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Male Infertility : Where is the Research Heading? A Bibliometric Perspective

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Abstract. *Male infertility is a growing concern in reproductive health, affecting millions worldwide. Despite its significant impact on couples' ability to conceive, it remains underexplored compared to female infertility. This study offers a comprehensive bibliometric analysis of male infertility research, identifying trends, key contributors, and emerging areas of focus. By analyzing publication patterns, leading journals, influential authors, and collaborative networks, we aim to provide a nuanced understanding of the current state and future directions of this research field. The insights gained are expected to guide future investigations, enhance collaborations, and inform policymakers and clinicians about this evolving area. A systematic literature search was conducted in Scopus and Web of Science databases to retrieve relevant publications on male infertility. ScientoPy was used and bibliometric indicators, such as publication output, citation analysis, author collaboration networks, and keyword co-occurrence analysis, were used to explore the intellectual structure and research trends in this domain. Visualization tools, including VOSviewer, were employed to present the findings. The analysis included 2726 publications spanning from 2014 to 2024. The results reveal the most productive authors, influential journals, and highly cited publications in the field. Key research themes, emerging topics, and the evolution of the research landscape are discussed. Collaborations among authors, institutions, and countries are also examined to identify the intellectual structure and global research networks. This analysis provides valuable insights into the current state of research on male infertility The findings highlight the critical areas of focus, influential studies, and collaborative patterns that have shaped the field. Implications for future research directions, evidence-based practice, and potential areas for interdisciplinary collaboration are discussed.*

Keywords. *male infertility, bibliometric analysis, reproductive medicine, emerging trends*

1. INTRODUCTION

Male infertility is a widespread health issue, affecting 8-12% of couples globally, with nearly half of these cases being due to male factors (The Lancet Diabetes & Endocrinology, 2022). Despite how common it is, research into male infertility has historically lagged behind that of female infertility, both in terms of funding and scientific output (Boivin et al., 2023). However, recent advances in reproductive medicine, molecular biology, and genomics have significantly pushed the field forward (Salinas-Ríos et al., 2022). To better address this issue, it is essential to understand where current research is headed, identify existing gaps, and find ways to improve clinical outcomes for affected men.

Bibliometric analysis provides a powerful tool to map the scientific landscape, uncovering trends, key contributors, and emerging areas of focus (Azizan et al., 2024). By examining patterns in research productivity, citations, and collaborations, this approach

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offers a comprehensive view of the field's progress. In the case of male infertility, bibliometric insights are invaluable for highlighting the work of leading countries, institutions, and researchers while identifying areas that still need more attention and innovation.

This study aims to provide a detailed bibliometric analysis of male infertility research over the past two decades. We will examine global trends, key research areas, and how interdisciplinary approaches have shaped the field's development. The insights from this analysis will help inform future research directions and highlight ways to address the remaining unmet needs in male reproductive health.

By offering a data-driven perspective on the state of male infertility research, this study seeks to contribute meaningfully to the ongoing discussion about the challenges and opportunities in this important area of reproductive medicine.

2. LITERATURE REVIEW

Male infertility research has gained significant attention in recent years, with oxidative stress, genetics, and assisted reproductive technologies (ART) emerging as key focus areas. Oxidative stress has been widely linked to sperm dysfunction, yet studies on antioxidant therapy show mixed results, with some highlighting its benefits (Agarwal et al., 2017) while others question its efficacy (Torres-Arce et al., 2021). Similarly, genetic factors such as Y chromosome microdeletions and epigenetic modifications are crucial in male infertility (Colaco & Modi, 2018; Urrutia et al., 2020), but genetic screening remains costly and inaccessible in many settings. ART, including intracytoplasmic sperm injection (ICSI) and in vitro fertilization (IVF), has provided alternative solutions, yet concerns remain regarding the transmission of genetic abnormalities (Palermo et al., 2019; Esteves et al., 2020). Additionally, emerging research in proteomics offers promising biomarkers for diagnosing unexplained infertility, though further validation is needed (Urrutia et al., 2020).

Despite these advancements, several contradictions and gaps persist. The lack of standardized antioxidant treatment protocols, limited application of genetic screening, and context-specific findings hinder universal adoption of research outcomes. Studies predominantly focus on Western populations, overlooking environmental and lifestyle influences in other regions (Azizan et al., 2023). Moreover, bibliometric analyses, while valuable for identifying research trends, often exclude non-indexed publications, leading to potential biases. Future research should prioritize standardized antioxidant therapies,

expand genetic and multi-omics studies, and assess long-term ART outcomes to develop more effective and personalized infertility treatments. Addressing these gaps through interdisciplinary collaboration will enhance diagnostic precision and treatment success for male infertility.

3. METHODS

Bibliometric Analysis

The bibliometric analysis in this study was conducted using the Web of Science (WoS) and Scopus databases. These two databases were selected based on the recommendations of previous bibliometric studies, which have highlighted the complementary coverage and advantages of using both databases (Azizan et al., 2024). The search was performed in August 2024 using a combination of keywords related to the research topic, including "male infertility," “men infertility,” and "bibliometric analysis." The search was limited to publications from 2014 to 2024 to ensure the inclusion of the most recent and relevant research in the field. The bibliometric data extracted from the databases included information such as publication year, author, affiliation, journal, citation count, and keywords. This data was then analyzed using a combination of performance analysis and science mapping techniques, as recommended by previous studies (Azizan et al., 2023). Performance analysis was used to assess the productivity and impact of the research, while science mapping techniques, such as co-authorship networks and keyword co-occurrence analysis, were employed to visualize the intellectual structure and thematic evolution of the field (Muhdi et al., 2024). The co-occurrence analysis of author keywords was conducted using VOSviewer, a widely used software for bibliometric visualization and analysis. This enrichment analysis provided insights into the main themes and research foci within the field (Salinas-Ríos et al., 2022).

Procedural Analysis

In addition to bibliometric analysis, a detailed procedural analysis was conducted to gain a deeper understanding of the research methods and approaches used in the identified studies. This involved a close review of the full-text articles, with a focus on the methodology sections. The keywords were selected based on a preliminary review of the literature and in consultation with subject matter experts (Azizan et al., 2024). The inclusion criteria were: (1) publications related to male infertility research, (2) articles or reviews published in peer-reviewed journals, and (3) publications in English. The exclusion criteria were: (1) conference papers, book chapters, or other non-peer-reviewed

publications, and (2) publications not related to the research topic (Salinas-Ríos et al., 2022). The findings from the procedural analysis were then integrated with the insights from the bibliometric analysis to provide a comprehensive overview of the current state of research on the topic and to identify potential areas for future investigation (Boivin et al., 2023).

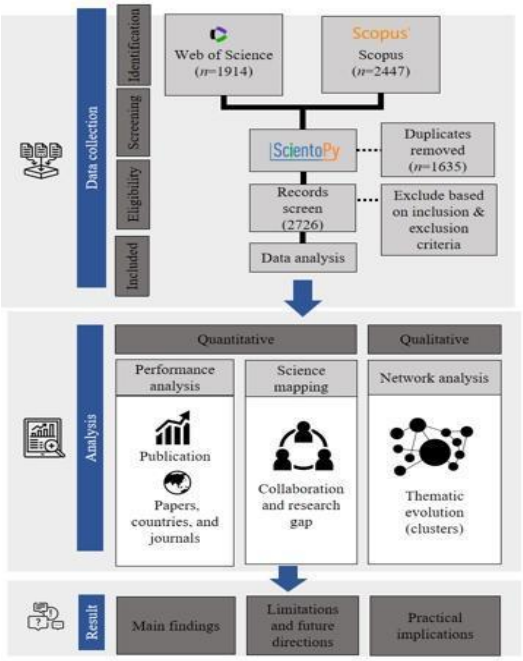

Figure. 1 The study flowchart

4. RESULTS

Publication trends over time

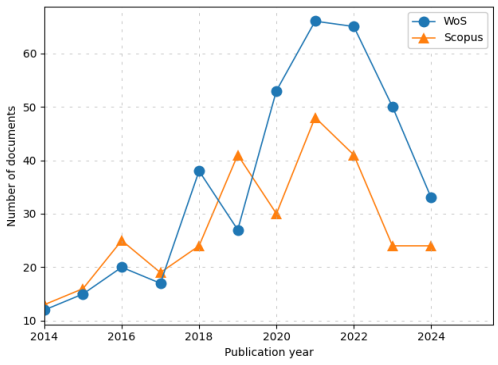

Fig. 2 Publication trends over time

The data shows that the Web of Science (WoS) consistently leads in publication output and impact compared to Scopus. WoS has a higher total number of publications (396 vs. 305), a stronger h-Index (63 vs. 34), and a greater average documents per year (41.5 vs. 24). These metrics indicate that research in WoS is more frequently cited and of higher

influence in the field. Despite this, both databases show negative annual growth rates (-16 for WoS and -8.5 for Scopus), signaling a decline in publication output over time. Notably, WoS has a higher percentage of documents published in the last year (21% vs. 15.7%), suggesting it remains more active in recent research.

Publication trends over time reveal that both databases saw a peak in output around 2021, followed by a decline in subsequent years. WoS reached its highest output in 2021 with 66 publications, while Scopus peaked at 48 publications. However, both databases experienced a significant drop by 2024, with WoS decreasing to 33 publications and Scopus stabilizing at 24. These trends could indicate that the research interest or funding in this area has diminished. Overall, WoS emerges as the more comprehensive and impactful database, especially during the peak years, though both sources reflect a waning interest in recent times.

Leading countries

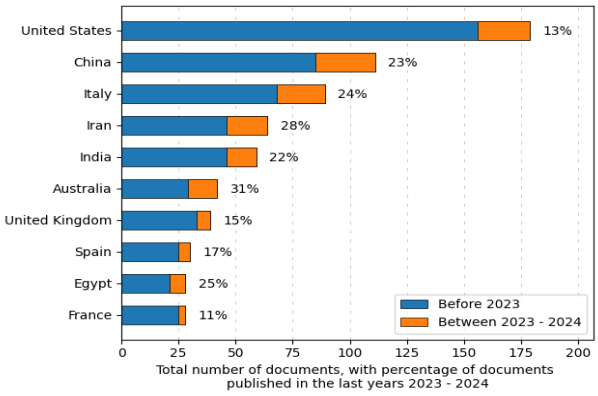

Fig. 3 Leading Countries

The data shows that while the United States has long been the leading contributor to research in this field, its influence appears to be fading in recent years as publication numbers decline. Meanwhile, countries like China and Italy are stepping up, particularly in the later years, reflecting increased interest and investment in this area. Iran, India, and Australia are also making steady progress, gradually becoming more significant contributors to the global research landscape. On the other hand, nations like Spain, Egypt, and France show more erratic engagement, with smaller and less consistent outputs.

This shift in research activity points to changing dynamics, with Asian and European countries playing a more prominent role. The declining output from traditionally dominant players like the United States may suggest that their focus and funding priorities are evolving, allowing for a more balanced global contribution to this research field.

Top journals

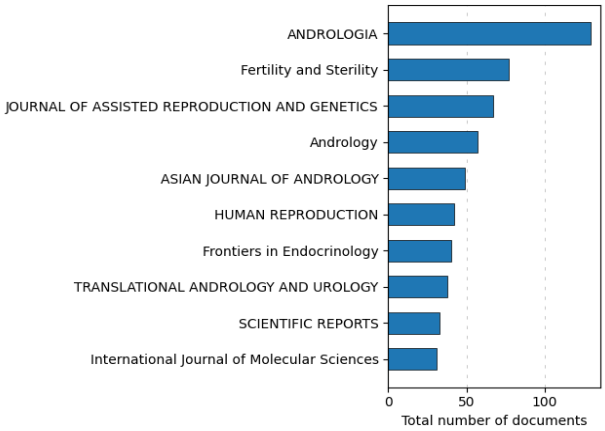

Fig. 4 Top Journals

The data shows that Andrologia (129 articles), Fertility and Sterility (77 articles), and the Journal of Assisted Reproduction and Genetics (67 articles) have published the most research on male infertility. Andrologia leads the field, with consistent publication activity and a notable peak in 2018 when it published 30 articles. This journal clearly plays a key role in advancing research on male infertility, particularly in clinical and diagnostic areas. Meanwhile, Fertility and Sterility and the Journal of Assisted Reproduction and Genetics are also highly influential, addressing a broader range of topics including reproductive technologies and genetic factors related to infertility.

Other noteworthy contributors include Andrology (57 articles), the Asian Journal of Andrology (49 articles), and Human Reproduction (42 articles), all of which are leading journals focused on reproductive medicine and male health. Additionally, newer players like Frontiers in Endocrinology and Scientific Reports are gaining prominence, especially in recent years, as they expand the field to include molecular and translational research perspectives. This spread highlights that the bulk of male infertility research is being concentrated in journals dedicated to reproductive health, andrology, and assisted reproduction

Top 10 Cited Articles (minimum 100 citations)

Table 1 Top 10 Cited Articles

Titles	Total Citation
A unique view on male infertility around the globe	1.064
Trends of male factor infertility, an important cause of infertility: A review of literature	680
Oxidative stress and male infertility	566
Male infertility	555

Mutations in DNAH1, which encodes an inner arm heavy chain dynein, lead to male infertility from multiple morphological abnormalities of the sperm flagella	336
The diagnosis of male infertility: an analysis of the evidence to support the development of global WHO guidance-challenges and future research opportunities	312
Role of oxidative stress in male infertility: An updated review	310
Oxidative stress and male infertility: current knowledge of pathophysiology and role of antioxidant therapy in disease management	300
Sperm DNA damage caused by oxidative stress: Modifiable clinical, lifestyle and nutritional factors in male infertility	294
Zika Virus Causes Testis Damage and Leads to Male Infertility in Mice	294

The table of highly cited papers on male infertility reveals key research themes and influential works shaping the field. The most cited article, *"A unique view on male infertility around the globe"*, with over 1,000 citations, underscores the global significance of male infertility and its wide-reaching impact on reproductive health. Similarly, the paper *"Trends of male factor infertility"* highlights male infertility as a crucial contributor to overall infertility, emphasizing its importance in scientific discourse. A notable trend in the research is the central role of oxidative stress, with multiple highly cited papers discussing its effects on sperm quality and DNA integrity. The substantial citation counts for these works reflect the recognition of oxidative stress as a critical factor in male infertility and its management through antioxidant therapies, making it a dominant research area.

In addition to oxidative stress, other important research themes include genetic factors and the development of diagnostic criteria. The article on *DNAH1 mutations*, which explores the genetic causes of sperm abnormalities, reflects the increasing focus on molecular and genetic mechanisms in male infertility. Papers such as *"The diagnosis of male infertility"*, which contributed to global WHO guidance, highlight the importance of standardized diagnostic tools in clinical practice. Emerging topics, such as the impact of infectious diseases like Zika on male fertility, also appear in the highly cited works, signaling a broadening scope of research. Overall, the bibliometric data points to a growing focus on oxidative stress, genetics, and diagnostics, while also emphasizing lifestyle factors and the global health implications of male infertility.

Co-occurrence analysis of keywords

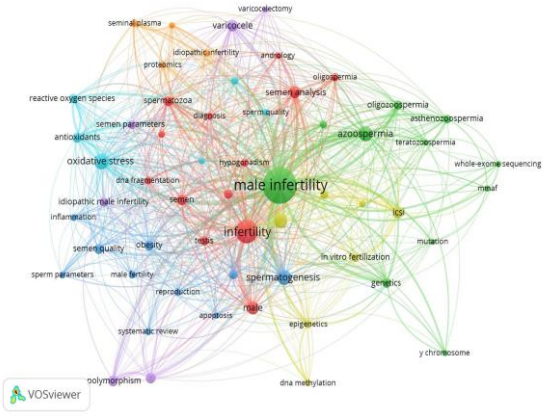

Fig.5 Co-occurrence analysis of all keywords

A co-occurrence analysis of author keywords was conducted using VOSviewer to map the intellectual structure of the literature (Fig. 5). The initial 4569 keywords from the selected papers were refined by merging singular and plural forms, reducing the list to 57 frequent terms that met the threshold of minimum 20 occurrences. The network mapping of these 57 keywords has grouped into 7 clusters based on their co occurrence frequencies.

The network visualization of male infertility research can be divided into seven distinct clusters, each representing a unique thematic focus. The green cluster highlights the role of genetic and molecular factors in male infertility, with key terms such as azoospermia, oligospermia, Y chromosome, genetics, and epigenetics. This cluster focuses on the genetic abnormalities and mutations that contribute to various male infertility conditions, particularly those related to sperm production and quality (Colaco & Modi, 2018). Assisted reproductive technologies (ART) like Intracytoplasmic Sperm Injection (ICSI) and In Vitro Fertilization (IVF) are prevalent in this cluster as potential interventions. For instance, studies have shown that genetic screening for Y chromosome microdeletions has been vital in diagnosing azoospermic individuals and guiding ART strategies (Carrell et al., 2016a). In addition, this cluster also touches on epigenetic mechanisms, such as DNA methylation, that influence gene expression without altering the genetic code, further complicating the diagnosis and treatment of male infertility (Urrutia et al., 2020).

The red cluster revolves around the process of spermatogenesis and its role in male fertility. This cluster emphasizes the biological mechanisms involved in sperm production, highlighting the role of conditions such as hypogonadism and the process of apoptosis (programmed cell death) that negatively affect sperm development (Palermo et al., 2019).

Treatments and diagnostics linked to this cluster focus on understanding how defects in spermatogenesis lead to infertility and how they can be identified and treated (Esteves et al., 2020). Similarly, the blue cluster deals with external factors like oxidative stress and its detrimental impact on sperm quality and DNA integrity. Oxidative stress is a significant factor contributing to male infertility, driven by an overproduction of Reactive Oxygen Species (ROS). Studies indicate that elevated ROS levels are correlated with increased sperm DNA fragmentation, reducing sperm viability and function (Agarwal et al., 2017). The presence of antioxidants in this cluster highlights research into potential therapeutic interventions aimed at reducing oxidative damage and improving overall semen quality (Torres-Arce et al., 2021).

Finally, the remaining clusters add depth to various aspects of male infertility research. The purple cluster focuses on varicocele, a common treatable cause of male infertility, and its surgical correction through varicocelectomy (Esteves et al., 2020). This cluster highlights the anatomical factors and surgical treatments that aim to improve testicular function and sperm quality in men affected by varicocele. In parallel, the light blue cluster delves deeper into sperm quality, semen parameters, and the role of antioxidants in improving sperm health. The orange cluster emphasizes the role of proteomics in male infertility research, particularly the identification of proteins in seminal plasma that could serve as biomarkers for idiopathic infertility—cases where no clear cause is identified (Urrutia et al., 2020). Proteomic approaches offer promising avenues for diagnostics and personalized treatments. Finally, the yellow cluster expands on the role of epigenetics and DNA methylation, linking them to genetic testing methods like whole-exome sequencing, which are pivotal in identifying mutations that do not necessarily alter DNA sequences but still affect fertility outcomes (Carrell et al., 2016b).

5. DISCUSSION

The insights from this bibliometric analysis have significant implications for the male infertility research field. First, the dominant focus on oxidative stress and its effect on sperm quality calls for more targeted research into antioxidant therapies (Agarwal et al., 2021). This could pave the way for novel therapeutic interventions aimed at reducing oxidative damage and improving sperm function, ultimately improving fertility outcomes in affected men. Moreover, the rising attention to genetic causes such as Y chromosome deletions and epigenetic modifications suggests that future research could focus more on personalized medicine and targeted treatments (Carrell et al., 2016a).

The collaborative networks identified between researchers and institutions from diverse countries highlight the importance of international cooperation in advancing the field. Such collaborations could accelerate the discovery of new biomarkers for infertility and the development of more effective treatments (Azizan et al., 2023). Additionally, the expanding role of assisted reproductive technologies (ART) like IVF and ICSI, as seen in recent studies, suggests that the field may move towards more integrated approaches that combine ART with genetic and molecular diagnostics to improve clinical outcomes (Palermo et al., 2019).

Future research in the male infertility field should prioritize longitudinal studies that examine the effects of oxidative stress over time, particularly in relation to lifestyle and environmental factors. Investigating how these elements interact with genetic predispositions could provide a more holistic understanding of male infertility and help develop more effective prevention strategies. Furthermore, the role of advanced genetic screening tools, such as whole-exome sequencing, in diagnosing idiopathic infertility cases should be explored in greater depth.

There is also a need for interdisciplinary collaboration between reproductive medicine specialists, geneticists, and molecular biologists to address the complexities of male infertility. Integrating proteomics and epigenetics into infertility research could reveal novel biomarkers for diagnosis and treatment. Expanding the geographic scope of research, particularly in underrepresented regions, could also provide a more comprehensive understanding of global male infertility trends and challenges

6. CONCLUSION

This bibliometric analysis provides valuable insights into the research landscape of male infertility over the past decade. The study highlights key trends, influential publications, leading authors, and collaborative networks shaping the field. A dominant focus on oxidative stress and its impact on sperm quality underscores the need for further research into antioxidant therapies. The increasing attention to genetic factors, particularly Y chromosome deletions and epigenetic modifications, suggests a growing interest in personalized medicine for male infertility. Furthermore, the shifting geographic distribution of research activity reflects a rising contribution from Asian and European countries, signaling changing priorities in global reproductive health research. Future studies should explore interdisciplinary approaches integrating reproductive medicine, genetics, and molecular biology to develop innovative diagnostic and therapeutic strategies.

7. LIMITATION

One of the key limitations of this bibliometric analysis is the reliance on two major databases, Web of Science and Scopus. While these databases provide comprehensive coverage, there is a possibility of missing relevant studies that are indexed in other databases such as PubMed or regional journals not covered by these platforms. Another limitation is the time frame of the analysis, which only includes publications from 2014 to 2024. This relatively short period may exclude earlier foundational studies that could provide valuable insights into long-term trends in male infertility research.

Additionally, the analysis primarily focuses on English-language publications, which may limit the inclusion of important research conducted in non-English-speaking regions. This language bias could potentially skew the understanding of global research trends. The reliance on citation counts as a measure of influence is also a limitation, as citation metrics can be influenced by factors unrelated to scientific quality, such as journal impact or self-citation practices

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