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Gut Microbiota and Cardiovascular Disease (2005–2025): A Bibliometric and Knowledge-Mapping Analysis

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Abstract: *Objective*: To quantitatively analyze global research trends on the gut microbiota and cardiovascular disease (CVD) from 2005–2025, identifying publication output, core themes, influential articles, and emerging research hotspots. *Methods:* We retrieved publications related to gut microbiota and CVD from 2005–2025 using standard bibliographic databases. A bibliometric analysis was conducted to evaluate annual output growth, leading journals, country and institutional contributions, author collaborations, citation networks, and keyword co-occurrence patterns. Descriptive statistics and visualization tools were used to map the developmental trajectory and research hotspots of this field. *Results:* The analysis included a sharp rise in publications over the past two decades, with especially rapid growth after 2015. Collaborative networks highlighted a few key countries and research centers driving the field. Highly cited papers clustered around themes such as microbiota-derived metabolites such as trimethylamine N-oxide, inflammation, and the "gut-heart axis." Keyword analysis indicated evolving focus from early descriptive studies to recent mechanistic and clinical translational research. *Conclusion:* Research linking gut microbiota and CVD has expanded exponentially in 2005–2025, transitioning from correlation studies to mechanistic and therapeutic explorations. The bibliometric trends underscore the gut-heart axis as an emerging interdisciplinary domain in cardiovascular research, with potential to inform novel preventive and therapeutic strategies.

Keywords: Gut microbiota; Cardiovascular disease; Bibliometric analysis; Dysbiosis; Gut-heart axis; Microbial metabolites

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1. Introduction

Over the past two decades, the gut microbiota has emerged as a key factor influencing cardiovascular

disease (CVD) pathogenesis [1]. Recent high-impact studies have elucidated mechanisms linking dysbiosis to atherosclerosis, heart failure, and hypertension via microbiota-derived metabolites such as trimethylamine-N-oxide and short-chain fatty acids [2–4]. This gut–heart axis is thought to modulate host immunity and inflammation, thereby influencing disease progression and clinical outcomes [5]. Reflecting the importance of this field, research output on gut microbiota and CVD has surged in recent years. Here, we present a bibliometric analysis of global literature (2005–2025) to highlight key trends, influential publications, and emerging themes in this rapidly evolving domain.

2. Methods

2.1. Data source and search strategy

A systematic search was conducted in the Web of Science Core Collection to retrieve publications related to the gut microbiota and cardiovascular disease. The search strategy was defined as follows: TS = ((cardiovascular OR "heart" OR circulation) AND ("gut microbiome" OR "gut microbiota" OR "intestinal microbiota" OR "intestinal flora" OR "intestinal microflora" OR "gut flora" OR "gut bacteria")) AND LA = English.

The search was restricted to peer-reviewed articles and reviews published in English between January 2000 and July 2025. Non-article materials, including conference abstracts, letters, and editorials, were excluded. The search was finalized on July 31, 2025, and all retrieved records were exported with complete bibliographic and citation information for subsequent bibliometric analysis.

2.2. Data analysis tools

Bibliometric indicators were evaluated using VOSviewer1.6.20. Annual publication trends, co-authorship and institutional collaborations, co-citation patterns, and keyword co-occurrence networks were generated. Prolific authors, institutions, journals, and high-frequency keywords were identified to assess research productivity, collaboration, and thematic evolution in this field.

3. Results

3.1. Annual publication trend

The publication trend illustrates the temporal trajectory and research activity of this field (**Figure 1**). Since 2005, the annual number of publications has shown an exponential growth pattern, with a marked acceleration after 2015. Between 2021 and 2024, the annual output peaked, exceeding 1,000 papers per year, suggesting that the field has entered a phase of rapid expansion. The cumulative publication curve exhibited a high degree of fit ($R^2 > 0.94$), indicating sustained and stable development. Although minor declines were observed in certain years, the overall trajectory remained upward, reflecting strong and persistent research momentum. This growth is closely associated with national research policy support, the application of interdisciplinary technologies such as omics and artificial intelligence–based analytical methods, and the pressing challenges of global health. Overall, the publication trend not only demonstrates the continued prosperity of the field, but also highlights its emergence as an important international research frontier.

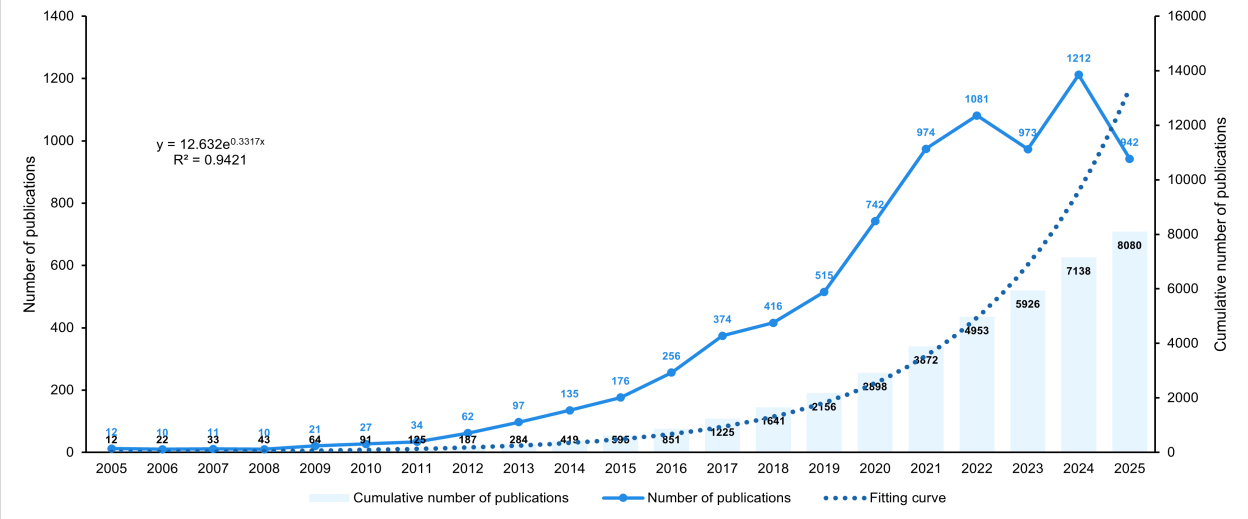

Figure 1. Annual number of publications on gut microbiota and cardiovascular disease (2000–2025).

3.2. Leading journals

As shown in **Table 1**, Nutrients was the most productive journal with 394 publications and the highest citation count (23,540, average 59.7 per article), followed by the International Journal of Molecular Sciences (230 articles) and Scientific Reports (131 articles). Several Frontiers series journals, including Frontiers in Microbiology, Frontiers in Pharmacology, Frontiers in Nutrition, and Frontiers in Immunology, also contributed substantially, together accounting for more than 450 publications. Notably, PLOS One achieved a high average citation rate (54.8 per article) despite fewer publications. These results highlight that research on gut microbiota and cardiovascular disease is disseminated across nutrition, molecular biology, microbiology, and pharmacology journals, reflecting the interdisciplinary nature of the field.

Table 1. Top 10 journals by publication output

Journal name	Total number of articles	Total citations	Average citations
Nutrients	394	23540	59.7462
International Journal of Molecular Sciences	230	9427	40.987
Scientific Reports	131	4984	38.0458
Frontiers in Microbiology	129	4404	34.1395
Frontiers in Pharmacology	99	2984	30.1414
Frontiers in Nutrition	88	3189	36.2386
Frontiers in Immunology	87	4305	49.4828
Food & Function	85	3314	38.9882
Plos One	84	4605	54.8214
Frontiers in Cellular and Infection Microbiology	82	2447	29.8415

3.3. Most productive authors and collaboration network

As shown in **Table 2**, Stanley L. Hazen ranked first with 70 publications and over 24,000 citations (average 345.8 citations per article), followed closely by W. H. Wilson Tang (57 articles, 20,793 citations) and Zeneng Wang (53 articles, 19,790

citations), all of whom demonstrated high productivity and strong citation impact. Other prolific contributors included Max Nieuwdorp (34 articles), Jing Li (32 articles), and Lin Li (30 articles). Although some authors, such as Rob Knight and Lin Li, had fewer publications, their average citation rates remained relatively high, reflecting notable influence within the field. Collectively, these findings indicate that leading investigators are concentrated in a small group of highly productive authors who play a pivotal role in advancing research on gut microbiota and cardiovascular disease.

Table 2. Top 10 authors by publication output

Author name	Total number of articles	Total citations	Average citations
Hazen, Stanley L.	70	24207	345.8143
Tang, W. H. Wilson	57	20793	364.7895
Wang, Zeneng	53	19790	373.3962
Nieuwdorp, Max	34	1838	54.0588
Li, Jing	32	2576	80.5
Li, Lin	30	8199	273.3
Li, Xinmin S.	28	3419	122.1071
Marques, Francine Z.	25	1994	79.76
Zhang, Hao	25	870	34.8
Knight, Rob	24	4158	173.25

The co-authorship network revealed the collaboration patterns and academic influence of researchers in this field (**Figure 2**). The overall structure exhibited several distinct collaborative clusters, where node size represented publication volume and influence, while link density reflected the strength of collaboration. Core authors such as Stanley L. Hazen, Max Nieuwdorp, and Rob Knight occupied central positions, producing a large number of high-quality publications and maintaining long-term, stable collaborations with multiple researchers, thereby forming cohesive academic communities. In addition, several regional or thematic research groups were identified, including networks led predominantly by Chinese scholars, which showed rapid expansion. This collaborative structure indicates a strong degree of internationalization, with leading investigators advancing knowledge dissemination through cross-national cooperation. Overall, the co-authorship analysis highlights the underlying academic collaboration mechanisms driving the development of this research domain.

3.4. Most productive institutions and collaboration network

As shown in **Table 3**, the Cleveland Clinic ranked first with 120 publications and the highest total citations (26,765, average 223.0 citations per article), highlighting its leading role in this research domain. Other major contributors included Sun Yat-sen University (104 articles), Harvard Medical School (102 articles), and Capital Medical University (100 articles). The University of Copenhagen also demonstrated strong academic influence, with 18,825 citations from 98 publications (average 192.1 citations per article). Several Chinese institutions, including Zhejiang University, Shanghai Jiao Tong University, Chinese Academy of Sciences, and Southern Medical University, ranked among the top 10, reflecting China's rapid growth in publication volume and scientific impact. Additionally, the Instituto de Salud Carlos III (Spain) contributed substantially with 85 publications and more than 5,000 citations, indicating a notable European presence.

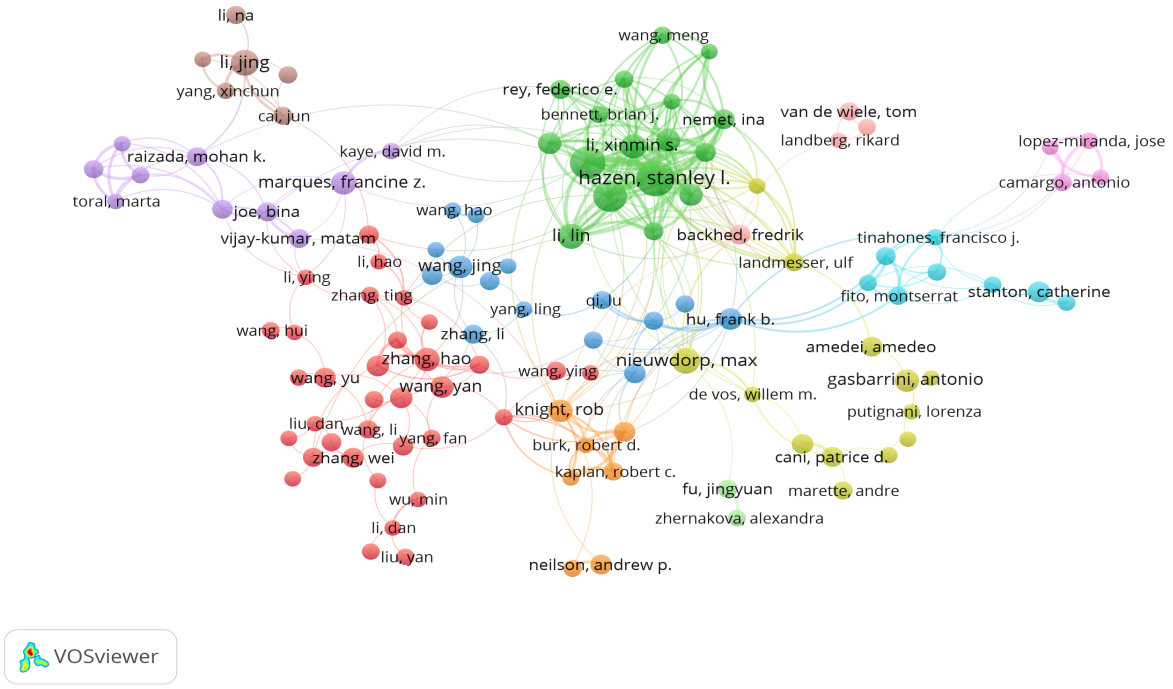

Figure 2. Co-authorship network of authors.

Table 3. Top 10 institutions by publication output

Institution name	Total number of articles	Total citations	Average citations
Cleveland Clin	120	26765	223.0417
Sun Yat Sen Univ	104	4835	46.4904
Harvard Med Sch	102	6324	62
Capital Med Univ	100	4158	41.58
Univ Copenhagen	98	18825	192.0918
Zhejiang Univ	97	4068	41.9381
Shanghai Jiao Tong Univ	97	3681	37.9485
Chinese Acad Sci	89	3799	42.6854
Southern Med Univ	88	3361	38.1932
Inst Salud Carlos Iii	85	5040	59.2941

The institutional collaboration network further revealed the structural dynamics of global cooperation (**Figure 3**). Several distinct clusters were formed, with Chinese institutions such as Fudan University, Shanghai Jiao Tong University, Zhejiang University, and Sun Yat-sen University occupying central positions, reflecting their significant contributions. In parallel, Western institutions, including Harvard University, Mayo Clinic, and the University of California system, appeared as key hubs maintaining extensive international partnerships. This pattern indicates a "dual-core, globally connected" structure, where Chinese institutions are rapidly expanding their output and collaborative reach, while Western institutions sustain their influence through interdisciplinary strength and long-standing academic networks. Notably, European institutions such as the University of Zurich, University of Copenhagen, and University College London acted as bridges in multinational collaboration, enhancing the overall

connectivity of the research landscape. Collectively, these findings highlight the emergence of a multi-centered, highly internationalized cooperation framework in the field.

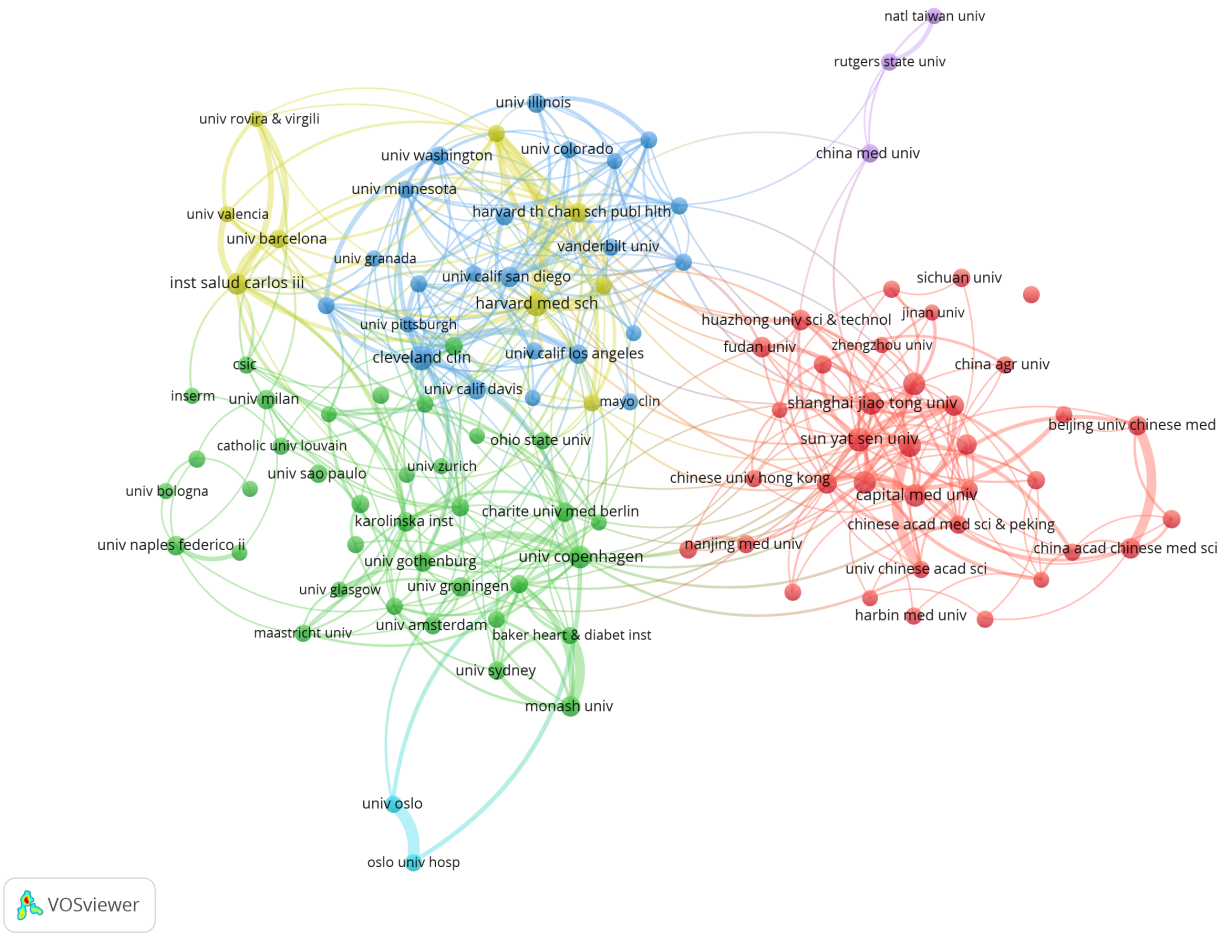

Figure 3. Institutional collaboration network.

3.5. Geographic distribution and international collaboration

The country co-authorship network reflected the academic contributions and collaborative relationships among nations in this field (**Figure 4**). The United States and China occupied dominant positions, leading not only in publication volume but also in establishing extensive global academic connections through wide-ranging international collaborations. European countries such as Germany, France, and the United Kingdom also held significant roles in the network, often emphasizing cross-border cooperation that fostered the development of regional knowledge clusters. Meanwhile, other Asian countries, including Japan, South Korea, and India, have gradually emerged, indicating a trend toward multipolar growth of research power. The overall network displayed a tightly interconnected structure, suggesting that this topic has a strong global dimension and that collaborative research has become a key driver of scientific advancement. This pattern reflects disparities in research resources and policy support, while also underscoring the central role of cross-national cooperation in enhancing research visibility and impact.

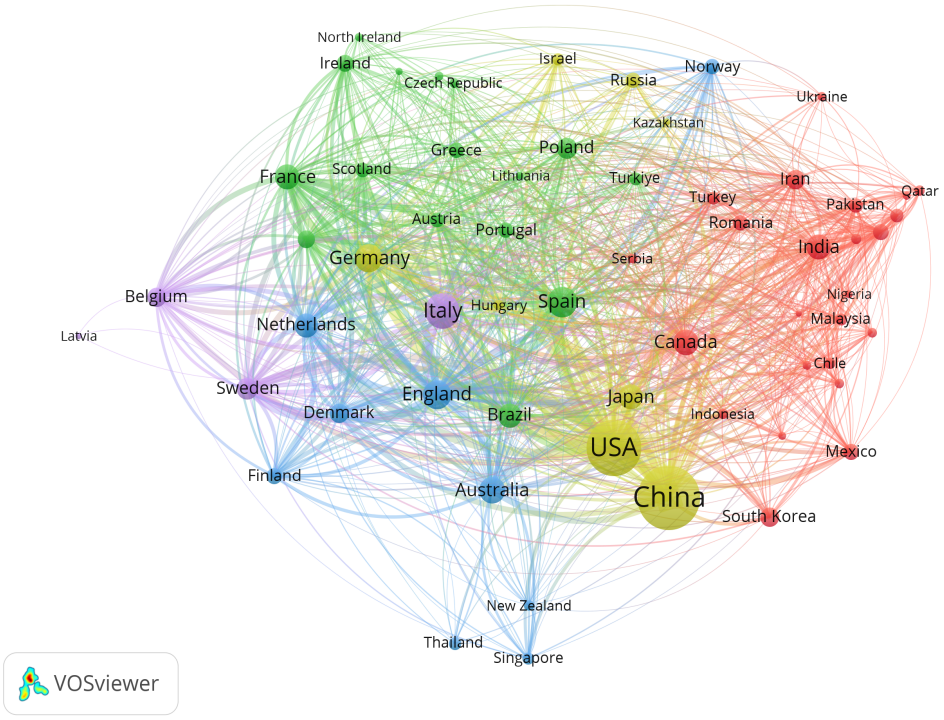

Figure 4. Country collaboration map.

3.6. Keyword co-occurrence analysis

As shown in **Table 4**, the most frequent keywords were "gut microbiota" (4030), "cardiovascular disease" (1493), "intestinal microbiota" (963), and "metabolism" (828). Other highly cited terms included "gut microbiome," "inflammation," "oxidative stress," "insulin resistance," "short-chain fatty acids," and "risk." These findings indicate that research in this field has consistently centered on the role of gut microbial dysbiosis in cardiovascular health, metabolic regulation, and immune-inflammatory responses. Temporal analysis further revealed that terms such as "metabolism" (2005) and "cardiovascular disease" (2006) appeared earlier, whereas "gut microbiome" and "risk" emerged later (2011), suggesting a shift from broad associations toward mechanistic pathways and clinical risk assessment.

Table 4. Top 10 keywords by co-occurrence frequency

Rank	Frequency	Centrality	Time	Keyword
1	4030	0	2009	gut microbiota
2	1493	0	2006	cardiovascular disease
3	963	0	2010	intestinal microbiota
4	828	0	2005	metabolism
5	823	0	2011	gut microbiome
6	814	0	2008	inflammation
7	761	0	2009	oxidative stress
8	740	0	2006	insulin resistance
9	728	0	2006	chain fatty acids
10	660	0	2011	risk

The keyword co-occurrence network provided an intuitive visualization of the thematic structure and knowledge associations within this field (**Figure 5**). Central keywords such as "gut microbiota," "inflammation," and "metabolism" highlighted the focus on microbial-host interactions in metabolic regulation and chronic disease. Surrounding these core terms, clusters extended to areas including "obesity," "insulin resistance," "cardiovascular disease," "probiotics," and "dietary fiber," reflecting the multidimensional development of the field. Distinct clusters were identified, such as those centered on "metabolites–trimethylamine N-oxide–atherosclerosis" (metabolic mechanisms), "obesity–insulin resistance–metabolic syndrome" (chronic disease interventions), and "probiotics–dietary intervention–microbiome modulation" (nutritional and therapeutic strategies). This network structure revealed strong thematic overlap and interdisciplinary integration, underscoring the dual focus on mechanistic exploration and translational application, and demonstrating the field's trajectory from theoretical foundations to practical interventions.

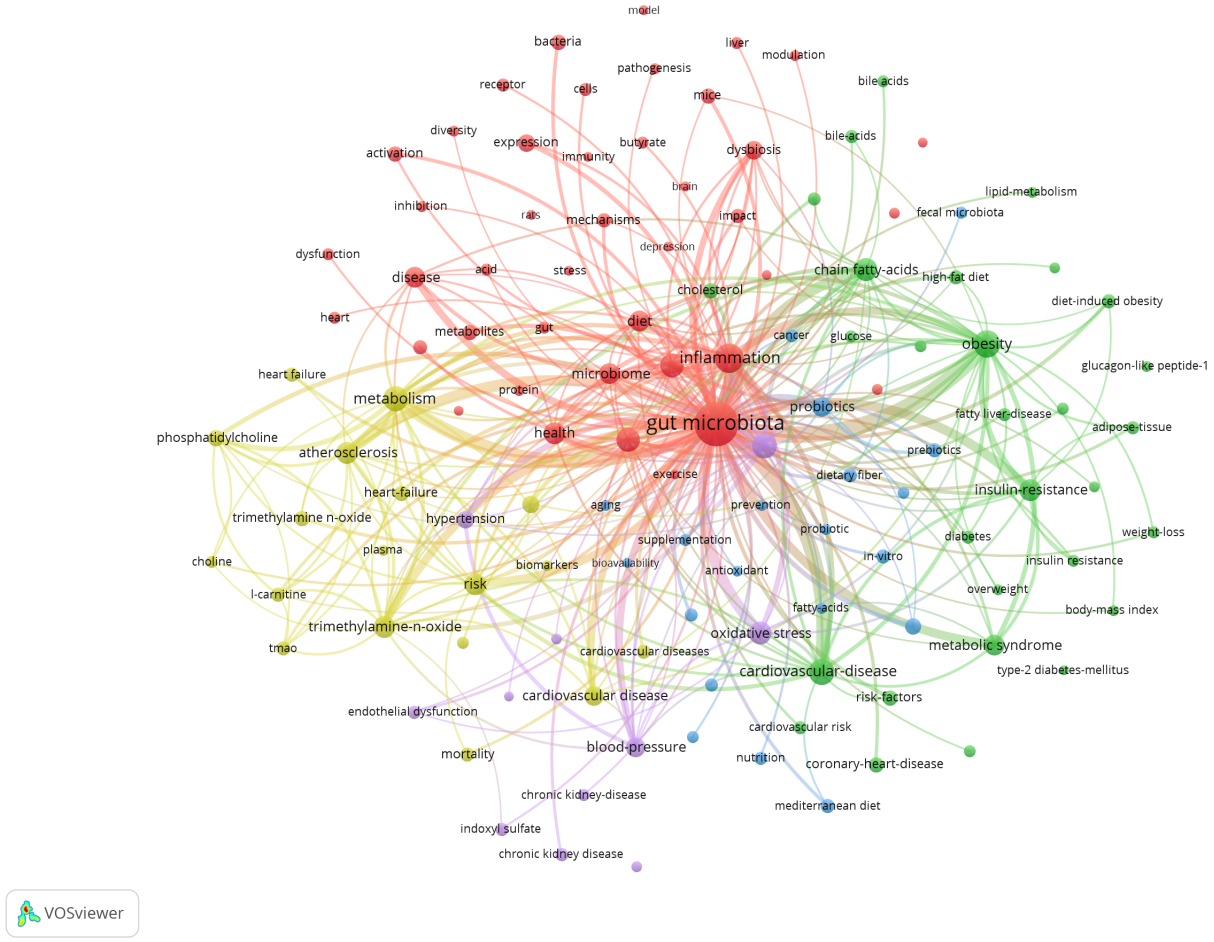

Figure 5. Keyword co-occurrence network.

3.7. Reference co-citation network analysis

The reference co-citation network reflected the intellectual foundation and coupling relationships among core publications in this field (**Figure 6**). The overall structure displayed multiple color-coded clusters, indicating the emergence of relatively independent yet interconnected research directions. Central nodes such as Tremaroli (2012), Wang (2011), and Jie (2017) exhibited high co-citation frequencies, suggesting that these seminal works

have been widely recognized and cited, thereby establishing theoretical and methodological cornerstones for subsequent studies. In contrast, peripheral nodes represented publications with lower citation frequency but potential frontier value, which may serve as entry points for future breakthroughs. Notably, the dense connections observed between clusters demonstrated frequent knowledge exchange and thematic convergence across subfields, highlighting the interdisciplinary nature of this domain. Overall, the co-citation network not only revealed the academic significance of landmark studies but also underscored the role of multidisciplinary approaches in driving knowledge diffusion and integration within this research area.

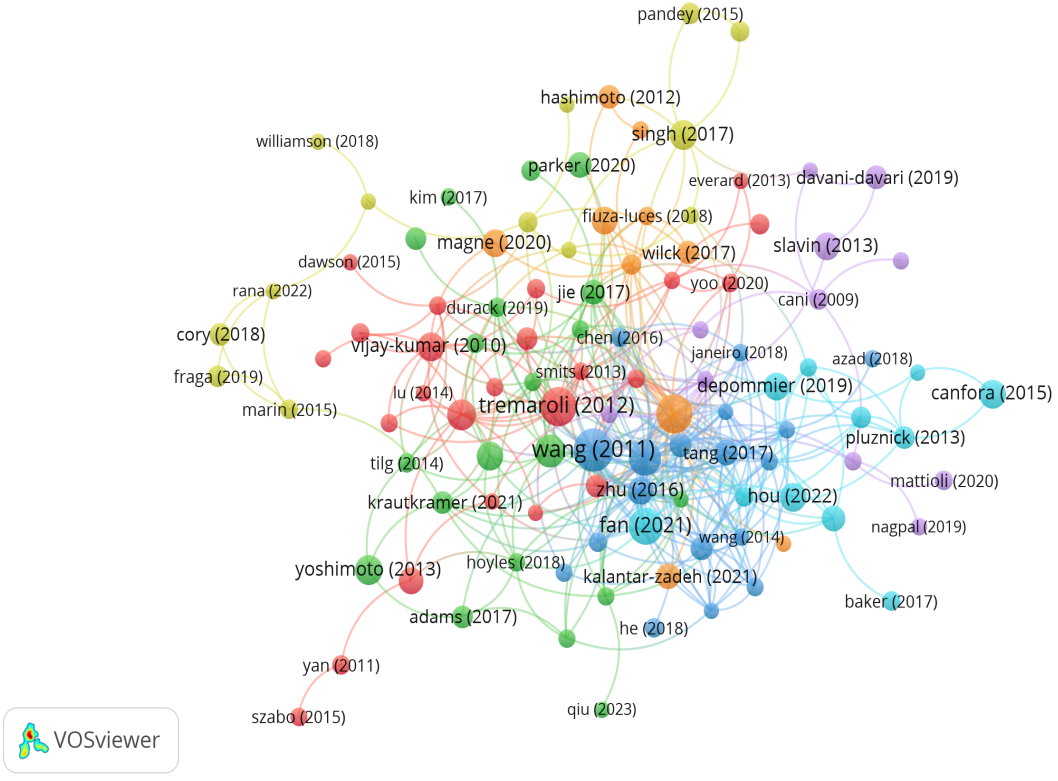

Figure 6. Co-cited reference network.

4. Discussion

Our bibliometric analysis reveals that research on the gut microbiota–cardiovascular disease (CVD) axis has expanded dramatically from 2005 to 2025. Early studies primarily documented correlations between gut dysbiosis and cardiovascular risk factors, emphasizing broad concepts like “metabolism” and “inflammation.” In the past decade, however, the field’s focus has shifted toward specific microbial metabolites and mechanistic pathways. Keyword analysis shows that terms such as “gut microbiome” and specific risk markers such as trimethylamine N-oxide, TMAO that surged in prevalence after 2010, reflecting a move from generic associations to targeted investigations [6]. Indeed, emerging research highlights microbial-derived molecules as key mediators: for example, the gut metabolite TMAO has been linked to atherosclerosis and adverse cardiac events, spurring intensive work on its role as both biomarker and causal factor [7]. Likewise, advanced multi-omics studies now uncover novel bacteria and metabolic pathways influencing CVD outcomes, a recent large cohort analysis

identified gut *Oscillibacter spp.* capable of metabolizing cholesterol and potentially modulating host lipid levels [8]. These findings illustrate how the field has progressed from observational reports to mechanistic insights, with an increasing emphasis on the "gut-heart" axis as a complex, bidirectional interplay.

This research area has become highly global and collaborative. The United States and China have emerged as dominant contributors in publication output and cross-national partnerships, alongside key European groups, resulting in a multi-centered but interconnected scientific network. For instance, Cleveland Clinic–affiliated researchers are among the most prolific, reflecting how a few expert groups have shaped the field. International consortia have yielded robust findings, for instance, a multi-ethnic study recently confirmed that elevated TMAO levels independently predict incident cardiovascular events across diverse populations [7]. The co-citation landscape is anchored by seminal studies that established gut microbes and their metabolites as novel factors in CVD. Foundational papers linking microbial metabolites like TMAO to coronary artery disease risk remain among the most frequently cited, forming the intellectual backbone of the field [9]. Collectively, the evolving collaboration and citation network indicates that microbiome research in cardiology is both widely influential and built on a core set of transformative findings.

Increasingly, investigators are exploring the gut microbiome as both a diagnostic tool and therapeutic target in cardiovascular medicine. Gut microbial signatures such as specific taxa or diversity measures are under study for prognostic value in stratifying patients' CVD risk, and microbial metabolites like TMAO are being examined as predictors and potential intervention targets [7]. Early interventional studies including dietary modifications, prebiotic or probiotic supplementation suggest it is possible to favorably alter host metabolic and inflammatory profiles, though results have been mixed. The concept of precision cardiology anchored in the microbiome is gaining traction: a 2023 review emphasized that tailoring heart failure management to an individual's gut microbiome profile could improve therapeutic responses [10]. Novel therapeutics aimed at microbial pathways are also on the horizon. For example, inhibitors of TMAO synthesis and other microbial enzymes have shown promise in preclinical models, pointing to new strategies to reduce cardiovascular risk by modulating the gut ecosystem. In summary, microbiome-based biomarkers and interventions are approaching clinical reality, and ongoing research will determine how best to harness the gut microbiota for improving cardiovascular health [1].

Despite tremendous progress, important knowledge gaps and challenges remain. Many studies linking gut microbes to CVD are observational, making it difficult to establish causality. Confounding factors such as diet, medication, and genetics can influence both microbiota composition and cardiovascular outcomes, and not all analyses fully account for these variables. Methodological heterogeneity in microbiome profiling with different sequencing platforms and analytical pipelines also contributes to inconsistent findings across studies. Our bibliometric approach has its own limitations, including potential bias toward English-language and indexed publications, and it may not capture the most recent emerging work. Moving forward, more longitudinal and intervention studies are needed to confirm causal relationships, for example, clinical trials to test whether modifying the gut microbiome can directly improve patient outcomes. Future research should also integrate multi-omic data with large patient cohorts to identify actionable microbial biomarkers and therapeutic targets. In conclusion, the period 2005–2025 has firmly established the gut microbiota as a significant player in cardiovascular disease. While challenges regarding causality and translation persist, the field's rapid development and collaborative depth bode well for its maturation. Addressing current limitations with rigorous, interdisciplinary research will be crucial to unlocking novel microbiome-based strategies for CVD prevention and therapy [1].

5. Conclusion

Over the two decades from 2005 to 2025, research on the gut microbiota and cardiovascular disease has expanded exponentially, evolving from initial correlation studies to in-depth mechanistic and therapeutic investigations. Bibliometric trends highlight the gut-heart axis as a rapidly emerging and interdisciplinary frontier within cardiovascular science. These advances underscore its significant potential to inform the development of novel preventive and therapeutic strategies for CVD.

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Disclosure statement

The authors declare no conflict of interest.

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