



Original article

Global trends and collaborative networks in endocrinology research: A 2000–2023 co-authorship analysis

Naruaki Ogasawara  ¹

¹The Japanese Society of Internal Medicine, Tokyo, Japan

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Abstract

Context: Endocrinology plays a critical role in understanding hormonal systems that regulate metabolism, growth, and reproductive health. Global research in this field has surged in response to the rising prevalence of endocrine disorders such as diabetes, thyroid diseases, and metabolic syndrome. Collaborative dynamics among researchers have driven advancements in diagnostic techniques, therapeutic approaches, and disease-prevention strategies.

Objective: This study aims to analyze the collaborative structure of co-authorship networks in endocrinology research from 2000 to 2023. It investigates patterns of international cooperation, identifies influential researchers and institutions, and examines how collaboration impacts research innovation and productivity.

Methodology: The research analyzed 19,127 endocrinology-related articles from the Web of Science (2000–2023). Using Python (version 3.10.5), the analysis applied macro-level metrics (network density, clustering coefficient, components, and average distance) and micro-level metrics (degree, closeness, and betweenness centrality) to evaluate network structures and identify key contributors.


Results: Endocrinology research networks evolved from fragmented structures with low density (2000–2009) to increasingly clustered and interconnected networks by 2020–2023. Key researchers, including Savage MO, Murad M. Hassan, and Ji Linong, demonstrated consistently high centrality measures and served as pivotal collaborators. Influential researchers and collaborative clusters shaping the field were identified.

Conclusion: This study highlights the significance of collaborative networks in shaping endocrinology research. By identifying influential contributors and collaboration clusters, the findings emphasize the value of international partnerships in addressing complex endocrine disorders. These insights provide a framework for enhancing scientific cooperation in medical research and offer strategies to optimize collaboration for future innovations in endocrinology.

Keywords: Endocrinology, Co-Authorship network, Research collaboration, Network analysis, Scientific cooperation, Research trends, Global health.

Highlights

- This study examines 19,127 endocrinology-related articles indexed in the Web of Science from 2000 to 2023, revealing collaboration patterns and network dynamics.
- Macro-level metrics (network density, clustering coefficient, components, average distance) and micro-level metrics (degree centrality, closeness centrality, betweenness centrality) were analyzed using Python (version 3.10.5).
- It evaluates insights into international research trends, highlighting key contributors and transnational partnerships in addressing endocrine disorders.
- Findings emphasize the pivotal role of international collaboration in driving innovation and addressing the global challenge of endocrine disorders.

 **Corresponding author:** Naruaki Ogasawara, The Japanese Society of Internal Medicine, 3-28-8 Hongo Bunkyo-Ward, Tokyo, Japan. E-mail: n-ogasawara@naika.or.jp

Tendencias mundiales y redes de colaboración en la investigación endocrinológica: un análisis de coautoría 2000–2023

Resumen

Contexto: la endocrinología desempeña un papel fundamental en la comprensión de los sistemas hormonales que regulan el metabolismo, el crecimiento y la salud reproductiva. La investigación mundial en este campo se ha disparado en respuesta a la creciente prevalencia de trastornos endocrinos, como la diabetes, las enfermedades tiroideas y el síndrome metabólico. La dinámica de colaboración entre investigadores ha impulsado avances en las técnicas de diagnóstico, los enfoques terapéuticos y las estrategias de prevención de enfermedades.

Objetivo: este estudio tiene como objetivo analizar la estructura de colaboración de las redes de coautoría en la investigación endocrinológica desde 2000 hasta 2023. Investiga patrones de cooperación internacional, identifica investigadores e instituciones influyentes y examina cómo la colaboración afecta a la innovación y la productividad de la investigación.

Metodología: la investigación analizó 19 127 artículos relacionados con la endocrinología de la Web of Science (2000–2023). Utilizando Python (versión 3.10.5), el análisis aplicó métricas de macronivel (densidad de red, coeficiente de agrupación, componentes, distancia media) y métricas de micronivel (grado, cercanía y centralidad de la interrelación) para evaluar las estructuras de red e identificar a los principales contribuyentes.

Resultados: las redes de investigación en endocrinología evolucionaron de estructuras fragmentadas con baja densidad (2000–2009) a redes cada vez más agrupadas e interconectadas en 2020–2023. Los investigadores clave, incluidos Savage MO, Murad M. Hassan y Ji Linong, demostraron medidas de centralidad consistentemente altas y sirvieron como colaboradores fundamentales. Se identificaron influenciadores clave y grupos de colaboración que configuran el campo.

Conclusiones: este estudio destaca la importancia de las redes de colaboración en la configuración de la investigación en endocrinología. Mediante la identificación de colaboradores influyentes y grupos de colaboración, los resultados ponen de relieve el valor de las asociaciones internacionales a la hora de abordar trastornos endocrinos complejos. Estas ideas proporcionan un marco para mejorar la cooperación científica en la investigación médica y ofrecen estrategias para optimizar la colaboración para futuras innovaciones en endocrinología.

Palabras clave: endocrinología, red de coautoría, colaboración en investigación, análisis de redes, cooperación científica, tendencias en investigación, salud global.

Destacados

- Este estudio examina 19 127 artículos relacionados con la endocrinología indexados en la Web of Science desde 2000 hasta 2023, revelando patrones de colaboración y dinámicas de red.
- Se analizaron métricas de nivel macro (densidad de red, coeficiente de agrupamiento, componentes, distancia media) y métricas de nivel micro (centralidad de grado, centralidad de proximidad, centralidad de interrelación) utilizando Python (versión 3.10.5).
- Se evalúan las perspectivas sobre las tendencias internacionales en investigación, destacando los principales contribuyentes y las alianzas transnacionales en la lucha contra los trastornos endocrinos.
- Los resultados destacan el papel fundamental de la colaboración internacional para impulsar la innovación y abordar el desafío mundial de los trastornos endocrinos.

Introduction

Endocrinology, a vital branch of medical science, investigates hormonal systems that regulate essential physiological processes, including metabolism, growth, and reproductive health. The global surge in endocrine disorders—including diabetes, thyroid diseases, and metabolic syndrome—has heightened the importance of research in this field (1). Researchers in the United States and European countries (such as the United

Kingdom, Germany, and France) have primarily focused on lifestyle-related diseases, particularly type 2 diabetes and obesity, driven by sedentary lifestyles and dietary habits (2). These regions have significantly advanced therapeutic strategies, notably in clinical treatments and patient health outcomes, through drug development, genetic research, and precision medicine (3). Additionally, cardiovascular risks associated with metabolic syndromes remain a major research focus in these countries (4–5).

Asian countries, particularly those in South Asia (with India as a primary contributor) and East Asia (especially Japan, China, and South Korea), face a unique dual burden of endocrine disorders. Lifestyle-related conditions have risen alongside genetic and environmentally influenced disorders. For instance, rapid urbanization and lifestyle shifts are directly linked to the high prevalence of diabetes and metabolic syndrome in India (6–7), while Japan, China, and South Korea exhibit high rates of thyroid disorders and metabolic conditions (8). Researchers in these regions contribute significantly to the genetic and epidemiological study of endocrine diseases, emphasizing treatment approaches tailored to their populations' genetic and environmental specificities. Brazil leads contributions in Latin America, with extensive research on obesity and diabetes that examines these conditions within broader socio-economic and lifestyle contexts (9–10).

The rapid expansion of endocrine disorders has made international collaboration essential for addressing shared global challenges. Network analysis serves as a powerful tool to examine patterns in scientific collaboration systematically, revealing structural dynamics and influence within research communities. Co-authorship network analysis, in particular, maps the interconnected relationships among endocrinology researchers, providing a comprehensive view of scientific cooperation across institutional and national boundaries.

Data and methods

Research scope and analytical framework

This study examines endocrinology-related literature indexed in the Web of Science (WoS) Core Collection from 2000 to 2023, analyzing 19,127 articles retrieved on October 17, 2024. Network analysis is used to elucidate collaboration patterns, identify leading researchers, and highlight prominent institutions in the field. The analysis tracks the evolution of international cooperation, identifies periods of intensified collaboration, and explores the impact of these relationships

on research productivity and innovation in endocrinology.

The WoS data reveals notable trends in publication volume. Publications increased sharply in 2009, peaked around 2012, declined temporarily in 2014, and resurged starting in 2019 (Figure 1). Advancements in technologies such as next-generation sequencing and enhanced diagnostic tools likely drove the initial surge. The growing prevalence of diabetes and obesity heightened research interest further. The 2019 resurgence reflects progress in therapeutic areas, such as immunotherapy and gene therapy, alongside increased research addressing the interplay between endocrine function and infectious diseases, particularly focusing on COVID-19's implications for endocrine health (11).

Data Collection: This study analyzed co-authorship networks based on endocrinology-related articles indexed in the WoS Core Collection, covering the period from 2000 to 2023. A total of 19,127 articles published during this period (as of October 2024) were collected. These articles were retrieved using the search topic "Endocrinology" to capture relevant publications, providing a comprehensive dataset to evaluate collaborative patterns in this field.

Analytical tools and environment: The analysis was conducted using the Python programming language (version 3.10.5) within the PyCharm Integrated Development Environment (IDE), version 2022.1.3. Python's robust libraries for network analysis, including NetworkX, provided the computational tools necessary to calculate both macro-level and micro-level network metrics in the co-authorship networks.

Network analysis methodology: The network analysis aims to examine the structure and collaborative dynamics of the co-authorship networks in endocrinology, with a focus on the following macro-level and micro-level metrics:

Macro-level metrics

Network density: Calculated as the ratio of the actual number of edges to the maximum possible number of edges in the network, this metric provides insight into the overall connectivity of the network (12).

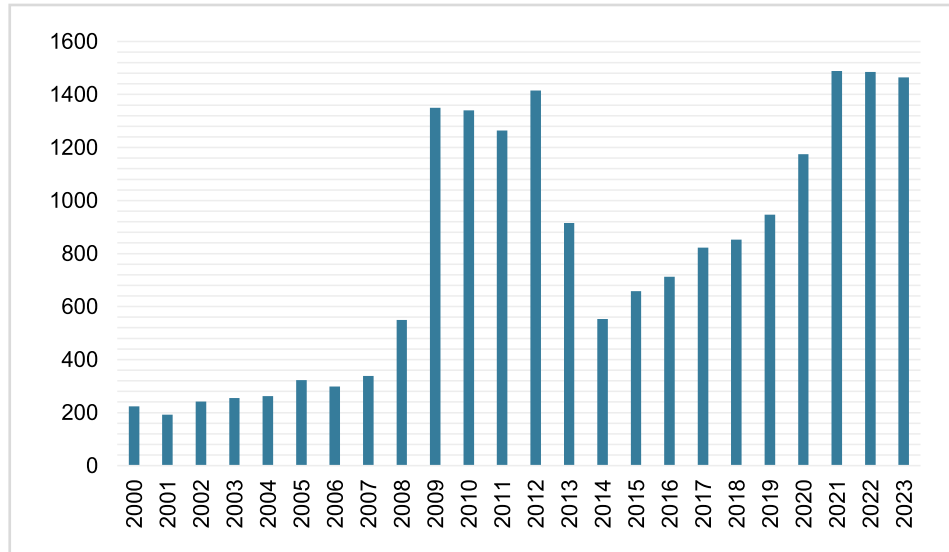


Figure 1. Trend of the number of papers published in the Web of Science Core Collection

Source: Own elaboration.

Clustering coefficient: This metric measures the extent to which nodes in the network tend to cluster together, indicating the degree of collaboration in research groups (13).

Components: The analysis identified and counted connected components within the network to understand the number and size of independent subgroups, illustrating the fragmentation or integration in research collaboration (14).

Average distance: The average shortest path length between nodes in the network was calculated, reflecting how closely connected researchers are across the entire network.

Micro-level metrics

Degree centrality: This metric represents the number of edges each node has, measuring each researcher's direct connections and their importance within the network (12).

Closeness centrality: Closeness centrality measures how close each node is to all other nodes in the network, indicating the efficiency with which a researcher can reach others (13).

Betweenness centrality: This metric evaluates the extent to which a node lies on the shortest path between other nodes, assessing

the influence of a researcher as a bridge between different parts of the network (14).

These metrics, grounded in network science methodology, enable an in-depth analysis of the collaborative structure and highlight key researchers in the field of endocrinology, allowing us to track the evolution of collaborative patterns from 2000 to 2023.

Results

2000–2009 Analysis of endocrinology research networks

During the 2000–2009 period, the network density of endocrinology research was calculated at 0.00044, indicating a sparse network with limited collaboration among researchers (Table 1). Despite this low density, the average clustering coefficient was high (0.9126), showing that research clusters, though loosely connected, tended to have strong internal collaborations (Figure 2). The network comprised 2,192 distinct components, suggesting fragmented collaboration structures (Table 1). The average distance was infinite, reflecting disconnected components (15).

Table 1. Network metrics

Metric	2000 - 2009	2010 - 2019	2020 - 2023
Network density	0,00044	0,00025	0,00037
Average clustering coefficient	0,9126	0,9129	0,9329
Number of components	2192	3550	2712
Average distance	infinite	infinite	infinite

Note. This table presents the overall network metrics for endocrinology research from 2000 to 2023. Metrics such as network density, clustering coefficient, average path length, and number of components are reported for each time period (2000–2009, 2010–2019, 2020–2023).

Source: Own elaboration.

Top 20 Endocrinology Researcher Network from 2000 to 2009

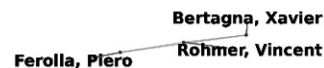
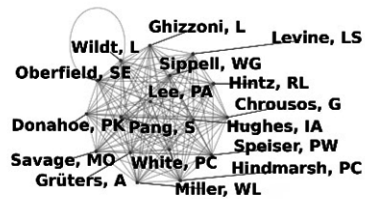


Figure 2. Top 20 endocrinology researcher network from 2000 to 2009

Note. This figure visualizes the co-authorship network of the top 20 researchers in endocrinology between 2000 and 2009. Node sizes are proportional to degree centrality, and edges represent collaborative relationships.

Source: Own elaboration.

In terms of centrality measures, the top contributors by degree centrality included Oberfield SE (0.0049), Levine LS (0.0045), and Savage MO (0.0044), indicating their frequent collaborations (Table 2). By closeness centrality, Savage MO (0.0113) and Grütters A (0.0110) demonstrated

high accessibility across collaborative pathways (Table 3). Betweenness centrality revealed Grossman AB (0.0004) and Savage MO (0.0004) as critical intermediaries, enhancing connectivity among disparate research groups (Table 4).

Table 2. Top 20 nodes by degree centrality

Rank	2000 - 2009	Degree Centrality	2010 - 2019	Degree Centrality	2020 - 2023	Degree Centrality
1	Oberfield, SE	0,0049	Yildiz, M.	0,0047	Sahin, Mustafa	0,0059
2	Levine, LS	0,0045	Boysan, S. N.	0,0047	Polak, Michel	0,0045
3	Savage, MO	0,0044	Polat, H.	0,0047	Canturk, Zeynep	0,0045
4	Pang, S	0,0043	Yasar, H. Y.	0,0047	Batman, Adnan	0,0045
5	Hindmarsh, PC	0,0042	Yilmaz, Candeger	0,0046	Yilmaz, Merve	0,0044
6	Sippell, WG	0,0041	Koc, G.	0,0046	Ugur, Kader	0,0043
7	Hintz, RL	0,0038	Satman, Ilhan	0,0045	Fisher, A. D.	0,0043
8	Speiser, PW	0,0037	Imamoglu, Sazi	0,0045	Ristori, J.	0,0043
9	Ghizzoni, L	0,0036	Akdere, T.	0,0045	Salerno, Mariacarolina	0,0043
10	Bertagna, Xavier	0,0036	Akdogan, C.	0,0045	Omma, Tulay	0,0043
11	Ferolla, Piero	0,0036	Akin, H. S.	0,0045	Karakilic, Ersen	0,0042
12	Donahoe, PK	0,0034	Akin, S. A.	0,0045	Pekkolay, Zafer	0,0041
13	Grütters, A	0,0034	Akinici, B.	0,0045	Topaloglu, Omercan	0,0041
14	Hughes, IA	0,0033	Akkorlu, S.	0,0045	Eroglu, Mustafa	0,0041
15	Miller, WL	0,0033	Akpinar, E.	0,0045	Ji, Linong	0,0041
16	Wildt, L	0,0033	Aksoy, D. G.	0,0045	Irwig, M. S.	0,0041
17	Rohmer, Vincent	0,0033	Aksoy, K.	0,0045	Yorulmaz, Goknur	0,0039

18	Lee, PA	0,0033	Aksoy, O. T.	0,0045	Iyidir, Ozlem Turhan	0,0039
19	Chrousos, G	0,0032	Aktan, A. H.	0,0045	Coleman, E.	0,0039
20	White, PC	0,0031	Alam, K.	0,0045	Radix, A. E.	0,0039

Note. This table lists the top 20 researchers in the endocrinology research network ranked by degree centrality. Degree centrality indicates the number of direct collaborations a researcher has within the network, representing their level of active participation.

Source: Own elaboration.

Table 3. Top 20 nodes by closeness centrality

Rank	2000 – 2009	Closeness Centrality	2010 – 2019	Closeness Centrality	2020 – 2023	Closeness Centrality
1	Savage, MO	0,0113	Murad, M. Hassan	0,0813	Polak, Michel	0,0725
2	Grüters, A	0,0110	Pasquali, Renato	0,0796	Umpierrez, Guillermo E.	0,0722
3	Ghizzoni, L	0,0110	Hoeger, Kathleen M.	0,0783	Samson, Susan L.	0,0722
4	Hughes, IA	0,0106	Gambineri, Alessandra	0,0770	Yuen, Kevin C. J.	0,0716
5	Lee, PA	0,0106	Yildiz, Bulent O.	0,0767	Kosiborod, Mikhail	0,0700
6	Oberfield, SE	0,0105	Legro, Richard S.	0,0761	Radovick, Sally	0,0698
7	Levine, LS	0,0105	Arlt, Wiebke	0,0755	Hirsch, Irl B.	0,0697
8	Sippell, WG	0,0105	Pagotto, Uberto	0,0753	Bancos, Irina	0,0697
9	Pang, S	0,0104	Tabarin, Antoine	0,0752	Karavitaki, Niki	0,0696
10	Hindmarsh, PC	0,0104	Tena-Sempere, Manuel	0,0750	McGill, Janet B.	0,0695
11	Hintz, RL	0,0104	Deeb, Asma	0,0748	Bidlingmaier, Martin	0,0695

12	Speiser, PW	0,0104	Marcocci, Claudio	0,0746	Johannsson, Gudmundur	0,0695
13	Donahoe, PK	0,0104	Horikawa, Reiko	0,0745	Hoffman, Andrew R.	0,0695
14	Chrousos, G	0,0104	Arslanian, Silva A.	0,0743	Melmed, Shlomo	0,0695
15	Miller, WL	0,0104	Ehrmann, David A.	0,0743	Coutant, Regis	0,0693
16	Wildt, L	0,0104	Welt, Corrine K.	0,0743	Isidori, Andrea M.	0,0692
17	White, PC	0,0103	Chang, R. Jeffrey	0,0741	Khunti, Kamlesh	0,0691
18	Fujieda, K	0,0103	Lee, Peter A.	0,0741	Garvey, W. Timothy	0,0690
19	Warne, GL	0,0103	Auchus, Richard J.	0,0740	Blonde, Lawrence	0,0688
20	Berenbaum, S	0,0103	Darendeliler, Feyza	0,0740	DeFronzo, Ralph A.	0,0687

Note. This table ranks the top 20 researchers in the endocrinology research network by closeness centrality, which measures how quickly a researcher can interact with others in the network. Researchers with high closeness centrality are positioned closer to all other nodes, facilitating efficient collaboration.

Source: Own elaboration.

Table 4. Top 20 nodes by betweenness centrality

Rank	2000 - 2009	Betweenness Centrality	2010 - 2019	Betweenness Centrality	2020 - 2023	Betweenness Centrality
1	Grossman, AB	0,0004	Murad, M. Hassan	0,0275	Ji, Linong	0,0368
2	Savage, MO	0,0004	Pasquali, Renato	0,0136	Kosiborod, Mikhail	0,0154
3	Grüters, A	0,0004	Millar, Robert P.	0,0121	Zhu, Dalong	0,0120
4	Bernasconi, S	0,0003	Tena-Sempere, Manuel	0,0120	Polak, Michel	0,0116

5	Ghizzoni, L	0,0003	Tsutsui, Kazuyoshi	0,0101	Samson, Susan L.	0,0112
6	Astrup, A	0,0002	Walker, Brian R.	0,0100	Umpierrez, Guillermo E.	0,0110
7	Casanueva, FF	0,0002	Darendeliler, Feyza	0,0086	Renard, Eric	0,0095
8	Holst, JJ	0,0002	Melmed, Shlomo	0,0084	Benhamou, Pierre-Yves	0,0092
9	Krude, H	0,0002	Bulun, Serdar E.	0,0077	Garber, Jeffrey R.	0,0091
10	Biebermann, H	0,0002	Juul, Anders	0,0077	Khunti, Kamlesh	0,0087
11	Monson, JP	0,0002	Arlt, Wiebke	0,0076	Akarsu, Ersin	0,0083
12	Cohen, P	0,0002	Chang, R. Jeffrey	0,0069	Yuen, Kevin C. J.	0,0080
13	Carel, JC	0,0001	Deeb, Asma	0,0067	Papini, Enrico	0,0077
14	Giustina, A	0,0001	Clarke, Iain J.	0,0067	Bancos, Irina	0,0069
15	Cavagnini, F	0,0001	Gambineri, Alessandra	0,0064	Bornstein, Stefan R.	0,0059
16	Ghigo, E	0,0001	Hoeger, Kathleen M.	0,0060	de Beaufort, Carine	0,0057
17	Hughes, IA	0,0001	Yildiz, Bulent O.	0,0060	Eckel, Robert H.	0,0054
18	Sippell, WG	0,0001	Tabarin, Antoine	0,0060	Fernandez, Alberto	0,0053
19	Lee, PA	0,0001	Horikawa, Reiko	0,0059	Hegedus, Laszlo	0,0052
20	Juul, A	0,0001	DeMayo, Francesco J.	0,0057	Arlt, Wiebke	0,0046

Note. This table displays the top 20 researchers in the Endocrinology research network ranked by betweenness centrality, highlighting individuals who act as key intermediaries or bridges within the network. These researchers play crucial roles in connecting disparate parts of the research community.

Source: Own elaboration.

2010–2019 Analysis of endocrinology research networks

From 2010 to 2019, network density decreased slightly to 0.00025, and the network became more fragmented, with 3,550 components (Table 1).

However, the clustering coefficient remained high at 0.9129 (Table 1), maintaining strong localized collaboration patterns (Figure 3). The average distance metric remained infinite, indicating continued separation among components (15).

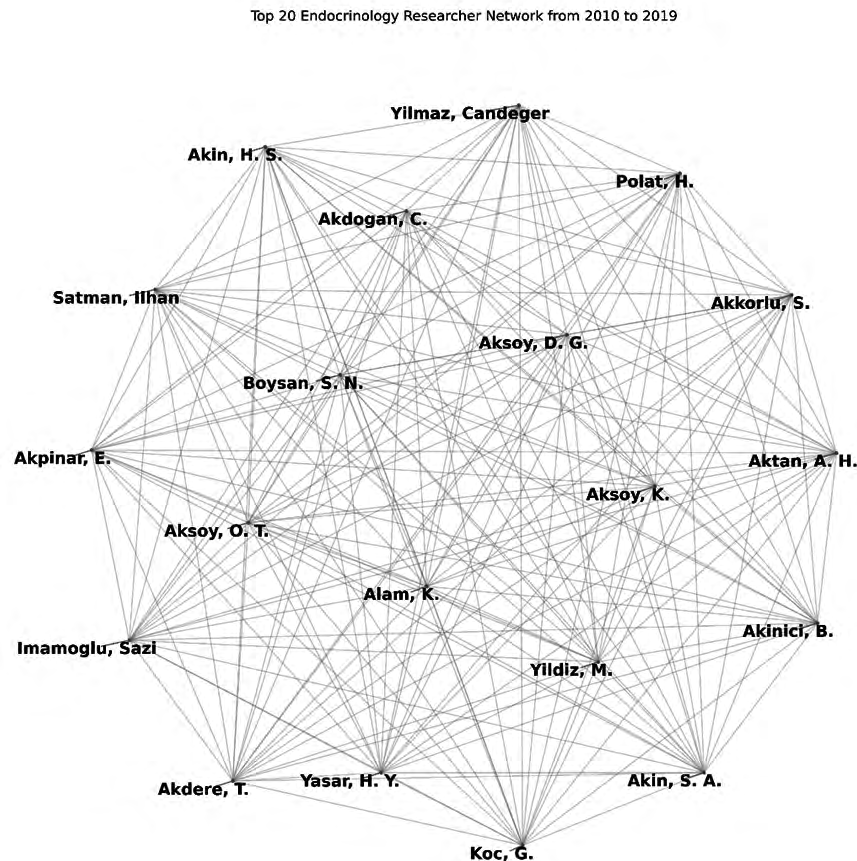


Figure 3. Top 20 endocrinology researcher network from 2010 to 2019

Note. This figure visualizes the co-authorship network of the top 20 researchers in endocrinology between 2010 and 2019. Node sizes are proportional to degree centrality, and edges represent collaborative relationships.

Source: Own elaboration.

This period saw Yildiz M. (0.0047) and Boysan SN (0.0047) as top nodes in degree centrality, highlighting their wide-reaching collaborations (Table 2). In closeness centrality, Murad M. Hassan (0.0813) and Pasquali Renato (0.0796) emerged as highly accessible researchers (Table 3). Murad M. Hassan (0.0275) led in betweenness centrality, followed by Pasquali Renato (0.0136), underscoring

their role as central connectors facilitating cross-group collaborations (Table 4).

Global research distribution and collaboration dynamics

The WoS data demonstrates concentrated endocrinology research output from the United States, with substantial contributions from the

United Kingdom, Germany, France, and other European countries (Figure 4). China, Japan, and India lead Asian contributions, while Brazil remains the primary contributor in Latin America.

This geographic distribution highlights both global commitment to addressing endocrine disorders and regional differences in research focus.

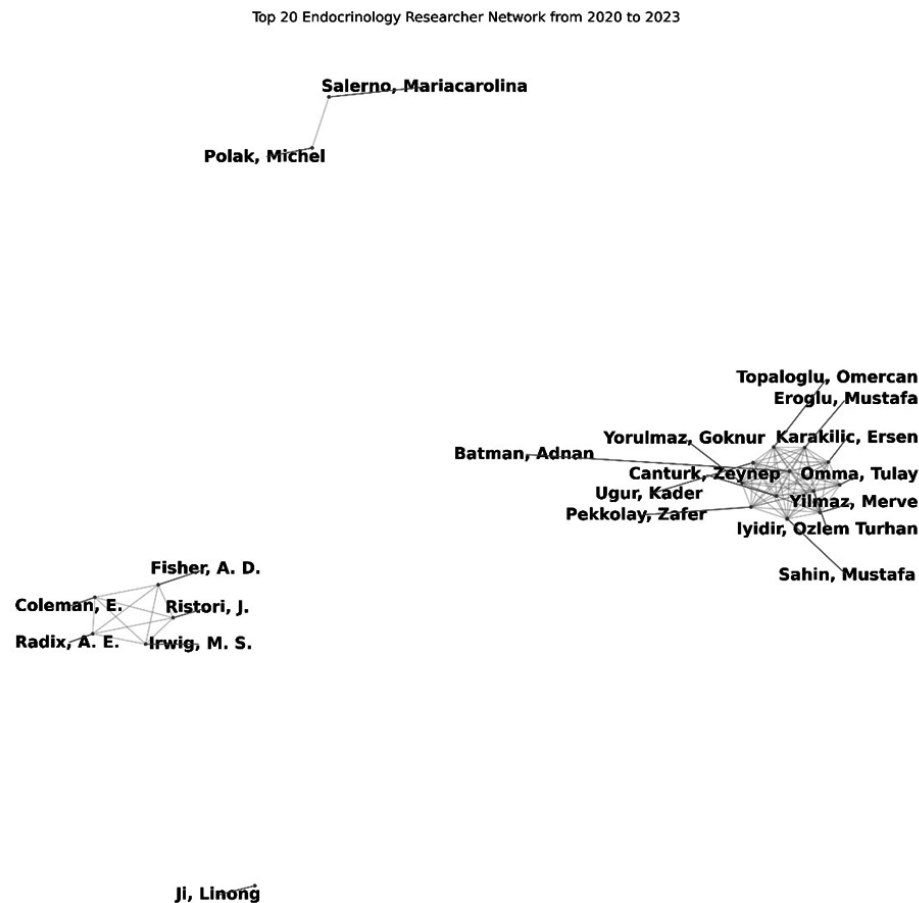


Figure 4. Top 20 endocrinology researcher network from 2020 to 2023

Note. This figure visualizes the co-authorship network of the top 20 researchers in endocrinology between 2020 and 2023. Node sizes are proportional to degree centrality, and edges represent collaborative relationships.

Source: Own elaboration.

The analysis explores these international trends in depth, focusing on key collaboration indicators to evaluate network structure evolution. Co-authorship ties reveal patterns of cross-border collaboration and the influence of key researchers in fostering transnational research partnerships. These insights illuminate how endocrinology research networks adapt to emerging challenges and opportunities.

2020–2023 Analysis of endocrinology research networks

The 2020–2023 period demonstrated an increase in network density to 0.00037, alongside a high clustering coefficient of 0.9329 (Table 1), which reflected an increasingly connected network structure with robust collaborative clusters (Figure 5). The network consisted of 2,712

components, suggesting a consolidation of collaborations compared to the previous period (Figure 5). The average distance remained infinite,

consistent with the presence of segmented network structure (15).

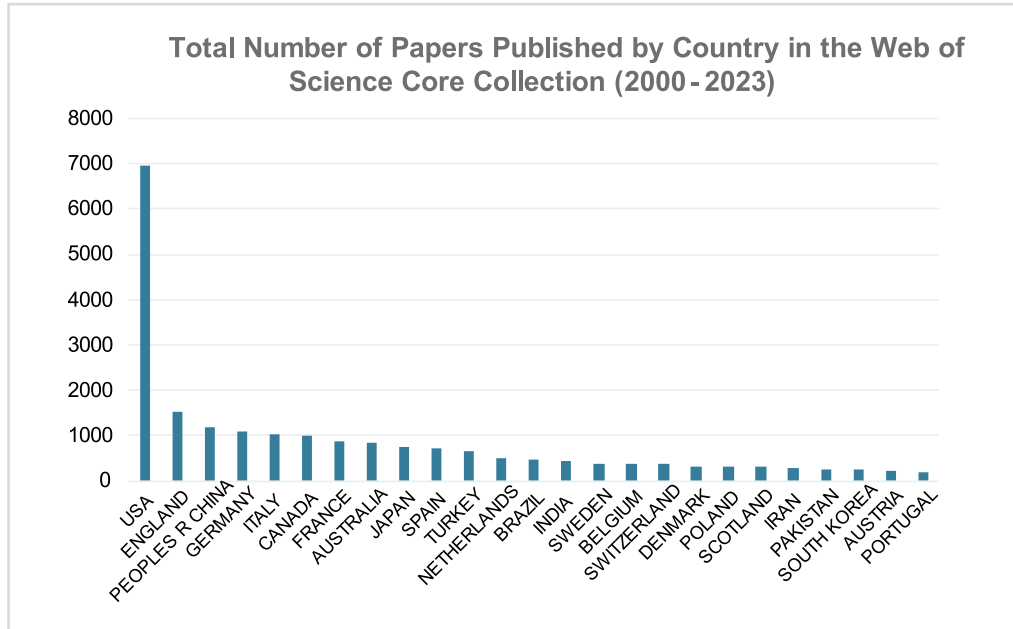


Figure 5. Total number of papers published by country in the Web of Science Core Collection (2000 – 2023)

Source: Own elaboration.

Top nodes by degree centrality in this period included Sahin Mustafa (0.0059) and Polak Michel (0.0045), indicating their extensive research collaborations (Table 2). Polak Michel (0.0725) and Umpierrez Guillermo E. (0.0722) scored highest in closeness centrality, making them central figures in collaboration pathways (Table 3). Betweenness centrality values were highest for Ji Linong (0.0368) and Kosiborod Mikhail (0.0154), emphasizing their roles as pivotal links across the research network (Table 4).

Summary of endocrinology research networks analysis (2000 – 2023)

Across the years analyzed, the endocrinology research network evolved from a fragmented structure with low density to a more interconnected network with increased collaboration and clustering. Researchers like Savage MO (University College

London, UK), Murad M. Hassan (Mayo Clinic, USA), and Ji Linong (Peking University, China) consistently maintained central positions, indicating their significant influence in fostering cross-group collaborations. The high clustering coefficients across periods highlight the presence of strongly connected collaborative clusters, which underpin the advancement of endocrinology research.

Discussion

This network analysis reveals significant patterns in endocrinology research collaboration from 2000 to 2023, demonstrating how the field's collaborative structure has evolved and influenced its development. The results indicate a transformation from a fragmented network structure to a more interconnected framework characterized by robust localized collaborations

and distinct research clusters. Throughout this period, several key researchers and institutions have emerged as central nodes, facilitating increased cross-institutional and international cooperation.

Evolution of network structure and collaborative patterns

The endocrinology research network exhibited distinct characteristics across three time periods analyzed. From 2000 to 2009, the network displayed sparse connectivity, with low density and high fragmentation, as evidenced by multiple components and an infinite average distance. The high clustering coefficient during this period indicates that researchers primarily collaborated within specific clusters, typically bounded by institutional or geographic boundaries. This pattern reflected the contemporary research funding landscape, which often confined collaboration within regional contexts.

During the 2010–2019 period, the network exhibited increased fragmentation while maintaining strong clustering patterns. The decreased network density combined with elevated clustering coefficients suggests that researchers concentrated their collaborative efforts within small, cohesive research groups. Notable researchers such as Murad M. Hassan and Pasquali Renato served as crucial intermediaries during this period, connecting disparate research groups and promoting international collaboration. This evolution coincided with significant advances in precision medicine and next-generation sequencing, which encouraged specialized research partnerships.

From 2020 to 2023, network density showed modest improvement, indicating partial consolidation of collaborative structures. The persistent high clustering coefficient suggests that while segmentation remained, these segments maintained strong internal cohesion. Researchers, including Mustafa Sahin, emerged as central network figures, promoting transnational collaboration. This period also corresponded with an increase in interdisciplinary research addressing global health challenges, particularly diabetes, metabolic syndrome, and COVID-19's impact on endocrine health.

Impact of central figures and institutions

Throughout these periods, researchers with high centrality measures served as collaboration hubs. Figures such as Savage MO, Murad M. Hassan, and Ji Linong consistently demonstrated leadership by contributing substantially to their research domains while facilitating connections across geographic and institutional boundaries. Their affiliations with prestigious institutions, like University College London, the Mayo Clinic, and Peking University, underscore the influential role of established research centers in driving the field's advancement.

Researchers with high betweenness centrality, particularly Ji Linong and Mikhail Kosiborod, functioned as critical network bridges, enabling knowledge and resource transfer between otherwise disconnected groups. This bridging function proves especially valuable in endocrinology, where diverse research areas—from genetic studies to lifestyle disease management—demand multidisciplinary approaches.

Implications and future directions

The analysis highlights the critical role of collaborative networks in advancing endocrinology research. While the consistently high clustering coefficient indicates strong intra-group collaboration, network fragmentation suggests opportunities for enhanced interdisciplinary and international partnerships. The persistence of regional clusters, particularly among researchers in North America, Europe, and Asia, reflects varying research priorities based on local health challenges. North American and European researchers often prioritize lifestyle-related diseases, while Asian researchers contribute significantly to the study of genetic and environmentally influenced disorders.

This research provides a framework for understanding collaborative dynamics in endocrinology and identifies opportunities for bridging network gaps. Future initiatives should focus on fostering cross-regional and interdisciplinary collaborations to address emerging global health challenges more effectively. National governments, healthcare institutions, and academic societies—particularly associations of internal

medicine and endocrinology—must establish stronger partnerships to promote interdisciplinary approaches. These institutional stakeholders should coordinate their efforts to facilitate joint research programs capable of addressing global health challenges that require worldwide coordination and resources. Such systematic collaboration among policymakers, healthcare providers, and academic organizations will create a more robust framework for tackling complex endocrine disorders that transcend national boundaries.

The findings from this network analysis provide valuable insights into the collaborative landscape of endocrinology research, highlighting the roles of key figures, institutions, and geographic regions in shaping the field. These insights suggest strategic directions for strengthening global efforts in endocrine disorder research and treatment.

Significance of the study

This mapping of collaborative dynamics within endocrinology research provides valuable insights on how scientific cooperation shapes the field's growth. The identification of influential researchers, leading research institutions, and key collaboration clusters contributes to understanding the factors driving endocrinology's rapid evolution. Network structure examination over time offers a model for assessing research networks in other medical fields, revealing how collaboration dynamics influence scientific discovery's pace and direction. This analysis emphasizes international collaboration's pivotal role in advancing scientific innovation and addressing endocrine disorders' growing complexity, paving the way for improved clinical outcomes worldwide.

The study presents a comprehensive view of the collaborative framework within endocrinology, demonstrating how collective research efforts worldwide contribute to understanding and addressing pressing medical challenges.

Conclusion

Network analysis of endocrinology research collaborations from 2000 to 2023 revealed a shift from fragmented, localized networks to increasingly connected and clustered international

collaborations. This transformation reflects the field's growing recognition that addressing complex endocrine disorders, which continue to surge globally, requires collective expertise and resources.

The early 2000s showed sparse connectivity in endocrinology research networks, characterized by low network density and numerous independent components with limited cross-group interactions. The field's expansion, driven by advancements in molecular biology, precision medicine, and increased focus on endocrine-related comorbidities such as metabolic syndrome and diabetes, catalyzed enhanced inter-group collaboration. By 2020–2023, the network demonstrated higher density, fewer isolated components, and consistently high clustering coefficients, indicating more mature collaborative structures that facilitate knowledge exchange and innovation.

Key researchers, including Savage MO (University College London, UK), Murad M. Hassan (Mayo Clinic, USA), and Ji Linong (Peking University, China), emerged as central figures across different periods. These individuals served as both direct collaborators and essential connectors across otherwise isolated research groups. Their sustained influence within co-authorship networks demonstrates how individual researchers can effectively bridge geographic and institutional divides, thereby enhancing the field's capacity to address pressing endocrine health challenges.

This analysis maps the collaborative landscape of endocrinology research and highlights the critical role of international partnerships in advancing scientific and clinical progress. The increasing complexity of global endocrine health issues makes it imperative to maintain and strengthen these interconnected research networks to accelerate discoveries and ensure the timely translation into meaningful clinical outcomes. These findings provide a framework for evaluating and enhancing collaborative efforts within medical research networks, contributing to more effective responses to endocrine health challenges worldwide.

Ethics approval statement

The present study did not require ethics committee approval as it relied on publicly available

data and employed network analysis methodologies using Python.

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