including the early phases of kidney dysfunction where objective polysomnographic studies have demonstrated reduced sleep efficiency, increased periodic limb movements, and a higher use of hypnotic agents compared with individuals with normal renal function.[6,8,9] In end-stage renal disease (ESRD), the burden is even greater: between 45% and 80% of hemodialysis patients report clinically significant sleep problems, including insomnia, restless legs syndrome (RLS), sleep-disordered breathing, nocturnal pruritus, and fragmented sleep architecture.[4,10,11] These disturbances are closely interrelated with CKD-specific symptoms such as fatigue, depression, pain, and pruritus—each independently associated with impaired sleep quality and diminished health-related quality of life.[5,11–16] Moreover, sleep abnormalities may influence CKD pathophysiology through mechanisms involving inflammation, sympathetic activation, metabolic dysregulation, and circadian disruption, potentially accelerating disease progression and elevating cardiovascular risk.[7,10,17]

Dialysis modality also plays a significant role in sleep outcomes.[10,18] While conventional hemodialysis is strongly associated with sleep fragmentation, periodic limb movements, and reduced sleep efficiency, peritoneal dialysis may promote better sleep quality in selected populations, and kidney transplantation appears to partially restore sleep parameters, although sleep disorders remain more common than in the general population.[4,10,15,18] Intensive hemodialysis schedules and targeted therapies, including recombinant human erythropoietin and difelikefalin, have demonstrated improvements in sleep-related parameters in randomized and observational studies, yet the overall evidence base for sleep-focused interventions remains limited, heterogeneous, and frequently of low certainty.[19–22] This underscores the need for more rigorous, standardized research aimed at understanding and managing sleep disturbances in CKD.

Despite the clinical importance of sleep disturbances in CKD, research in this area remains fragmented, variably distributed across countries, and lacking in methodological consistency—particularly with respect to objective sleep assessment tools, intervention trials, and longitudinal outcomes.[22] Bibliometric analysis provides a valuable approach for mapping the scientific landscape, identifying research clusters, quantifying scholarly influence, and highlighting gaps in knowledge.[23,24] When integrated with a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, bibliometric mapping enables a strategic evaluation of the field, offering deeper insight into existing evidence, unmet needs, and future directions.

Accordingly, the present study aims to conduct a comprehensive global bibliometric assessment of the literature on sleep quality in chronic kidney disease and to complement these findings with a SWOT analysis. This combined approach seeks to delineate research trends, synthesize thematic patterns, and identify both the opportunities and challenges that shape this evolving domain.

Materials and Methods

A bibliometric search was conducted in the Web of Science (WoS) Core Collection database on 10 February 2023. The search strategy used the terms “Sleep Quality” AND “Kidney” in the Topics Search, without applying language or document-type restrictions. Publications indexed between 1 January 2020 and 10 February 2023 were included. All retrieved records were exported in full-record and cited-reference format. Quantitative indicators such as annual publication counts, citation numbers, and the distribution of publications across authors, institutions, and countries were examined to characterize the research activity in this field.

Bibliometric maps were generated using VOSviewer software (version 1.6.17; Centre for Science and Technology Studies, Leiden University). VOSviewer was used to visualize keyword co-occurrence patterns, authorship networks, citation relationships, and thematic clusters. The association strength normalization method was applied for all network visualizations. Default thresholds for keyword frequencies and citation counts were used unless otherwise specified.

Statistical Analysis

Statistical analyses focused on evaluating temporal trends in publication output between 2020 and 2023. Annual publication counts were summarized descriptively and assessed using simple linear regression to examine whether research activity demonstrated a statistically significant upward or downward trend over time. Model assumptions, including linearity and homoscedasticity, were verified using standard diagnostic plots. All statistical analyses were performed using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA). A two-sided p-value < 0.05 was considered statistically significant. No imputation or additional adjustments were required, as bibliometric metadata were complete for the variables analyzed.

Results

Keyword and Cluster Analysis

A total of 149 publications indexed between 2020 and 2023 were analyzed to characterize global research activity on sleep quality in the context of chronic kidney disease. Analysis of the keyword co-occurrence network demonstrated that the most frequently used and highly connected concepts in the literature were “sleep quality” (occurrence: 33; total link strength: 118), “hemodialysis” (23; 102), “chronic kidney disease” (22; 93), “depression” (17; 66), and “quality of life” (16; 71). These keywords formed the structural core of the research field, with “chronic kidney disease” and “sleep quality” emerging as the central nodes of the bibliometric map, reflecting their dominant conceptual influence (Figure 1). In the co-occurrence map, the term chronic renal failure appears as the central node; however, this reflects a controlled vocabulary adjustment applied through the VOSviewer thesaurus file, in which all related expressions (including ‘CKD’ and ‘chronic kidney disease’) were standardized under a single unified label to ensure terminological consistency across the dataset. Additional frequently occurring terms included “sleep” (13; 58), and “sleep disturbance” (6; 20).

The first cluster encompassed terms predominantly related to hemodialysis and psychosocial dimensions of CKD, including hemodialysis, depression, quality of life, and sleep. The relatively high link strengths of hemodialysis (102) and quality of life (71) highlight the density of research addressing sleep-related symptoms among hemodialysis patients, as well as their psychosocial correlates. The second cluster represented the conceptual foundation of CKD–sleep research, linking chronic renal failure with sleep quality, sleep duration, and systematic reviews; this grouping reflects a core research domain centered on the clinical and physiological dimensions of sleep disturbances in CKD. The third cluster included pre-dialysis and sleep disorders, indicating that sleep disturbances have been studied not only in advanced disease but also in earlier stages of renal impairment. The fourth and smallest cluster contained estimated glomerular filtration rate and sleep disturbance, suggesting an emerging line of inquiry examining the relationship between objective renal function markers and specific sleep parameters.

Across the network, frequent co-linkage between hemodialysis and quality of life was apparent through visibly stronger and thicker connecting lines, consistent with their high co-occurrence metrics. Depression exhibited multiple connections with both sleep and sleep disorders, reflecting its recurring presence across clusters. Spatial proximity within the map corroborated these patterns, illustrating the interconnected nature of psychological, clinical, and treatment-related factors in CKD-related sleep research (Figure 1).

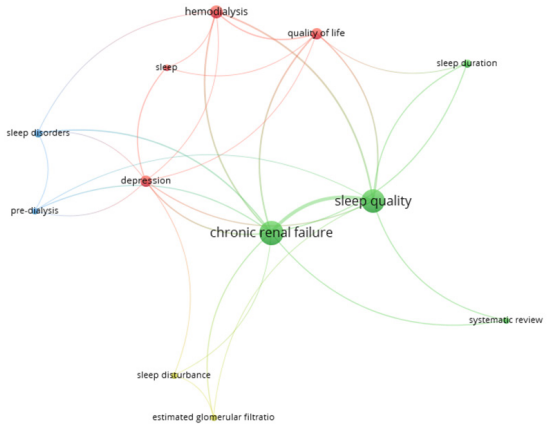

Figure 1. Keyword Co-occurrence Network Map of Publications on Sleep Quality and Chronic Kidney Disease

Country-Level Productivity and Collaboration

A total of 44 countries contributed to the global literature during the study period, with 18 countries producing four or more publications (Table 1). The collaboration network demonstrated extensive international engagement, with China, Türkiye, and the United States functioning as major hubs exhibiting broad cross-national linkages (Figure 2a). Density visualization further highlighted the United States and Canada as the most concentrated centers of activity, reflecting their combined strength in publication output and citation influence (Figure 2b).

Table 1. Productivity and Citation Metrics of the Most Active Countries

Country	Publication Count	Total Citations	Total Link Strength
China	13	45	5
USA	12	265	18
Türkiye	11	70	12
Canada	8	235	10
Italy	7	50	21
Sweden	6	40	21
Brazil	5	82	8
Iran	4	30	3

China ranked first in publication volume (n=13), followed closely by the United States (n=12) and Türkiye (n=11). Canada produced fewer publications (n=8) but displayed a disproportionately high citation count (235 citations), nearly matching that of the United States (265 citations), indicating substantial scientific influence relative to output. Italy and Sweden demonstrated the highest total link strengths (both 21), suggesting robust international collaboration and strong inte-

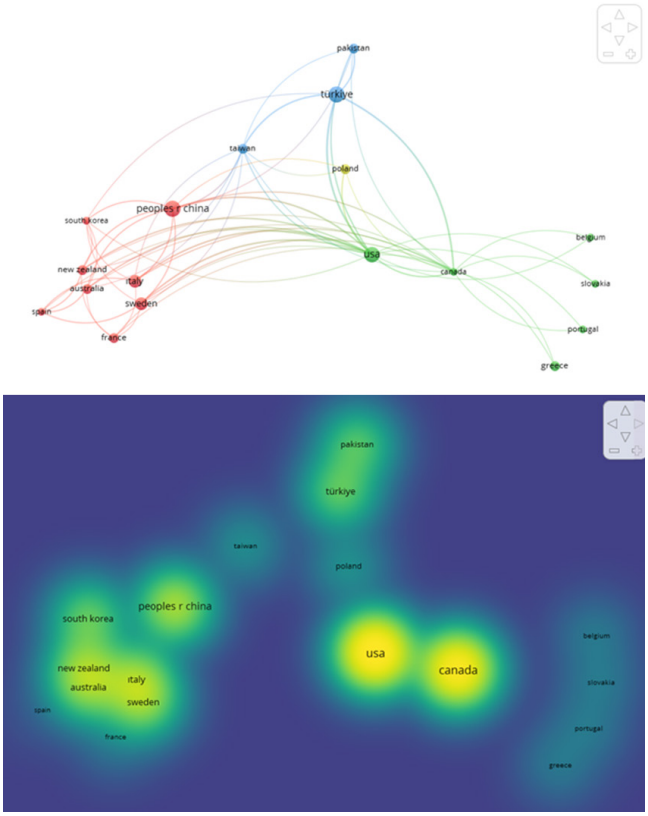

Figure 2. International Collaboration Network and Citation Density Mapping of Countries Contributing to Research on Sleep Quality and Chronic Kidney Disease

gration within the global research network despite producing comparatively fewer publications.

The structural topology of the collaboration map positioned the United States as the primary global connector, with prominent ties to Canada, Türkiye, and several European nations. China formed a dense subnetwork characterized by collaborations with East Asian and Southern European countries, including South Korea, Italy, and Sweden. Türkiye occupied an important intermediary position, acting as a bridge between regions through its linkages with Pakistan, Taiwan, and Poland. This arrangement highlights a globally distributed yet interconnected research environment, characterized by both regional clusters and influential central hubs.

Global Publication Trends and Future Forecast

The temporal analysis of global research output demonstrated a consistent upward trajectory in publications addressing sleep quality in the context of chronic kidney disease. Annual publication counts increased steadily from 27–34 articles in 2017–2019 to 38 in 2020, followed by continued growth through 2021 (51), 2022 (46), and 2023 (55). Forecasting based on exponential and cubic models indicated further expansion of scientific activity in the upcoming years, with projected counts of 65 publications in 2024 and 67 in 2025. The model estimated 103 publications for 2026 (95% CI: 42.7–248.9) and a substantial rise to 202 publications by 2030 (95% CI: 81.4–505.7), suggesting an accelerating research trend with wide confidence bounds reflecting increasing uncertainty over extended forecasting intervals. Collectively, these findings indicate that the scientific attention directed toward CKD-related sleep disturbances is not only sustained but expected to intensify, with a marked expansion in global research productivity over the coming decade (Figure 3).

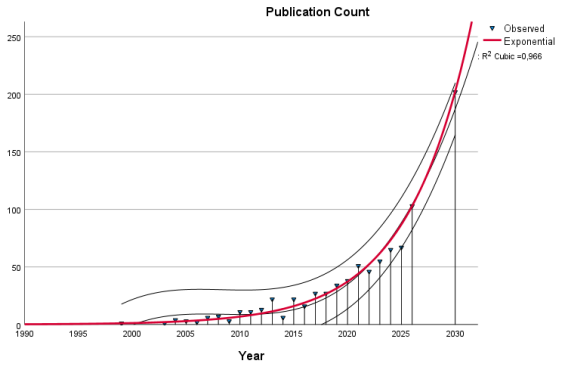

Figure 3. Global publication trends on sleep quality and chronic kidney disease (2010–2030), including observed annual outputs (2010–2023) and model-based forecasts with 95% confidence intervals (2024–2030).

Discussion

This bibliometric analysis provides a comprehensive overview of global research trends examining sleep quality in the context of chronic kidney disease. The findings highlight that interest in the interplay between CKD and sleep disturbances has grown steadily in recent years, reflecting increasing recognition of sleep quality as a clinically significant yet frequently overlooked dimension of CKD care. The predominance of the keywords “chronic renal failure” and “sleep quality” at the center of the co-occurrence network underscores the central role of sleep-related outcomes within nephrology research, particularly regarding their influence on physical and psychological well-being.

SWOT Analysis

The SWOT assessment provided a structured overview of the current research landscape concerning sleep quality in individuals with chronic kidney disease (Table 2).

Strengths

The field demonstrates a mature and well-established research core supported by substantial bibliometric density. Across 149 publications from 44 countries, high-frequency keywords such as sleep quality (33 occurrences; total link strength 118), hemodialysis (23; TLS 102), chronic kidney disease (22; TLS 93), and depression (17; TLS 66) dominate the conceptual landscape, indicating consistent scientific engagement with these

themes. The clustering structure further shows that research involving hemodialysis patients constitutes the largest and densest thematic group, benefitting from abundant citation linkages and strong inter-keyword connectivity. Countries with the highest research output include China (n=13), the United States (n=12), and Türkiye (n=11), while the United States (265 citations) and Canada (235 citations) show the strongest global citation impact. These metrics collectively demonstrate both the breadth and depth of existing literature, confirming sleep quality as an increasingly recognized and clinically relevant dimension of CKD research.

Weaknesses

Despite the overall richness of the dataset, several measurable gaps persist. Keywords associated with early-stage CKD—such as pre-dialysis and sleep disorders—appear infrequently and show comparatively lower total link strength, indicating limited focus on these populations. Only 18 of the 44 contributing countries produced four or more publications, suggesting that global research activity remains unevenly distributed. The presence of smaller, low-connectivity clusters (e.g., eGFR and sleep disturbance) reflects insufficient integration of objective renal markers or standardized sleep assessment methods. The dominance of subjective terms such as sleep quality, fatigue, and mental health, combined with the absence of high-frequency objective sleep terms (e.g., polysomnography, actigraphy), implies limited use of validated quantitative tools across the dataset. Together, these patterns highlight restricted methodological diversity, insufficient coverage of pre-dialysis populations, and a likely predominance of small, cross-sectional studies.

Opportunities

Emerging bibliometric patterns suggest clear prospects for scientific advancement. The presence of terms such as systematic review, sleep duration, and restless legs syndrome with moderate frequencies (9–13 occurrences) indicates expanding thematic directions, particularly toward integrative symptom clusters and long-term physiological outcomes. The temporal distribution of the dataset (2020–2023) reflects consistent annual publication activity, implying continuing academic interest. Countries such as Italy and Sweden, despite having moderate publication counts (n=7 and n=6), demonstrate high total link strength (both 21), positioning them as structurally influential collaborators and indicating readiness for multinational cohort studies. The growing density of connections between sleep-related keywords (sleep quality, sleep duration, sleep disturbance) and CKD-related constructs (eGFR, chronic renal failure, quality of life) suggests opportunities for refined mechanistic research addressing cardiovascular risk, mortality, inflammation, and patient-centered outcomes. The current bibliometric landscape therefore supports the development of standardized longitudinal research frameworks and multicenter trials.

Threats

Several identifiable challenges pose potential barriers to future progress. The dispersion of sleep-related terminology across multiple small clusters, combined with uneven co-occurrence patterns, reflects substantial methodological heterogeneity within the field. The lack of high-frequency objective sleep keywords indicates that most studies rely on subjective instruments such as the Pittsburgh Sleep Quality Index, suggesting limited comparability across publications. Furthermore, the uneven geographic distribution of research—with only a minority of countries contributing more than four publications—may reduce the generalizability of findings and exacerbate population-level biases. The tight linkage of sleep-related keywords with multifactorial constructs such as depression, quality of life, and fatigue highlights the complexity of establishing causality in a domain heavily influenced by psychological, social, and treatment-related factors. These

Table 2. SWOT Analysis Table

Category	Summary of Key Findings
Strengths	A substantial and internationally distributed body of literature (149 publications from 44 countries) centers on strong conceptual anchors such as sleep quality, hemodialysis, and chronic kidney disease. Hemodialysis-related sleep research forms the densest and most methodologically developed cluster, supported by high citation activity from leading contributors (e.g., United States: 265 Canada: 235 citations).
Weaknesses	Early-stage CKD and pre-dialysis populations remain underrepresented, reflected by low-frequency, low-link-strength keywords and small peripheral clusters. Objective sleep assessments are rarely used, with minimal representation of polysomnography or actigraphy. Methodological variation across studies and inconsistent use of standardized tools limit cross-study comparability and hinder synthesis.
Opportunities	Expanding themes such as sleep duration, restless legs syndrome, and integrative symptom clusters indicate growing diversification. Strong collaborative potential exists in countries with high link strength but modest publication output (e.g., Italy and Sweden). Increasing annual publication activity (2020–2023) supports feasibility for future multicenter cohort studies and deeper exploration of cardiovascular, inflammatory, and mortality-related pathways.
Threats	Heterogeneous terminology, inconsistent assessment methods, and reliance on subjective tools create structural barriers to standardization. Uneven geographic distribution may introduce population biases. The multifactorial nature of sleep disturbances in CKD—spanning psychological, physiological, and treatment-related domains—complicates causal inference and risks fragmentation of future research trajectories.

structural constraints may impede the development of standardized outcome measures and complicate attempts to synthesize data across diverse study designs.

Overview of Bibliometric Trends

The clustering patterns observed in this study reveal distinct thematic research domains. The first cluster, which encompasses hemodialysis, depression, quality of life, and sleep, aligns with established evidence suggesting that hemodialysis patients exhibit some of the highest rates of sleep disruption among individuals with CKD.[4,10,18] This may be attributed to the cumulative burden of uremic toxins, metabolic derangements, fluid shifts, and treatment-related stress, all of which adversely affect sleep architecture.[4,10] The strong association between "hemodialysis" and "quality of life" within the network further reinforces the multidimensional impact of sleep problems in this population. Poor sleep quality has been linked to increased fatigue, diminished treatment adherence, and impaired psychosocial functioning, thereby contributing to the already complex morbidity profile of ESRD patients.[5,11,13,14]

The second and largest cluster, dominated by chronic renal failure and sleep quality, reflects the foundational research direction aimed at characterizing the extent and nature of sleep disturbances across CKD stages.[5–7,9,17] Notably, the presence of "systematic review" within this cluster suggests that synthesizing and consolidating evidence on sleep disorders in CKD has become an emerging priority. This indicates a maturing research field that is advancing beyond isolated observational studies toward broader theoretical and clinical frameworks.

The third cluster, comprising pre-dialysis and sleep disorders, highlights an important but understudied area: sleep disruption in earlier CKD stages. Although this study shows that these concepts are linked, the relatively limited number of publications in this domain suggests that early identification and management of sleep problems remain insufficiently addressed.[4,6–9] This represents a clinically meaningful gap, as sleep disturbances may precede overt renal deterioration and contribute to downstream neurocognitive, cardiovascular, and metabolic complications.

The fourth cluster links estimated glomerular filtration rate with sleep disturbance, reflecting a growing interest in integrating objective renal function indices with sleep-related outcomes. While preliminary research has demonstrated associations between lower GFR and poorer sleep metrics, these relationships are complex and may be influenced by inflammatory pathways, autonomic dysfunction, and comorbidities such as diabetes or heart failure.[6,8,9,25] The scarcity of studies in this domain underscores the need for methodologically rigorous investigations using standardized sleep assessment tools, including actigraphy and polysomnography.

Global Collaboration Patterns

The country-level analysis reveals substantial geographical variability in research productivity and citation impact. The United States and Canada distinguish themselves with high citation counts, indicating strong international visibility and influence. In contrast, China and Türkiye demonstrate high publication output but lower collaboration strength, suggesting that expanding international partnerships may enhance global integration and research impact. European countries such as Italy and Sweden exhibit high connection strength despite modest publication volume, reflecting strong engagement in collaborative, multinational research networks. These patterns collectively point to a research landscape that is expanding but remains unevenly distributed across regions.

Methodological Gaps and Limitations in the Literature

This study also identifies notable gaps within the existing literature. Research examining the interaction between sleep quality and psychological parameters such as depression appears limited, despite evidence that depressive symptoms are highly prevalent in CKD and intricately linked with sleep physiology.[5,13,15,16] Additionally, the variability in renal replacement therapy modalities and their differential effects on sleep appear to be acknowledged but not comprehensively explored.[10,18,21] The relative scarcity of longitudinal or intervention-based studies further restricts the ability to establish temporal or causal relationships between declining kidney function and sleep impairment.[22]

Sleep disturbances in pre-dialysis CKD may represent an early, modifiable risk marker for adverse cardiovascular and metabolic outcomes. Identifying and managing sleep disorders at earlier disease stages could offer opportunities to mitigate symptom burden, delay disease progression, and improve long-term quality of life before irreversible renal decline occurs. The relative scarcity of research in this population therefore represents not only a bibliometric gap but also a clinically meaningful limitation in current nephrology practice.

The incorporation of SWOT analysis offers additional insight into the structural characteristics of this research field. Strengths include a solid body of evidence focusing on hemodialysis patients and increasing recognition of sleep quality as a vital component of CKD management. However, weaknesses such as small sample sizes, limited research in pre-dialysis populations, and inconsistent sleep assessment methods hinder the development of unified clinical guidelines. Opportuni-

ties exist for research exploring mechanistic pathways linking sleep quality to cardiovascular outcomes, inflammation, and mortality—areas with significant potential for advancing patient care. Conversely, threats include the multifactorial nature of sleep disturbances, which complicates causal inference, and the lack of standardized, objective sleep measurement tools specific to CKD populations.

Overall, this bibliometric analysis demonstrates that sleep quality has emerged as an important research focus in nephrology, yet several key areas remain underdeveloped. Expanding collaborative networks, enhancing methodological rigor, incorporating objective sleep assessments, and prioritizing understudied patient groups such as pre-dialysis populations will be critical for advancing the field. Addressing these gaps may ultimately contribute to a more nuanced understanding of sleep disturbances throughout the CKD continuum and inform targeted interventions aimed at improving patient outcomes.

Conclusion

This bibliometric analysis highlights sleep quality as an increasingly recognized yet still underdeveloped research domain within chronic kidney disease. While hemodialysis populations have been the primary focus of existing studies, thematic clustering reveals that sleep disturbances affect patients across all stages of CKD and intersect with psychological well-being, quality of life, and objective markers of renal function. Despite growing global interest, significant gaps persist, particularly regarding pre-dialysis populations, the use of standardized and objective sleep assessments, and the elucidation of mechanistic links between renal dysfunction and sleep impairment. The observed disparities in research productivity and collaboration further underscore the need for broader international engagement and methodologically robust, longitudinal investigations. Advancing research in this field has the potential to inform targeted interventions and ultimately improve clinical outcomes for individuals living with CKD.

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