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Gut Microbiota and Cardiovascular Disease: A Bibliometric Analysis of Knowledge Mapping and Trend Evolution over a Decade

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Abstract

Background: The gut microbiota, as a vital "microbial organ" in the human body, has attracted increasing attention for its close relationship with cardiovascular diseases (CVDs). This study aims to systematically review the research progress in this field from 2015 to 2025 using bibliometric methods, revealing its knowledge structure, evolution, and emerging trends. **Methods:** Publications from January 1, 2015, to July 1, 2025, were retrieved from the Web of Science Core Collection (WoSCC). CiteSpace and VOSviewer were used to conduct a visualized analysis of annual output, countries/regions, institutions, authorship networks, and keyword evolution. **Results:** Over the past decade, the number of publications in this field has grown rapidly, entering a high-speed development phase. China (2376 articles) and the United States (1401 articles) are the most prolific countries and play a central role in international collaboration. Leading institutions include the University of California System (207 articles), Harvard University (178 articles), and Southern Medical University (156 articles). Influential authors such as Hazen, Stanley L. (83 articles) and Wang, Zeneng (61 articles) have formed core research teams. Keyword co-occurrence and clustering analysis show that research hotspots focus on the gut microbiota's involvement in "inflammation", "obesity", and "atherosclerosis". The field has evolved from association studies to mechanistic and clinical explorations, with emerging frontiers such as "Mendelian randomization", "ischemic stroke", and "cognitive impairment" indicating a shift toward causality and disease-specific endpoints. **Conclusion:** The intersection of gut microbiota and cardiovascular disease represents a rapidly expanding research frontier characterized by active global collabora-

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tion and concentrated thematic focus. Future studies are expected to deepen causal inference, target specific clinical outcomes (e.g., ischemic stroke), and expand toward cross-disciplinary domains such as the gut-heart-brain axis and cognitive dysfunction.

Keywords

Gut Microbiota, Cardiovascular Disease, Bibliometric Analysis, Inflammation

1. Introduction

Cardiovascular diseases (CVDs) are the leading cause of death and disability worldwide, posing a severe public health challenge and an enormous socioeconomic burden [1] [2]. Despite significant progress in controlling traditional risk factors such as hypertension, hyperlipidemia, and diabetes, the incidence and mortality of CVDs remain high, prompting the scientific community to continuously explore new risk factors and pathophysiological mechanisms [3] [4].

In this context, the trillions of microorganisms residing in the human gastrointestinal tract—the gut microbiota—acting as a "microbial organ" that co-evolves with the host, are being increasingly recognized for their critical role in health and disease [5]. The gut microbiota not only participates in the digestion and absorption of nutrients but also profoundly influences the host's metabolic regulation, immune system maturation, and nervous system function. A large body of evidence indicates that the composition and functional imbalance of the gut microbiota (*i.e.*, "dysbiosis") are closely related to the development of various cardiovascular diseases, including atherosclerosis, hypertension, heart failure, and thrombotic diseases [6]. The underlying mechanisms are multi-faceted: the gut microbiota can metabolize specific dietary components (such as choline and L-carnitine) to produce precursors that are converted by the liver into the pro-atherogenic trimethylamine N-oxide (TMAO) [7]; short-chain fatty acids (SCFAs) produced by the microbiota can regulate blood pressure and host immunity [8]; meanwhile, the microbiota also exerts a profound influence on the cardiovascular system by regulating bile acid metabolism, affecting systemic inflammatory responses, and modulating intestinal barrier function [9].

As the importance of this interdisciplinary field has grown, the number of related research publications has exploded over the past decade. However, this vast body of literature makes it difficult for researchers to quickly and systematically grasp the overall landscape of the field, identify its core knowledge structure, and track the evolution of research hotspots and frontiers. Therefore, a comprehensive review using bibliometric methods is particularly necessary. Bibliometrics employs mathematical and statistical tools to quantitatively analyze literature in a specific field, objectively revealing its development patterns and future trends [10].

This study aims to use visualization analysis tools such as CiteSpace and VOSviewer to conduct a systematic bibliometric analysis of the literature on gut microbiota and cardiovascular disease from 2015 to 2025. The objectives are: 1) to delineate the temporal distribution characteristics of research output in this field; 2) to identify core countries, institutions, and authors and to reveal their collaborative network patterns; 3) to outline the research hotspots and core knowledge clusters through keyword analysis; and 4) to detect the dynamic evolutionary paths of the research frontiers and predict future development trends, thereby providing a valuable reference for subsequent research.

2. Materials and Methods

2.1. Data Source and Search Strategy

The data for this study were sourced from the Web of Science Core Collection (WoSCC) database. To ensure both recall and precision, the search strategy was constructed around the two main themes of "gut microbiota" and "cardiovascular disease". To maximize retrieval, the search also included broad terms for relevant metabolites and interventions (e.g., "SCFAs", "probiotic", "prebiotic"). These terms were justified based on their wide usage in literature describing gut microbiota-related metabolic pathways implicated in cardiovascular health. Off-topic results were filtered by screening titles and abstracts to ensure relevance. The search period was set from January 1, 2015, to July 1, 2025. Non-English articles, conference proceedings, and early-access papers were excluded to maintain consistency and ensure access to peer-reviewed, full-text, and language-accessible data. To ensure the quality and consistency of the included literature, the document type was limited to "Article". After the initial retrieval, all records were exported and deduplicated using EndNote X9 software to enhance data reliability. The specific search query was as follows:

Topic (TS) = ("gut microbiota" OR "gut microbiome*" OR "gut flora" OR "gut dysbiosis" OR "intestinal microflora" OR "intestinal microbiota" OR "intestinal microbiome*" OR "fecal microbiota" OR "fecal microbiome*" OR "gut microecolog*" OR "gut bacteria" OR "gut commensal*" OR TMAO OR "trimethylamine N-oxide" OR "short-chain fatty acid*" OR SCFAs OR probiotic* OR prebiotic* OR synbiotic*) AND Topic (TS) = ("cardiovascular disease*" OR CVD OR "heart disease*" OR "vascular disease*" OR cardiometabolic OR cardio-metabolic OR "coronary artery disease" OR "coronary heart disease" OR "myocardial infarction" OR "heart attack" OR "acute coronary syndrome" OR "heart failure" OR "cardiac failure" OR cardiomyopathy OR "atrial fibrillation" OR arrhythmia* OR hypertension OR "high blood pressure" OR "blood pressure" OR stroke OR "cerebrovascular accident" OR atherosclerosis OR atherogenesis OR "arterial stiffness" OR "endothelial dysfunction").

2.2. Analysis Tools and Methods

The bibliographic information of the retrieved literature was exported in the "Full

Record and Cited References" format and deduplicated. Two mainstream bibliometric software, CiteSpace (6.2.R4) and VOSviewer (1.6.18), were used for visual analysis. CiteSpace was used to generate collaboration network maps for countries, institutions, and authors, as well as keyword cluster maps, timeline views, and burst detection. The CiteSpace parameters were: time slicing (2015-2025), years per slice (1), node types (author, institution, keyword), selection criteria (Top N = 50), pruning method (pathfinder and pruning sliced networks). VOSviewer was used to generate a keyword co-occurrence network density map. The VOSviewer parameters included full counting method with a minimum keyword occurrence threshold of 10.

3. Results and Analysis

3.1. Publication Trend Analysis

The trend of publications from 2015 to 2025 (**Figure 1**) shows that research in this field has undergone significant growth. The annual number of publications increased from 185 in 2015 to a peak of 1005 in 2022 and 999 in 2024, indicating sustained high attention from the academic community. The fitting curve for the cumulative number of publications shows exponential growth, suggesting that research on gut microbiota and cardiovascular disease is in a "boom" period of rapid development.

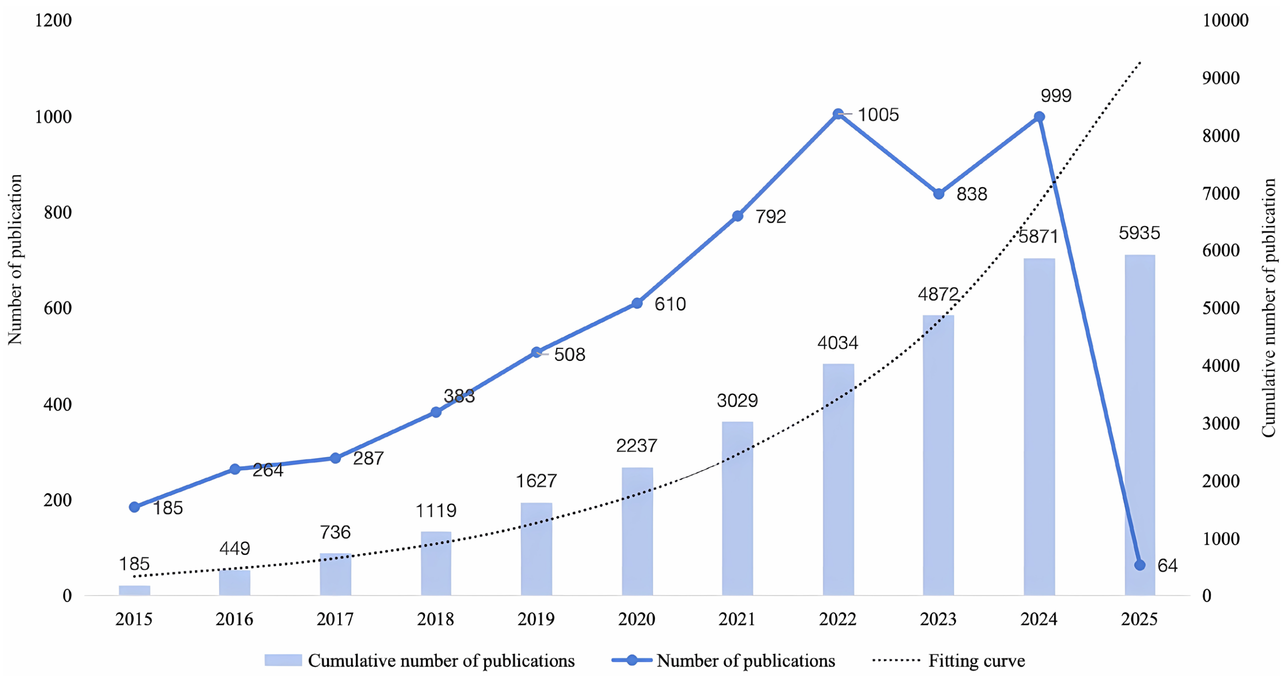


Figure 1. Annual and cumulative publication trends (2015-2025).

3.2. National and Institutional Collaboration Network Analysis

National Level: The global collaboration network map (**Figure 2**) illustrates a robust and interconnected research landscape involving 120 countries and regions.

The map is characterized by dense clusters of collaboration centered in North America, East Asia, and Western Europe. Based on the publication volume, China (2376 articles) and the United States (1401 articles) emerge as the largest nodes, indicating their high publication output and central role in the network. The connecting lines between countries signify active collaborative relationships. For a detailed breakdown of publication counts and centrality scores for the top 10 most productive countries, see **Table 1**. In terms of centrality, the USA (0.19) and Germany (0.13) are among the most influential, indicating their key bridging roles in the international collaboration network. Furthermore, the analysis of citation bursts among countries (**Figure 3**) highlights nations with a recent surge in research impact. Notably, Turkey and Georgia show strong citation bursts extending to 2025, marking them as emerging forces in the field.

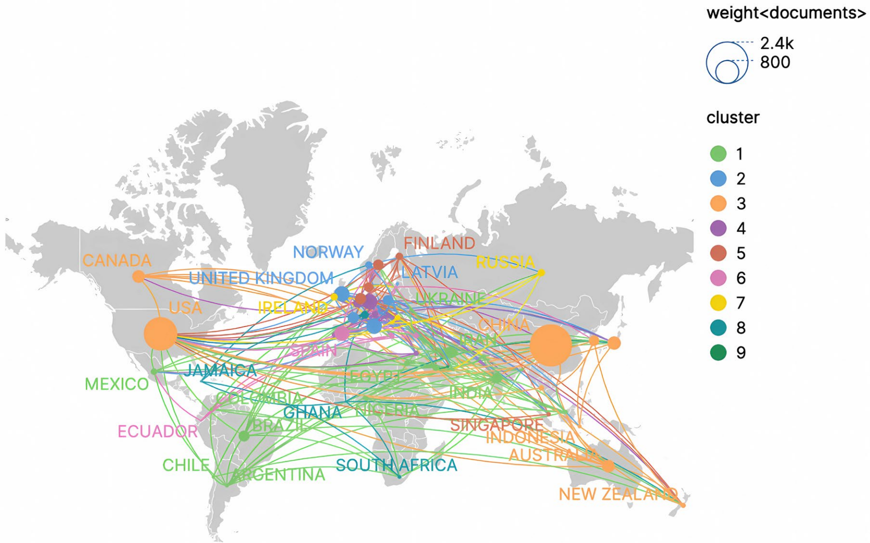


Figure 2. Global collaboration network of countries.

Table 1. Top 10 countries/regions by publication volume.

Rank	Country/Region	Publications	Centrality
1	PEOPLES R CHINA	2376	0
2	USA	1401	0.19
3	ITALY	302	0.07
4	ENGLAND	296	0.07
5	GERMANY	283	0.13
6	SPAIN	274	0.1
7	JAPAN	222	0
8	AUSTRALIA	201	0.03
9	CANADA	201	0.07
10	IRAN	169	0

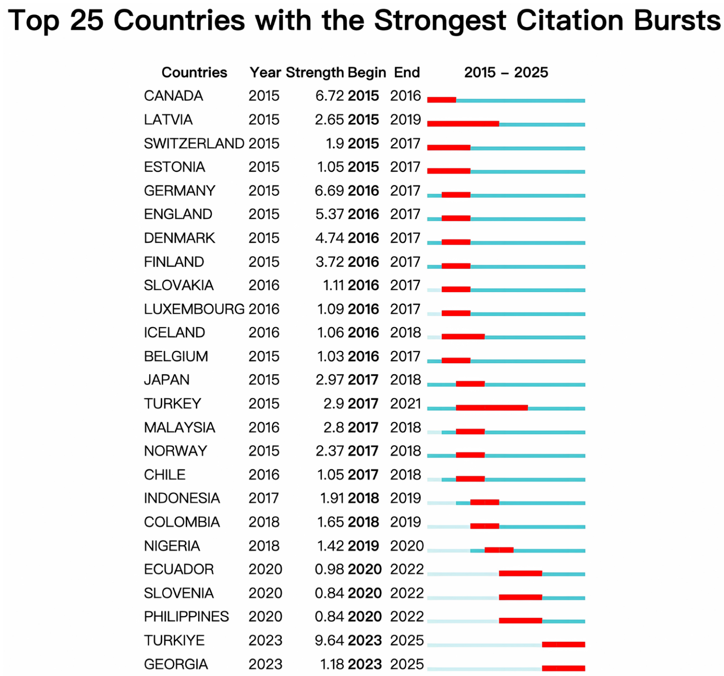


Figure 3. Top 25 countries with the strongest citation bursts.

Institutional Level: The institutional collaboration network (Figure 4) reveals the key research organizations driving the field. Large nodes in the network, such as the University of California System, Harvard University, and Southern Medical University-China, represent the most prolific institutions. The dense connections between these nodes indicate a highly collaborative research environment. Quantitative data on the top 10 institutions are provided in Table 2. The citation burst analysis for institutions (Figure 5) identifies organizations with a recent and significant increase in scientific impact. Notably, institutions like Wenzhou Medical University and Guangzhou University of Chinese Medicine have shown strong citation bursts in recent years (2022-2025), signaling their rise as important contributors.

Table 2. Top 10 research institutions by publication volume.

Rank	Institution	Publications	Centrality
1	University of California System	207	0.35
2	Harvard University	178	0.32
3	Southern Medical University-China	156	0.07
4	University System of Ohio	132	0.19
5	Chinese Academy of Medical Sciences-Peking Union Medical College	129	0.19
6	Harvard University Medical Affiliates	127	0.36
7	CIBER-Centro de Investigacion Biomedica en Red	119	0.14
8	Cleveland Clinic Foundation	114	0.12
9	Harvard Medical School	108	0.28
10	Capital Medical University	100	0.1

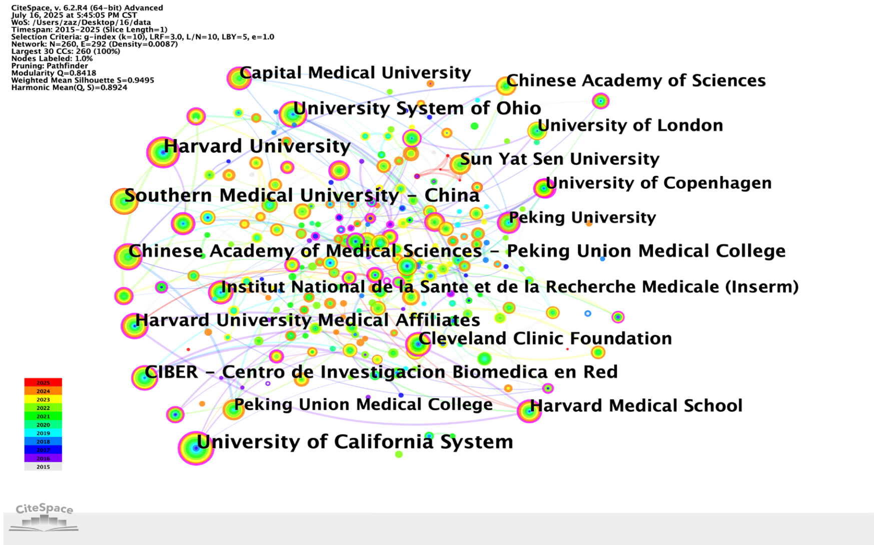
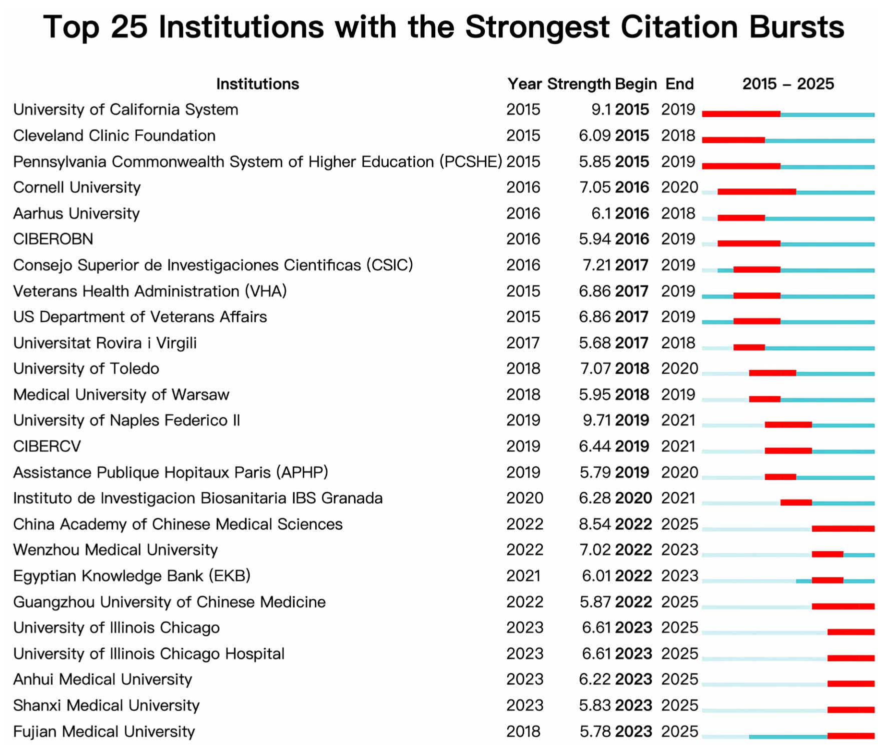


Figure 4. Collaboration network of research institutions.



Top 25 Institutions with the Strongest Citation Bursts

Institutions	Year	Strength	Begin	End	2015 – 2025
University of California System	2015	9.1	**2015**	2019	
Cleveland Clinic Foundation	2015	6.09	**2015**	2018	
Pennsylvania Commonwealth System of Higher Education (PCSHE)	2015	5.85	**2015**	2019	
Cornell University	2016	7.05	**2016**	2020	
Aarhus University	2016	6.1	**2016**	2018	
CIBEROBN	2016	5.94	**2016**	2019	
Consejo Superior de Investigaciones Cientificas (CSIC)	2016	7.21	**2017**	2019	
Veterans Health Administration (VHA)	2015	6.86	**2017**	2019	
US Department of Veterans Affairs	2015	6.86	**2017**	2019	
Universitat Rovira i Virgili	2017	5.68	**2017**	2018	
University of Toledo	2018	7.07	**2018**	2020	
Medical University of Warsaw	2018	5.95	**2018**	2019	
University of Naples Federico II	2019	9.71	**2019**	2021	
CIBERCV	2019	6.44	**2019**	2021	
Assistance Publique Hopitaux Paris (APHP)	2019	5.79	**2019**	2020	
Instituto de Investigacion Biosanitaria IBS Granada	2020	6.28	**2020**	2021	
China Academy of Chinese Medical Sciences	2022	8.54	**2022**	2025	
Wenzhou Medical University	2022	7.02	**2022**	2023	
Egyptian Knowledge Bank (EKB)	2021	6.01	**2022**	2023	
Guangzhou University of Chinese Medicine	2022	5.87	**2022**	2025	
University of Illinois Chicago	2023	6.61	**2023**	2025	
University of Illinois Chicago Hospital	2023	6.61	**2023**	2025	
Anhui Medical University	2023	6.22	**2023**	2025	
Shanxi Medical University	2023	5.83	**2023**	2025	
Fujian Medical University	2018	5.78	**2023**	2025	

Figure 5. Top 25 institutions with the strongest citation bursts.

Author Level: The author collaboration network is visualized in Figure 6. The map reveals distinct research communities, represented by different colored clusters. Within this network, certain authors appear as large nodes, indicating high productivity. The most prominent research group is centered around Hazen, Stanley L. (83 articles), who, along with his collaborators like Wang, Zeneng (61 articles), forms a tightly-knit cluster. This indicates a strong and influential research team. The top 10 most prolific authors are listed in Table 3 for reference.

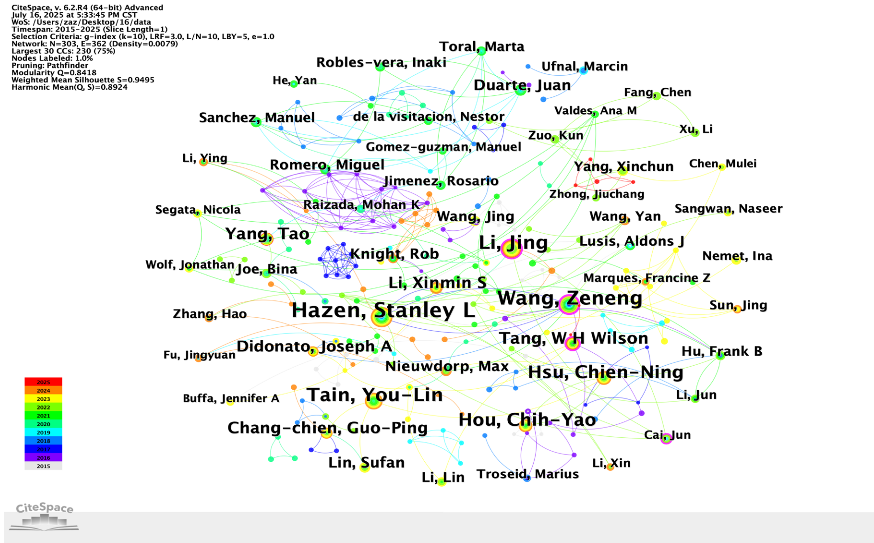


Figure 6. Collaboration network of authors.

Table 3. Top 10 authors by publication volume.

Rank	Author	Publications	Centrality
1	Hazen, Stanley L	83	0.07
2	Wang, Zeneng	61	0.2
3	Li, Jing	57	0.12
4	Tain, You-Lin	47	0
5	Hou, Chih-Yao	39	0
6	Hsu, Chien-Ning	39	0
7	Tang, W H Wilson	28	0.13
8	Yang, Tao	28	0.03
9	Chang-Chien, Guo-Ping	26	0
10	Li, Xinmin S	25	0.04

3.3. Research Hotspots and Thematic Evolution

Core Research Themes: The keyword co-occurrence map (Figure 7) provides a visual representation of the field's intellectual landscape. The size of each node corresponds to the frequency of the keyword. "Gut microbiota" is the largest and most central node, with strong connections to other major keywords such as "inflammation", "hypertension", "obesity", and "atherosclerosis", indicating these are the core research topics. The keyword cluster map (Figure 8) further groups these topics into distinct thematic areas. The largest and most coherent clusters include #0 high-fat diet & insulin resistance, #1 metabolic syndrome, #2 weight loss, #3 bile acids & probiotics, and #4 cardiovascular diseases. This demonstrates that research is heavily focused on the mechanistic links between diet, microbiota, and metabolic dysregulation in CVD. For detailed quantitative data on keyword cluster composition, refer to Table 4.

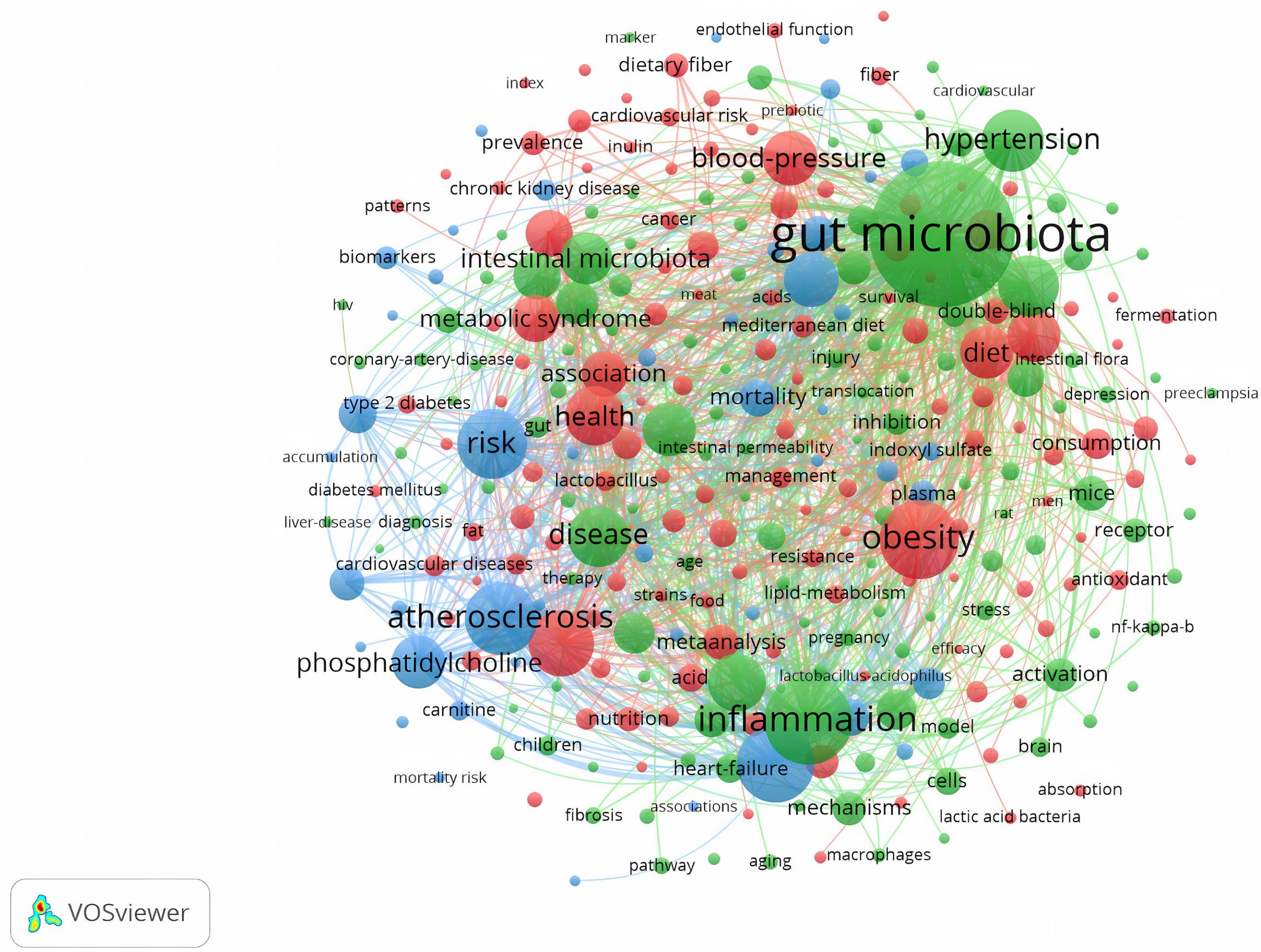


Figure 7. Co-occurrence network of keywords.

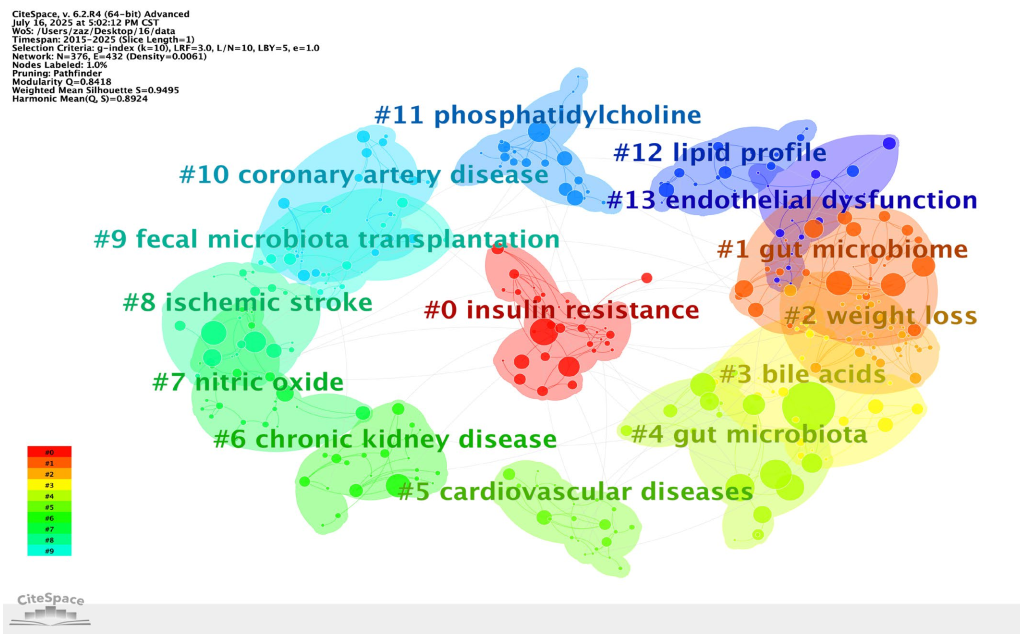


Figure 8. Cluster map of keywords.

Table 4. Summary of keyword cluster analysis.

Cluster ID	Size	Silhouette	Top Terms
#0	33	0.96	gut microbiota; high-fat diet; systems biology; non-absorbable antibiotics; arterial stiffness|insulin resistance; metabolic syndrome; obesity; adipose tissue; mice
#1	32	0.955	gut microbiota; metabolic syndrome; glucose homeostasis; arterial stiffness; animal models|gut microbiome; heart failure; energy metabolism; shen-fu formula; cecal microbiome
#2	31	0.913	gut microbiota; body composition; animal models; heavy metals; serine-rich coiled-coil protein|metabolic syndrome; liver steatosis; animal models; heavy metals; serine-rich coiled-coil protein
#3	25	0.981	gut microbiota; natto yogurt; lactobacillus plantarum; bacillus natto; dual protein|gut microbiome; mendelian randomization; conduction block; non-absorbable antibiotics; pentadecanoic acid
#4	24	0.961	gut microbiota; cardiovascular diseases; metabolic diseases; neurodegenerative diseases; arterial stiffness|cardiovascular disease; inflammation; metabolism; obesity; health
#5	33	0.96	gut microbiota; network pharmacology; molecular docking; gut-derived uremic toxins; endothelial dysfunction|cardiovascular diseases; oral fat tolerance test; non-fasting lipid; postprandial lipid; arterial stiffness

Evolution of Research Frontiers: The timeline visualization of keyword clusters (**Figure 9**) illustrates the evolution of research topics over the past decade. Early research (2015-2018) focused on foundational concepts like "insulin resistance" and "atherosclerosis". More recent years have seen the emergence of topics such as "clinical trial" and "mendelian randomization", indicating a shift towards clinical and causal inference studies. The keyword burst detection analysis (**Figure 10**) pinpoints the most significant research frontiers. The red bars indicate the period of a keyword's citation burst. Notably, "mendelian randomization" (strength 19.84), "ischemic stroke" (strength 17.1), and "cognitive impairment" (strength 8.45) show the strongest and most recent bursts, highlighting them as the key emerging frontiers that are shaping the future direction of the field.

4. Discussion

This study is the first to use bibliometric methods to systematically and comprehensively map the research landscape, hotspot shifts, and frontier trends in the interdisciplinary field of gut microbiota and cardiovascular disease over the past decade (2015-2025).

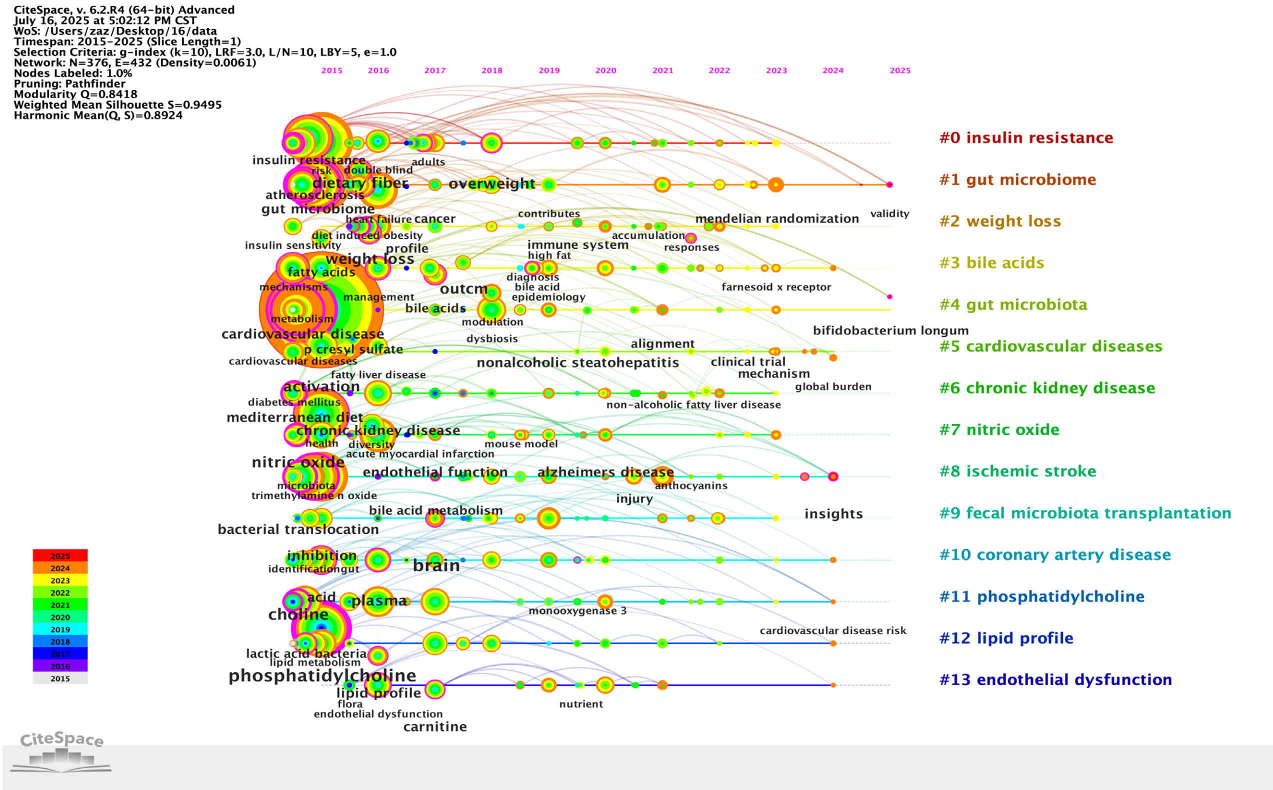


Figure 9. Timeline visualization of keyword clusters.

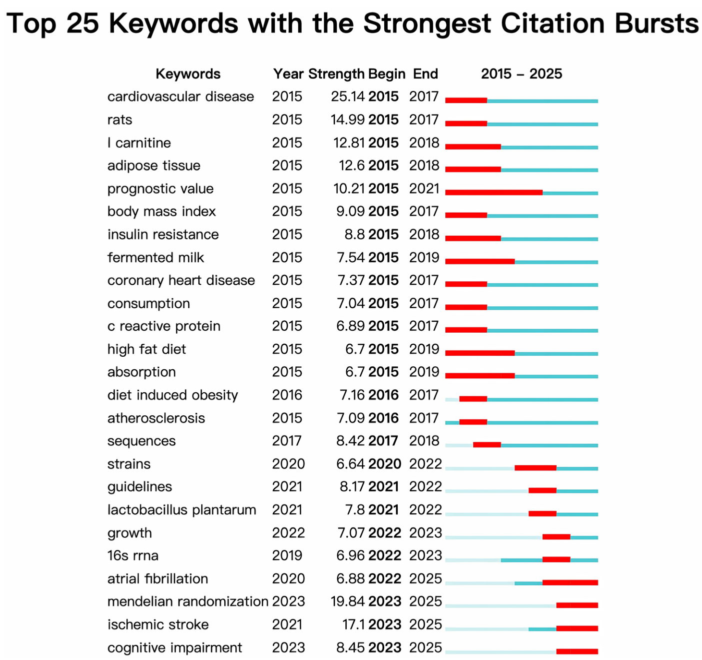


Figure 10. Top 25 keywords with the strongest citation bursts.

4.1. Overall Development Trend of the Field: From Rise to Explosion

Our analysis reveals that the annual publication volume in this field has increased more than fivefold within a decade, with an exponential growth fitting curve. This clearly indicates that the relationship between gut microbiota and CVD has evolved from an emerging concept to a mainstream research direction in life sciences and clinical medicine. This trend is inextricably linked to the sharp decline in sequencing costs, the popularization of bioinformatics analysis tools, and a deepened understanding of the importance of the microbiome in the academic community [11]. The burgeoning research signifies a general consensus that the gut microbiota is another critical dimension for understanding and intervening in CVD, alongside genetic and environmental factors [12].

4.2. Global Collaboration Pattern: Led by China and the US, with Multiple Points of Growth

Our analysis shows that the United States and China are the absolute leaders in this field, contributing more than half of the literature. The leading position of the US benefits from its strong basic research capabilities and long-term funding, particularly highlighted by the author analysis, where American scholars, represented by the team of Hazen, Stanley L. at the Cleveland Clinic, laid an important theoretical foundation for the field through their pioneering research on TMAO [13]. Meanwhile, the contribution of Chinese scholars has shown rapid growth, with institutions like Capital Medical University now ranking among the top globally in publication volume, reflecting China's high emphasis and investment in cutting-edge life science fields. The rise of Chinese institutions such as Wenzhou Medical University and Guangzhou University of Chinese Medicine in the institutional burst detection also suggests that the combination of traditional Chinese medicine and gut microbiota may become a new, distinctive research direction. Countries (e.g., UK, Germany) and institutions (e.g., Harvard University, CIBER) with high centrality play important "bridge" roles in the global collaboration network, promoting the transnational flow of knowledge and technology.

4.3. Analysis of Research Hotspots: From Phenomenon Association to Mechanistic Exploration

The results of keyword co-occurrence and cluster analysis systematically outline the core knowledge map of this field. Research hotspots are highly concentrated on the association of classic CVD risk factors such as "inflammation", "atherosclerosis", "obesity", and "metabolic syndrome" with "gut microbiota". This is highly consistent with the mainstream academic view that gut dysbiosis primarily drives CVD progression through a "metabolic-inflammatory" axis [14] [15]. For example, Cluster #0 (insulin resistance) and Cluster #3 (bile acids) directly point to the core role of the gut microbiota in glucose and lipid metabolism regulation. The high-frequency keywords "oxidative stress" and "inflammation" highlight the key pathological process where microbiota-derived metabolites (like LPS, TMAO) trigger low-grade systemic inflammation, thereby damaging the vascular endothelium. This knowledge structure clearly reflects that research in this field has moved beyond simple observation of phenomena to in-depth exploration of the underlying molecular mechanisms.

4.4. Insights into Research Frontiers: Three Major Trends Leading the Future

The keyword burst detection is one of the most valuable findings of this study, revealing three key future directions for the field:

1) A Paradigm Shift in Research: From "Association" to "Causation." "Mendelian randomization" (MR) has become the most prominent frontier with an extremely high burst strength (19.84), signaling a profound paradigm shift in the field. Early observational studies established a broad association between the microbiota and CVD but could not rule out confounding factors. MR analysis uses genetic variants as instrumental variables to simulate randomized controlled trials, providing strong evidence for inferring causal relationships. In recent years, several high-quality MR studies have been used to assess the causal effects of specific bacteria, microbial metabolites (like TMAO), on coronary heart disease, hypertension, and other diseases, significantly enhancing the reliability level of evidence in this field [16]-[18].

2) Focusing Research Objectives: From "General CVD" to "Specific Endpoints." The strong burst of "ischemic stroke" (strength 17.1) indicates that research is shifting from a general discussion of "cardiovascular disease" to more specific and clinically significant hard endpoint events. The gut microbiota has been shown to be involved in the development of stroke through multiple pathways, including influencing atherosclerosis, atrial fibrillation-related thrombosis, and ischemia-reperfusion injury [19] [20]. Focusing on specific diseases like ischemic stroke not only helps to elucidate more precise pathological mechanisms but also points the way for developing targeted prevention and treatment strategies (e.g., modulating the microbiota to stabilize plaques or prevent atrial fibrillation).

3) Expanding the Research Horizon: From "Gut-Heart Dialogue" to the "Gut-Heart-Brain Axis." The unexpected emergence of "cognitive impairment" (strength 8.45) reveals a highly potential new cross-disciplinary frontier. Traditionally, the relationship between cardiovascular health and cognitive function is well-known (*i.e.*, "vascular cognitive impairment"). This new trend suggests that the gut microbiota may act as a key node connecting the heart and the brain, forming a "gut-heart-brain axis." Possible mechanisms include: gut dysbiosis exacerbating cardiovascular disease, which in turn affects cerebral blood supply and neuronal health; or, microbiota-derived metabolites and neurotransmitters may directly cross the blood-brain barrier to affect neural function [21] [22]. This discovery will greatly expand the research boundaries of the field and provide a new perspective for understanding and intervening in age-related cognitive decline.

4.5. Strengths and Limitations of This Study

The strength of this study lies in its use of objective, quantitative bibliometric methods to conduct a panoramic scan of a rapidly developing hot field. Its conclusions are not affected by the subjectivity of single articles and can macroscopically reveal the knowledge structure and evolutionary context of the field.

However, this study also has some limitations. First, the data were sourced only from the WoSCC database. Although it is a core database, it may still miss literature indexed in other databases. Second, bibliometric analysis focuses on the external characteristics of literature (such as keywords, authors, countries) and cannot conduct an in-depth evaluation of the quality and specific content of individual studies. Finally, some of the latest research concepts that have not yet formed fixed keywords may not have been fully captured in this analysis.

4.6. Additional Methodological Clarifications

Centrality values in collaboration networks were calculated using betweenness centrality, which reflects the importance of a node in bridging different clusters in the network. Nodes with centrality scores above 0.1 were considered "influential" based on conventional thresholds used in bibliometric network analysis.

4.7. Expanded Limitations

However, this study also has some limitations. First, the data were sourced only from the WoSCC database. Although it is a core database, it may still miss literature indexed in other databases. This reliance may introduce citation bias, as WoSCC has a stronger representation of certain regions and journals. Future studies should consider integrating data from Scopus or PubMed to obtain a more comprehensive and balanced literature base. Second, bibliometric analysis focuses on the external characteristics of literature (such as keywords, authors, countries) and cannot conduct an in-depth evaluation of the quality and specific content of individual studies. Finally, some of the latest research concepts that have not yet formed fixed keywords may not have been fully captured in this analysis.

5. Conclusion

Through a bibliometric analysis of the literature on gut microbiota and cardiovascular disease from 2015 to 2025, this study finds that the field is in a golden age of rapid development, with a global collaboration network centered on the United States and China. Research hotspots focus on the role of metabolic disorders and inflammatory responses mediated by the gut microbiota in CVD. More importantly, we have identified three major frontier trends in the field: causal inference research represented by Mendelian randomization, clinical endpoint event research represented by ischemic stroke, and cross-disciplinary research on the "gut-heart-brain axis" represented by cognitive impairment. These findings provide a valuable reference for researchers in the field to systematically understand the disciplinary landscape and grasp future development directions.

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Author Contributions

Conceptualization, J. H. (Jinchen He) and Q. W. (Qi Wu); Methodology, H. Z. (Heng Zhu) and Q. L. (Qinke Li); Software, H. Z. and Q. L.; Validation, M. J. (Meng Jia) and C. L. (Chunmei Liu); Formal Analysis, H. Z. and Q. L.; Investigation, H. Z., Q. L., M. J. and C. L.; Resources, J. H. and Q. W.; Data Curation, H. Z. and M. J.; Writing–Original Draft Preparation, H. Z. (Heng Zhu) and Q. L. (Qinke Li); Writing–Review & Editing, J. H. (Jinchen He) and Q. W. (Qi Wu); Visualization, H. Z.; Supervision, J. H. and Q. W.; Project Administration, Q. W.; Funding Acquisition, J. H. and Q. W. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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