

Emerging Trends and Conceptual Mapping in Network Pharmacology Research: A Bibliometric Analysis (2008-2023) Using VOSviewer

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ABSTRACT

Background: Network Pharmacology (NP) aims to understand drug actions and their interactions with multiple targets using computational methods. **Objectives:** This provides a network-based approach to comprehensively investigating the effects of drugs on complex biological systems. The main objective of this bibliometric analysis in NP research (NPR) is to gain insight into the impact of research, emerging trends, collaborations, and the overall research landscape. **Materials and Methods:** The study retrieved data from the Scopus database and employed advanced bibliometric techniques, including citation analysis, co-occurrence mapping, and trend detection using VOSviewer software. The analysis examined the annual publication trends, authorship patterns, collaborations, and the emergence of key research themes in NPR. **Results:** A total of 6,134 articles were extracted. NPR exhibited steady growth. China is the most productive and collaborative country. Five clusters of research themes were derived: mechanisms of action and molecular mechanisms, Traditional Chinese Medicine (TCM) and herbal compounds, disease-specific research, inflammation and immune-related research, and validation and simulation. In NPR, molecular docking, apoptosis, the cell cycle, ulcerative colitis, and sepsis are trending topics. **Conclusion:** The study revealed an increase in the production of NPR and its conceptual structures. It lays the foundation for advancing knowledge of what has been published and possible areas for improvement in NPR.

Keywords: Network pharmacology, Performance, Themes clustering, Bibliometrics, VOSviewer.

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INTRODUCTION

The process of discovering new drugs initially involved randomly searching for therapeutic agents in plants, animals, and minerals. Later, classical pharmacology emerged, focusing on testing the effects of small molecules on cells or organisms. The advent of human genome sequencing led to the discovery of target-based drugs, in which specific proteins are identified as targets for

therapeutic intervention. This approach involves screening small molecules for their impact on the target's function and making modifications to enhance their interactions. However, this one-drug/one-target approach has limitations in terms of side effects and addressing complex diseases.¹⁻⁶

The revolution in information technology transforms the drug discovery process. The genomic technologies and computational power are used to predict drug properties and simulate interactions between molecules and proteins.^{1,7,8} This led to a decline in the magic bullet approach, which aimed at particular drugs, and a shift toward exploring natural products with their diverse chemical composition and safety profile. While bioactive substances from traditional medicine sources act on several targets, the current focus of drug development is on the synthesis



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of mono-targeted molecules.^{9,10} There is currently a push to combine traditional knowledge with cutting edge technologies, realizing the need of addressing several goals and attaining holistic management.¹¹⁻¹³

Drug, target, and disease interactions at the network level are understood through the multidisciplinary subject of Network Pharmacology (NP), which incorporates concepts from pharmacology, systems biology, and network science. Through the construction and analysis of biological networks, NP seeks to understand the mechanisms underlying medication action and pinpoint important nodes in the network that are essential to the processes of illness. Using this method, novel drug leads can be found, current medications can be repurposed, and therapeutic approaches can be optimized. Drug action may be predicted and the development of more efficient medications can be facilitated by NP's integration of computational techniques and data-driven methodologies. Researchers can also use the wisdom of traditional medicine to help target selection, find new drug scaffolds, and guide formulation development and repurposing techniques by integrating traditional knowledge with NP. Drug development, safety and effectiveness of drugs, and the gap between traditional and modern medicine may all be advanced by NPs.^{1,4,5,14-17}

Drugs examined with NP methods include selumetinib, dasatinib, tocilizumab, and ibrutinib.^{11,13,15,18} Targeting proteins in the MAPK/ERK signaling pathway, selumetinib is a treatment for metastatic melanoma.¹¹ Effectively treating chronic myeloid leukemia, dasatinib targets SRC and BCR-ABL kinases as a tyrosine kinase inhibitor.¹⁵ In inflammatory diseases including rheumatoid arthritis, tocilizumab controls the immune response by modifying the IL-6 receptor.¹⁵ Ibrutinib, used in B-cell malignancies, targets BTK in B-cell receptor signaling.¹⁸ These medications show how natural products offer understanding of intricate interactions, which facilitates the identification of therapeutic targets and the development of focused and efficient treatments.

NP has witnessed significant progress and trends in its incorporation into drug discovery,¹³ and bibliometric analysis is the most suitable method to assess and demonstrate this progress. Bibliometrics, introduced by Alan Pritchard in 1989, has gained attention due to advancements in evidence science, computer accessibility, internet availability, and specialized software such as VOSviewer, CiteSpace, and Biblioshiny.¹⁹⁻²¹ Scientific databases, such as Web of Science, Scopus, and PubMed, have facilitated bibliometric analyses, allowing the examination of contribution distribution, hotspots, and projected trends.^{20,22} VOSviewer, a bibliometric software, aids data analysis and visualization by generating co-occurrence network maps of coauthors, and keywords networks.²³ Although NPR has garnered global attention, more bibliometric studies in this area should be published. While other bibliometric studies have looked at NP research in certain domains such cancer therapy²⁴

and Traditional Chinese Medicine,²⁵ the present study attempts to completely investigate the NP research terrain in a broader, cross-disciplinary approach. This more general view can reveal fresh research possibilities and synergies that might have been missed in earlier domain-specific studies, therefore guiding strategic planning and cooperative opportunities to further the discipline of network pharmacology.

This study, conducted using Scopus databases and VOSviewer, aims to address this gap and provide a comprehensive analysis of the integrating NP research. The significance of this bibliometric analysis on NPR is multifaceted. It provides insight into the impact and progress of NPR, identifies hotspots and projected trends, facilitates the integration of research findings, addresses the need for more bibliometric studies in this field, and utilizes advanced bibliometric software for data analysis and visualization. This comprehensive study serves as a valuable resource for researchers, policymakers, and stakeholders in the field of NP.

MATERIALS AND METHODS

Study design and database selection

A bibliometric analysis was performed to examine the trends in the published literature on NP.^{19,20,26} The study used the Scopus database, which offers a wide coverage of more than 25,100 journals and access to 1.7 billion citations (<https://www.scopus.com/>).²² Scopus data were collected on 1 January 2024, and all retrievals were completed in a single day to mitigate the variations resulting from daily updates. The search strategy focused on retrieving original studies conducted in English without setting a specific time limit for included studies. The exact search string employed in the Scopus database was: TITLE-ABS-KEY ("network pharmacology") AND (EXCLUDE (PUBYEAR, 2024) OR EXCLUDE (PUBYEAR, 2025)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")), which yielded 6,314 documents. A broader search using "network pharmacology" without field tags or restrictions returned 9,706 documents. To ensure pertinent references were included, the references mentioned in the obtained papers were manually searched.

Inclusion and Exclusion Criteria

Original research published in English, indexed in the Scopus database, and studies on the theme of "Network Pharmacology" comprised the inclusion criteria for the bibliographic data. Studies not published in English, studies not connected to the theme of "Network Pharmacology," and review articles, editorials, letters, and other non-original research publications comprised the exclusion criteria.

Analysis

The bibliometric data were analyzed and shown using the data analysis and visualization program VOSviewer.²³ Coauthorship,

co-occurrence, and citation analyses were carried out.²³ While co-occurrence analysis finds how often terms appear together in the literature, co-authorship analysis looks at author collaboration patterns. Citation analysis looks at citations that publications have received. Links and Total Link Strength (TLS) are two often utilized weight qualities. These characteristics reveal details about the relationships amongst objects. The Links attribute represents the number of links that an item has with other items, while the TLS attribute indicates the overall strength of the links that an item has with other items.²³ Networks of co-occurrences of keywords have been studied.¹⁹⁻²¹ The idea of visualizing bibliometric networks, often referred to as 'science mapping', has received serious attention since the early days of bibliometric research. Visualization has turned out to be a powerful approach to analyze bibliometric networks of co-occurrence relations between keywords. Keywords were extracted from the author-supplied keyword list of a publication. The number of co-occurrences of two keywords is the number of publications in which both keywords occur together. Visualizing the network of keywords used by authors in NPR. The analysis comprises a total of 10,084 keywords and aims to categorize them into distinct clusters. The graphic omits the term "NP" in order to emphasize other pertinent NP terms. This visualization offers a succinct summary of the conceptual framework and connections between the author's keywords in NPR.^{19-21,23}

RESULTS

Annual Distribution and Growth Trend of Publications

A total of 6,134 documents were retrieved in NP. The first article was published in 2008;²⁷ since then, there has been a steady increase in the number of publications (Figure 1). Based on the data provided, it appears that there was a significant spike in the number of publications related to NP from 2018 to 2023, with the number of publications increasing from 119 in 2018 to 2,064 in 2023, representing a steep growth trend, and the percentage of publications also increasing from 1.88% in 2018 to 32.69% in 2023, indicating that NP-related research has become a much more prominent area of focus.

Global Distribution

Analysis of the articles recovered revealed contributions from 84 different countries. In particular, China had the highest volume of published manuscripts, totalling 5569. Following China, the United States contributed 242 articles, whereas India produced 231. Impressively, at least 30 countries published a minimum of ten articles each. In terms of the total percentage of published articles, the cumulative total for China, the United States, India, South Korea, Hong Kong, the United Kingdom and Saudi Arabia reached 88.81%. Interestingly, 18 countries had only one research paper to their name, while 11 countries had a modest output of two research papers each. China received the highest number

of citations (46,215), followed by the United States (3,437) and Hong Kong (1,737). Finland had the highest average citation per document (83.9). China also led in total link strength (1,584), with the United States (344) and Hong Kong (78) following behind.

The top productive institutions (Table 1) in NPR include Beijing University of Chinese Medicine (488 publications), Ministry of Education of the People's Republic of China (430 publications), Guangzhou University of Chinese Medicine (298 publications), China Academy of Chinese Medical Sciences (288 publications), Nanjing University of Traditional Chinese Medicine (244 publications) and Chengdu University of Traditional Chinese Medicine (241 publications). In NPR, 28,376 scholars have contributed. Prominent authors, based on document count, include Wu, J.,²⁸ Oh, K.K.,²⁷ Khanal, P.,²⁵ Xiao, W.,²⁵ and Qin, X.²³ (Table 1). The top cited scholars are Li, Shao (2326 citations), Zhang, Bo (1718 citations), Li, Yan (1229 citations), and Wang, Yonghua (1036 citations).

The most prolific scholar

Table 2 provides the key metrics for the top authors of the NPR. Wu Jiarui from China ranks first with 28 documents, 2,341 total citations, and an *h*-index of 24. The second-ranked author was Oh Kikwang from South Korea, with 27 documents, 413 citations, and an *h*-index of 11. Khanal Pukar of India ranks third with 25 documents, 757 citations, and an *h*-index of 18. Notable authors from China include Xiao Wei (25 documents, 8,008 citations, *h*-index of 43), Qin Xuemei (23 documents, 7,019 citations, *h*-index of 39), Li Shao (21 documents, 8,224 citations, *h*-index of 47), and Zhou Wei (21 documents, 512 citations, *h*-index of 12). Efferth Thomas H. from Germany stands out with 20 documents, an impressive 40,606 citations, and an *h*-index of 94. Li Rong from China also ranks with 20 documents, 2,212 citations, and an *h*-index of 30.

Ranking was based on the number of documents published in NPR. *Documents related to NPR. **The *h*-index is determined by examining an individual's list of publications and ranking them in descending order based on the number of citations they have received. The *h*-index itself is defined as the highest number of "h" for which the researcher has published at least "h" papers, each of which has received at least "h" citations.

Accommodating Sources

Frontiers in Pharmacology, with 552 documents, 5321 citations, an average citation of 9.64, and a total link strength of 456 is the leading journal. Then comes Evidence-Based Complementary and Alternative Medicine, with 546 documents, 4060 citations, an average citation of 7.44, and a total link strength of 442. The Journal of Ethnopharmacology secures the third position with 437 documents, 5198 citations, an average citation of 11.89, and a total link strength of 683 (Table 3).

Impactful NPR

Table 4 presents the most cited documents. Notable entries include "In silico screening of Chinese herbal medicines with the potential to directly inhibit the new coronavirus of 2019" published in the Journal of Integrative Medicine in 2020, with 373 citations and an average of 93.25 citations. Another significant document is "A Novel Network Pharmacology Approach to Analyze Traditional Herbal Formulae: The Liu-Wei-Di-Huang pill as a case study" published in Molecular BioSystems in 2014, with 217 citations and an average of 21.70 citations. Additional highly cited articles cover topics such as COVID-19 treatment, TCM mechanisms, and network pharmacology analysis of herbal formulas.^{1,2,5-10,16,28}

Co-authorship

According to Figure 2, which illustrates the mapping of 46 countries with a minimum of 5 documents using network visualization, the top collaborating countries according to total link strength (TLS) are China (TLS: 539), followed by the United States (TLS: 250), Saudi Arabia (TLS: 123), the United Kingdom (TLS: 121), India (TLS: 118), Hong Kong (TLS: 102), Pakistan (TLS: 89), Germany (TLS: 72), Macao (TLS: 71), South Korea (TLS: 64), and Italy (TLS: 52).

Conceptual Mapping

The dataset included a total of 10,084 author keywords, and Figure 3 provides a visual representation of the most frequent

author keywords. The keyword "NP" appears 3528 times, followed by "molecular docking" (1104 occurrences), "traditional Chinese medicine" (321 occurrences), "apoptosis" (235 occurrences), "metabolomics" (224 occurrences), "inflammation" (212 occurrences), "COVID-19" (191 occurrences), "mechanism" (152 occurrences) and "bioinformatics" (116 occurrences). The most frequent keywords ($n=46$) were clustered using network visualization to reveal the conceptual structure of NPR. The map consists of five distinct clusters: red, blue, yellow, green, and purple. Each node within the clusters represents a specific keyword. Notably, the term "NP" was excluded from the map to allow other related NP terms to emerge. The red cluster is anchored by the keyword "metabolomics," while the green cluster is centered around the keyword "apoptosis." The blue cluster is led by the term "traditional Chinese medicine," and the yellow cluster is influenced by the keyword "molecular docking." Lastly, the purple cluster is headed by the term "COVID-19." This visualization offers insights into the interconnectedness and thematic organization of NPR based on the most frequent author's keywords.

Emerging NP

Using an overlay visualization technique, Figure 4 reveals the emerging research themes. Within the visualization, the yellow nodes represent the trending topics that have gained attention in NPR. Prominent examples of these emerging research themes

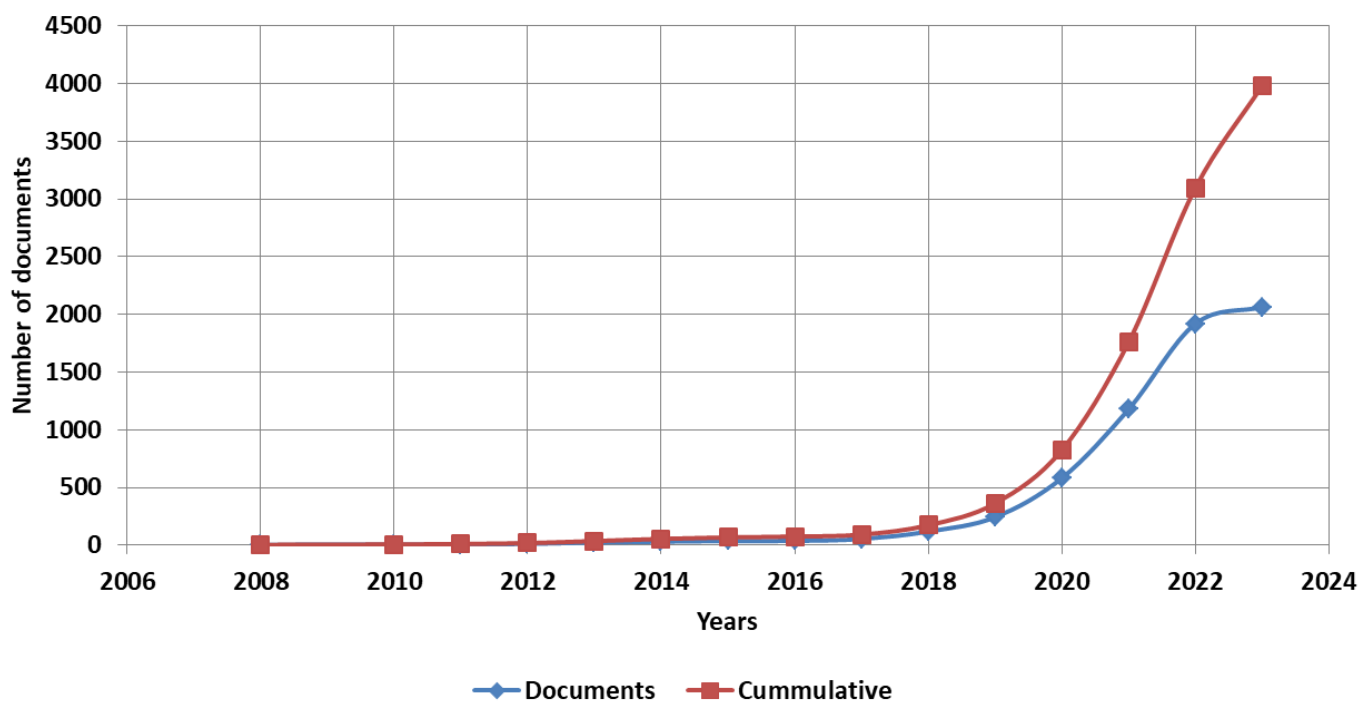


Figure 1: The annual changes in the number of publications and the total number of publications. The figure illustrates the trends and growth of the publication output over time. The x-axis represents the years, while the y-axis represents the number of publications. The line graph showcases fluctuations in the annual publication count, showcasing any increases or decreases in a given year. In addition, the cumulative total number of publications is depicted, showing the overall growth in the number of publications over the years.

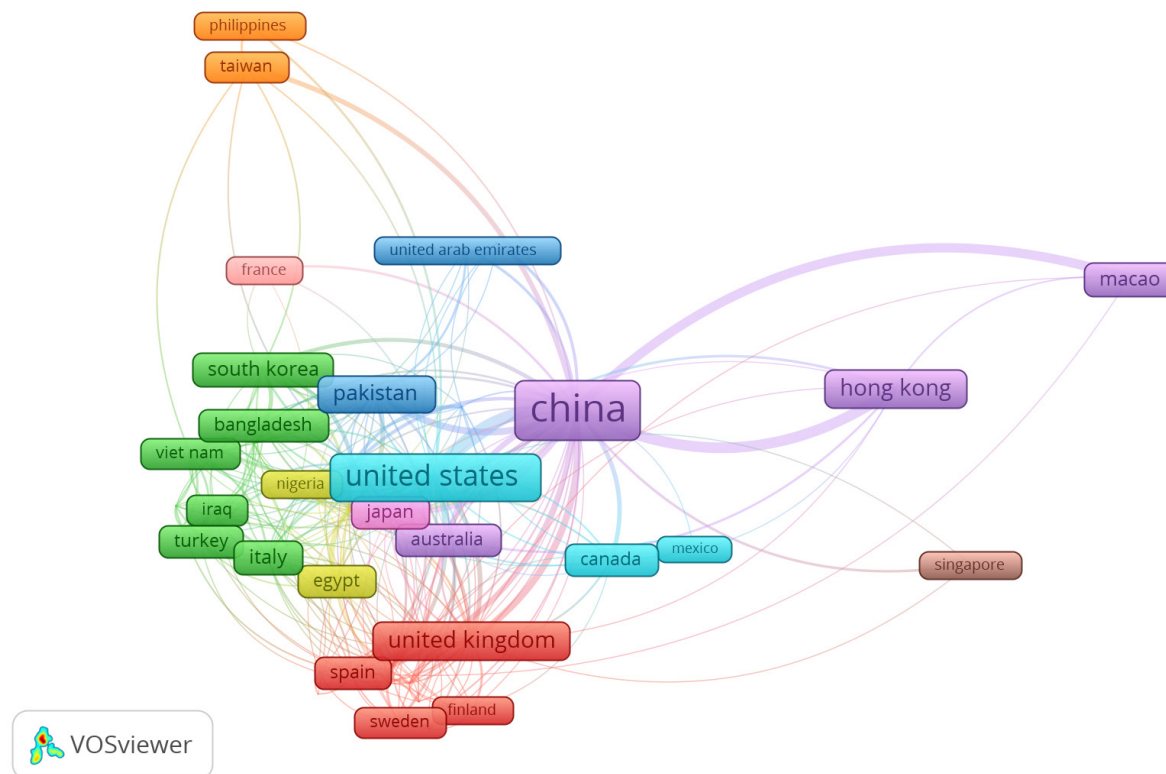


Figure 2: Network visualization of the participating countries in NPR. This figure shows the collaboration among 46 countries, with node sizes representing the Total Link Strength (TLS). China has the highest TLS (539), followed by the United States (250). The visualization highlights extensive collaborations in the field.

include molecular docking, apoptosis, cell cycle, ulcerative colitis, and sepsis.

DISCUSSION

Bibliometric analysis of data-driven NPR was performed using VOSviewer software. The authors preferred the Scopus database because of its numerous benefits, including comprehensive coverage and reliable data.²² Using these tools, researchers have gained insight into NP publication patterns, collaboration networks, and emerging research themes. The use of data-driven research in this bibliometric analysis provides several strengths. This allows for a comprehensive examination of the entire NPR landscape, ensuring objectivity and scalability. The analysis captures emerging trends and patterns and provides information on the evolving field of NPR. Compared with studies^{29,30} relying solely on original research, the data-driven approach offers broader coverage, reduces biases, and facilitates reproducibility for future updates.

With the number of publications rising from 119 in 2018 to 2,064 in 2023 and the percentage of articles rising from 1.88% to 32.69% over this period, the data reveals a notable increase in publications connected to NP from 2018 to 2023. Thanks to developments in computational and network analysis methods, rising interest in systems biology approaches, effective NP

applications in drug discovery and development, and more multidisciplinary cooperation, this steep growth trend suggests that NP has become a much more prominent area of attention. Although the succinct justification for "NP is having growing importance" does not point to a single causative event, the data unequivocally shows that network pharmacology has gone through a phase of fast expansion and rising importance in the scientific literature during the 2018-2023 period.

China's leading position in Network Pharmacology (NP) research is rooted in a powerful synergy between its rich heritage in Traditional Chinese Medicine (TCM) and a comprehensive national strategy. The philosophical alignment between TCM and NP is a key driver; both disciplines view health and disease from a holistic, systems-level perspective, moving beyond the "one target, one drug" model to a more complex "network target, multicomponents" approach. This allows for the effective use of network-based methods to understand how multi-compound herbal formulas interact with complex biological systems. This research paradigm is significantly bolstered by substantial government support and strategic planning. China has made significant investments in TCM research and development, with a notable increase in funding under national initiatives. Policy efforts, such as the 2017 Law of the People's Republic of China on Traditional Chinese Medicine, have elevated the legal status of TCM and encouraged its integration with modern scientific

Table 1: Most profiling institutions/affiliations.

Ranking	Affiliations	Documents
1	Beijing University of Chinese Medicine	488
2	Ministry of Education of the People's Republic of China	430
3	Guangzhou University of Chinese Medicine	298
4	China Academy of Chinese Medical Sciences	288
5	Nanjing University of Traditional Chinese Medicine	244
6	Chengdu University of Traditional Chinese Medicine	241
7	Shanghai University of Traditional Chinese Medicine	239
8	Shandong University of Traditional Chinese Medicine	179
9	Tianjin University of Traditional Chinese Medicine	177
10	Zhejiang Chinese Medical University	173

Table 2: Key metrics for prominent authors in NPR.

Ranking	Author name	Country	Documents*	Total documents	Total Citations	H-index**
	Wu, Jiarui	China	28	160	2,341	24
	Oh, Kikwang	South Korea	27	46	413	11
	Khanal, Pukar	India	25	70	757	18
	Xiao, Wei	China	25	727	8,008	43
	Qin, Xuemei	China	23	653	7,019	39
	Adnan, Md Tareek	United States	21	59	965	17
	Li, Shao	China	21	153	8,224	47
	Zhou, Wei	China	21	47	512	12
	Efferth, Thomas H.	Germany	20	961	40,606	94
	Li, Rong	China	20	82	2,212	30

methods like NP. Long-term strategies, including the Strategic Plan on TCM Development (2016-2030), emphasize innovation, standardization, and international collaboration. This is further supported by leading academic institutions and global initiatives like the Belt and Road, which collectively contribute to China's prominence in the field, particularly in areas such as AI-TCM applications.^{5,7,8,13,31}

The retrieval of 6,134 documents in NP indicates the growing importance of this research field. Figure 1 further supports this trend and shows a consistent increase in NP publications over time. This rising volume of research highlights the expanding influence and recognition of NP within the scientific community. Compared to previous studies on innovative approaches in drug discovery,^{32,33} this study reflects the increasing interest in studying drug actions and interactions from a network perspective, emphasizing the interconnectedness and complexity of biological systems. The significant number of publications on NP underscores its relevance and the growing recognition of its potential to advance drug discovery and therapeutic approaches.

The increasing volume of published literature and citation metrics have been classified according to highly active researchers in the field.²⁰ Wu is the most prolific scholar in NPR. Wu and his research team provided articles that have focused on various research interests in the field of NP. These include investigating the mechanisms of specific treatments for COVID-19, gastric cancer, lung cancer, hepatitis C, and hepatitis B using network pharmacology approaches. Wu utilized methods such as experimental verification, molecular docking, and integrated bioinformatics analysis to understand the underlying molecular mechanisms of these treatments. Wu's studies have contributed to a better understanding of the potential therapeutic effects and mechanisms of action of different herbal compounds and formulations in the context of these diseases.

The analysis of the institutions involved in NPR provides valuable information for aspiring researchers. It offers a comprehensive understanding of topics already covered in the field and identifies potential research gaps. This knowledge is a foundation for future researchers, which guides them in selecting study areas and identifying collaboration opportunities with experienced peers.

Interdisciplinary collaborations can effectively address identified research gaps and advance the field further.³⁴

Based on the analysis of the cooccurrence of author keywords (Figure 4), the five research themes identified in NPR are:

Molecular mechanisms and mechanisms of action: This research area aims to investigate the underlying molecular pathways and signaling systems involved in order to comprehend how various drugs or therapies produce their effects. It explores particular pathways, such as NF- κ B and PI3K/AKT that are essential to illnesses including inflammation, diabetes, and cancer. Researchers can learn about the interactions and targets that support the therapeutic effects of drugs by dissecting these mechanisms.^{5,17,35-37}

TCM and herbal compounds: This theme looked at using NP to investigate the therapeutic effects and mechanisms of action of TCM and herbal compounds. This is looking at how several chemicals in TCM formulations interact with their intended objectives. Researchers may identify the synergistic effects and possible pharmacological targets behind the effectiveness of TCMs by knowing how these chemicals interact. The focus of this study theme is frequently on particular illnesses including rheumatoid arthritis, ulcerative colitis, and stomach cancer.^{1,2,5,8-10,16,28,31}

Disease-specific research is a theme in which NP is used to investigate certain illnesses or disorders. NP has been utilized by researchers to clarify the molecular processes, pathways, and possible targets for therapeutic intervention related to various disorders. The wide range of conditions examined within this research theme includes COVID-19, Alzheimer's disease, colorectal cancer, depression, osteoporosis, lung cancer, ischemic stroke, diabetic nephropathy, and neuroinflammation, among other conditions listed in the previous response. Through a molecular landscape analysis of various disorders, scientists have looked for novel therapy approaches and intervention targets.^{15,31,36,38,39}

Investigations on inflammation and immunity: The understanding of the molecular processes underlying inflammation and immunological responses in different diseases was the main goal of this work. The impacts of the gut flora and inflammatory pathways including oxidative stress and NF- κ B signaling have been investigated by researchers. Hepatocellular cancer, ulcerative colitis, atherosclerosis, and rheumatoid arthritis are among the diseases that have been examined. Through the deciphering of the complex relationships between the immune system and diseases, scientists have sought to create focused treatments for diseases associated to inflammation.^{2,7,12,32}

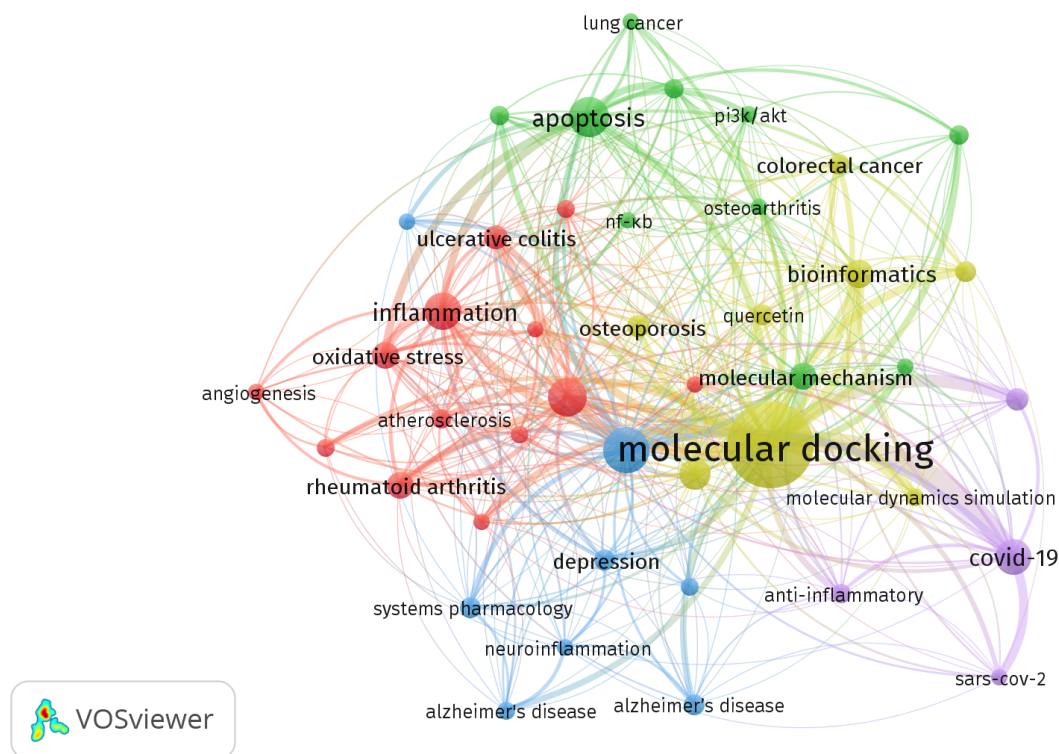


Figure 3: Network Visualization of Author's Keywords in NPR. The analysis includes 10,084 keywords clustered into five color-coded clusters: red, blue, yellow, green, and purple. The visualization excludes the term "NP" to highlight other relevant NP terms. Clusters are anchored by keywords such as "metabolomics" (red), "apoptosis" (green), "traditional Chinese medicine" (blue), "molecular coupling" (yellow), and "COVID-19" (purple). This visualization provides a concise overview of the conceptual structure and interrelationships among author's keywords in NPR.

Validation and simulation: This theme involves experimental validation and molecular dynamics simulations to confirm and refine the findings obtained by NP approaches. Researchers have conducted experiments to empirically validate the predicted interactions, mechanisms, and effects of compounds and treatments. Molecular dynamics simulations were employed to model and simulate the behavior of compounds within biological systems. By combining computational predictions with experimental data, researchers can strengthen the reliability and utility of their findings, ultimately improving our understanding of complex interactions within NP.^{8,11,12,32,40}

The thorough review of the five main study themes found by means of keyword co-occurrences in the NPR offers insightful analysis of the several uses and areas of concentration of this multidisciplinary technique. These results have important ramifications for NP study going forward. From clarifying molecular mechanisms and researching the effects of traditional Chinese medicine² to disease-specific studies and investigations of inflammation and immunity,^{10,12} the range of topics suggests that NP will remain a potent tool for handling difficult biomedical problems. Especially remarkable is the focus on validation and simulation, which emphasizes the need of combining computational predictions with experimental data to increase the dependability and influence of NP results.^{17,41} Investigating the relationships between these fundamental concepts as the field develops could expose fresh chances for synergies and teamwork that propel NP research ahead. By means of comparison with

other bibliometric analyses,^{24,25} these findings help to further contextualize the positioning and special contributions of NP within the larger terrain of network biology and systems pharmacology research, so possibly revealing significant trends and trajectories deserving of more research. These results suggest generally a future in which NP keeps extending its influence and reach, giving researchers even more advanced tools to break through the complexity of biological systems and create new therapeutic approaches.

Apoptosis, or programmed cell death, is a trending topic in NPR (Figure 4) due to its therapeutic implications in diseases such as cancer and neurodegenerative disorders.⁴¹ NPR focusing on apoptosis helps to discover and evaluate potential drug candidates by studying interactions with key apoptotic pathways such as the extrinsic pathway (through death receptors), the intrinsic pathway (involving mitochondria), and the execution phase mediated by caspases.⁴¹ Utilizing network analysis, researchers can unravel the complex interactions and crosstalk between these pathways, shedding light on the regulatory mechanisms involved. Additionally, studying apoptosis contributes to the development of personalized medicine approaches by identifying biomarkers and genetic factors that influence apoptotic processes, enabling tailored treatment strategies.⁴² Furthermore, investigating apoptosis in NPR facilitates the development of combination therapies that target multiple pathways, such as proteins of the Bcl-2 family proteins regulating mitochondrial apoptosis,⁴¹ the FAS-FASL pathway,⁴³ and the p53 pathway,⁴⁴ enhancing treatment

Table 3: Top Journal in NPR.

Rank	Source	Documents	Citations	Citation Average	Total Link Strength
	Frontiers in Pharmacology	552	5321	9.64	456
	Evidence-Based Complementary and Alternative Medicine.	546	4060	7.44	442
	Journal of Ethnopharmacology	437	5198	11.89	683
	Phytomedicine	195	2441	12.52	184
	Medicine (United States)	162	259	1.60	91
	Scientific Reports	126	1867	14.82	144
	Drug Design, Development and Therapy.	124	1099	8.86	428
	BMC Complementary Medicine and Therapies.	108	590	5.46	75
	Natural Product Communications	99	147	1.48	78
	Biomedicine and Pharmacotherapy	98	1408	14.37	133
	Biomed Research International	94	603	6.41	67
	Molecules.	91	761	8.36	67
	Chinese Medicine (United Kingdom)	73	851	11.66	61
	Combinatorial Chemistry and High Throughput Screening.	71	385	5.42	144
	International Journal of Molecular Sciences.	64	533	8.33	57

Table 4: Top-cited documents in NPR.

Title	Year	Source	Citation	Citation average
<i>In silico</i> screening of Chinese herbal medicines with the potential to directly inhibit 2019 novel coronavirus.	2020	Journal of Integrative Medicine.	373	93.25
A novel network pharmacology approach to analyse traditional herbal formulae: The Liu-Wei-Di-Huang pill as a case study.	2014	Molecular BioSystems.	217	21.70
Chemical composition and pharmacological mechanism of Qingfei Paidu Decoction and Ma Xing Shi Gan Decoction against Coronavirus Disease 2019 (COVID-19): <i>In silico</i> and experimental study.	2020	Pharmacological Research.	163	40.75
A System-Level Investigation into the Mechanisms of Chinese Traditional Medicine: Compound Danshen Formula for Cardiovascular Disease Treatment.	2012	PLoS ONE	157	13.08
A network pharmacology approach to determine active compounds and action mechanisms of Ge-Gen-Qin-Lian decoction for treatment of type 2 diabetes.	2014	Evidence-based Complementary and Alternative Medicine.	152	15.20
An integrative platform of TCM network pharmacology and its application on a herbal formula, Qing-Luo-Yin.	2013	Evidence-based Complementary and Alternative Medicine.	150	13.64
Network pharmacology and molecular docking analysis on molecular targets and mechanisms of Huashi Baidu formula in the treatment of COVID-19., 1345-1353.	2020	Drug Development and Industrial Pharmacy.	141	35.25
Network pharmacology and molecular docking analyses on Lianhua Qingwen capsule indicate Akt1 is a potential target to treat and prevent COVID-19.	2020	Cell Proliferation	141	35.25
Treatment efficacy analysis of traditional Chinese medicine for novel coronavirus pneumonia (COVID-19): An empirical study from Wuhan, Hubei Province, China.	2020	Chinese Medicine (United Kingdom).	119	29.75
A network pharmacology study of Chinese medicine QiShenYiQi to reveal its underlying multi-compound, multi-target, multi-pathway mode of action.	2014	PLoS ONE	111	11.10

efficacy. In general, the study of apoptosis in NPR holds significant promise to advance our understanding of disease mechanisms and develop more effective therapeutic interventions.

Including NP methods into Ulcerative Colitis (UC) research has great promise. NP can clarify the molecular pathways causing UC pathogenesis, provide fresh therapeutic targets, and help to create focused, tailored treatments-including those resulting from traditional Chinese medicine. The disease-specific NP research offer a road map for implementing this strategy to address the special features of UC, such the interaction among inflammation, gut microbiome, and epithelial barrier malfunction. All things considered, NP has the ability to become a vital instrument for simplifying UC complexity and hastening the creation of individualized treatments.⁴⁵⁻⁴⁷

Using Network Pharmacology (NP) in sepsis studies offers great potential. NP can clarify difficult processes, point out therapeutic targets, and guide the creation of focused, immunomodulating

treatments. Translation of NP results into clinical practice depends critically on the validation and simulation theme.^{48,49} Using these NP research themes will help experts better grasp sepsis pathogenesis and create creative, individualized treatments. Although network NPR has advanced significantly through *in silico* modeling, the translation of predictions into clinical applications remains limited without experimental validation. Our analysis shows that several highly cited NPR papers include *in vitro* or *in vivo* confirmation, highlighting the critical role of experimental evidence in enhancing scientific credibility and translational relevance. This integration strengthens confidence in computational predictions and accelerates their applicability in drug discovery and therapeutic strategies. Future NPR studies should prioritize coupling computational approaches with laboratory and clinical validation to ensure robust, clinically meaningful outcomes that bridge modeling with real-world applications.

ABBREVIATIONS

NP: Network Pharmacology; **NPR:** Network Pharmacology Research; **TCM:** Traditional Chinese Medicine; **TLS:** Total Link Strength; **UC:** Ulcerative Colitis.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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AUTHORS' CONTRIBUTIONS

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

SUMMARY

This bibliometric analysis explores Network Pharmacology (NP) research from 2008 to 2023, using Scopus data and VOSviewer software. Analyzing 6,134 articles, it reveals steady growth, with China leading in publications and collaborations. Five research themes emerged: molecular mechanisms, traditional Chinese medicine, disease-specific studies, inflammation/immunity, and validation/simulation. Trending topics include molecular docking, apoptosis, and ulcerative colitis. The study highlights NP's role in advancing drug discovery by integrating computational and traditional approaches. Despite limitations from relying solely on Scopus, it provides a comprehensive overview, identifying research gaps and future directions for personalized medicine and holistic drug action understanding.

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