

Research Performance in Reproductive Biomedicine: A National Scientometrics Study

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Abstract

Recent achievements in reproductive biomedicine have led to a revolution in infertility treatment. A comprehensive understanding of the current status of reproductive medicine is necessary for the development of a forward-looking plan by health policymakers, based on fundamental requirements. This study is a systematic review of the Scopus database to assess reproductive biomedicine publications within Iran and compared to the rest of the world from 1990 to 2020. The data were categorized by geographical distribution across five continents. National data were assessed in comparison with the world and with neighboring countries. Finally, prominent national research institutes in the field of reproductive biomedicine in Iran were identified, and their contributions to the field highlighted. Of the five continents, the highest number of publications and citations is from Europe (36% publications and 41.5% citations). Corresponding numbers for the other continents are 32 and 33% for America, and 26 and 18.4% for Asia respectively. The remaining publications and citations were from Australia (3.8 and 4.1%) and Africa (2.6 and 3.1%). In a national analysis, the highest-ranking institutes in reproductive biomedicine are in Tehran province (50.9% of all Iranian publications), Shiraz (8.8%), Yazd (7.8%), Isfahan (7.1%), and Tabriz (6.9%). More specifically, Tehran University of Medical Science (15.9%), the Royan Institute (12.2%), Shahid Beheshti Medical University (10.1%), Shahid Sadoughi University of Medical Sciences (6.9%), and Tarbiat Modares University (6.7%) account for more than 50% of all Iranian scientific publications. In recent decades, reproductive biomedical research has grown significantly in Iran. Reviewing publications in this field helps health policy decision makers to monitor the direction of research and adjust investment in the treatment of infertility. In addition, it is necessary to expand and organize inter-organizational and international collaborations to improve the research, gain the benefits of different experiences, and engage in international multicenter studies.

Keywords: Bibliometrics, Infertility, Iran, Reproductive, Scientometric

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Introduction

According to reports from the International Committee for the Monitoring of Assisted Reproductive Technology (ICMART) and the World Health Organization (WHO), infertility is a disease of the male or female reproductive system and defined as the failure to achieve a pregnancy after 12 months or more of regular unprotected sexual intercourse. According to global statistics, each year 60 to 80 million couples suffer from infertility complications.

The prevalence of infertility is not the same in different societies; for example, its prevalence has risen from 3.5 to 16.7% in more developed nations and from 6.9 to 9.3% in less-developed countries (1, 2). Primary causes of infertility include genetic factors, hormonal disorders, birth defects, or diseases of the reproductive system. Secondary factors are those related to lifestyle, such as obesity, diet, smoking, alcohol consumption, polluted environments, and stressful situations. To overcome this problem and

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increase quality of life, biomedical researchers and medical professionals specializing in various reproductive fields, such as reproductive endocrinology, *in vitro* fertilization (IVF), embryology, andrology, reproductive genetics, reproductive immunology, and more, have been actively engaged in establishing clinical settings dedicated to infertility treatment. The advent of ART has played a pivotal role in this endeavor, giving rise to specialized infertility treatment centers across the globe (3-6). Thanks to the successful implementation of ART, an astonishing 10 million babies worldwide have been born since the birth of the first IVF baby in 1978. With an estimated four million ART cycles conducted annually, approximately one million babies are born via these procedures each year. These numbers reflect the increasing reliance on ART as a reliable and effective method for achieving successful pregnancies around the world (7-9).

According to recent reports, approximately one out of every six couples globally encounter infertility issues at least once during their reproductive lifespan. The current prevalence of infertility, persisting for a minimum of 12 months, is estimated to be around 8-12% in women aged 20-44 worldwide (10-12), while prevalence rates for primary and secondary infertility are slowly increasing. Along with the rest of the world, infertility research in Iran gained much from the work of pioneer researchers, like Saremi and Aflatoonian in 1987. Later the same year, the first infertility treatment department was established at Aban Hospital in Tehran. After that, in 1989, an infertility research center and a clinical center were established at Shahid Sadoughi University of Medical Sciences in Yazd (13). The first IVF clinic was opened at Afshar Hospital in Yazd. The first successful IVF procedure was performed there and the first IVF baby was born in 1990. The Royan Institute was the first IVF clinic in Tehran. It was established in 1991, and the first IVF baby born there was in 1993. Following these achievements, the first embryos resulting from intracytoplasmic sperm injection (ICSI) and *in vitro* maturation (IVM) were born in Yazd, and the first child was born from a frozen embryo. Building on these achievements, the preimplantation genetic diagnosis (PGD) method was developed for the first time in 2004 at the Royan institute (13, 14). Success stories from these centers boosted interest in research in reproductive science and gradually, scientists and experts in the field of reproduction produced further significant accomplishments. Currently, there are more than 60 infertility centers in service in Iran (8-15).

Given the importance of infertility treatment and the remarkable advances of Iranian scientists, there has emerged the need for a scientometric study that comprehensively examines past achievements. The objective of such a study would be to provide valuable insights that can guide future research endeavors in this field. Consequently, we conducted a systematic evaluation of research on this subject, encompassing an analysis of published documents, top institutions, author productivity, networking, and an impact assessment of

publications across various regions (16, 17). This type of study is a prerequisite for the future planning and basic management of financial and human resources (18, 19). We mapped studies conducted in this field across different geographical regions of the country and compared them to global trends from 1990 to 2020. The outcomes of this study will serve as a valuable resource for researchers, aiding their understanding of the prospects for diverse research projects within the realm of reproductive biomedicine in Iran. In addition, this research can provide more information for health policy makers concerned about the current low fertility rate in the country and the potential threat of an aging society.

Materials and Methods

Source of data

This aim of systematic review was to undertake a retrospective analysis of publications in reproductive biomedicine originating from Iran over two decades to the end of 2020. First, available databases such as Scopus, Web of Science, and Google Scholar were evaluated. Scopus (<http://www.scopus.com>) was chosen as the most comprehensive bibliographic database from which to retrieve data as it has the greatest coverage of journals and publications and is updated regularly. The database also enabled analyses by different criteria, such as number of publications per year, author's name, subject area, document type, publication stage, source title, keyword, affiliation, funding sponsor, journal, country, or territory, source type, and language. This type of information is very useful and necessary to bibliometric and scientometric studies. The study included Iranian and non-Iranian publications on reproductive biomedicine and spanned from 1990 until the end of 2020 (<http://www.scopus.com>) (20, 21).

Data retrieval

The Scopus database was searched for publications with any of the following keywords: "Reproductive science", "Fertility", "Infertility", or "Assisted reproductive technologies" separately. These keywords were selected to ensure that the main subject areas in reproductive biomedicine would be completely covered. These keywords were searched for in the titles, abstracts, and keywords of the reviewed publications. Only publications in English published between 1990 and the end of 2020 were included. Finally, the data from all countries which had more than 500 publications were extracted in Comma-Separated Value (CSV) format. All the CSV files were converted to Microsoft Excel files for statistical analysis (22).

Scientometrics analysis

Microsoft Excel files for 52 countries were combined into one file and all the statistical analyses were performed using Microsoft Excel. The citation rate was calculated using the following formula in Microsoft Excel 2018 (23). Citation rate = (number of citations)/(2021-year of publications)

Results

Overview of the global output

A total of 254394 publications were extracted from 52 countries that had more than 500 English publications in the field of reproductive biomedicine from 1990 to the end of 2020. Next, the contribution of each continent to reproductive biomedical studies was determined; Europe, America, and Asia were found to have produced a remarkably large share of all reproductive biomedicine publications. European countries (including the UK, Germany, Italy, France, Netherlands, Spain, Belgium, Denmark, Switzerland, Sweden, Finland, Norway, Austria, Greece, Poland, Portugal, Ireland, Czech Republic, Romania, and Hungary) accounted for 92,192 publications, almost 36% of the overall total. American countries (including the US, Canada, Brazil, Mexico, Argentina, Colombia, and Chile) had 80,845 publications, equal to 32% of all the total. Asian countries (including Israel, Iran, Turkey, Egypt, Saudi Arabia, Iraq, India, Pakistan, Russian Federation, China, Japan, South Korea, Taiwan, Singapore, Hong Kong, Malaysia, Indonesia, and Thailand) had 65,106 publications, equal to 26% of all the total. Australia had 9564 publications, equal to 3.8% of the total, while African countries (including South Africa, Kenya, Nigeria, and Ethiopia) published 6,687 papers, equal to 2.6% of the total (Fig.1). Countries in brackets were ordered by number of publications.

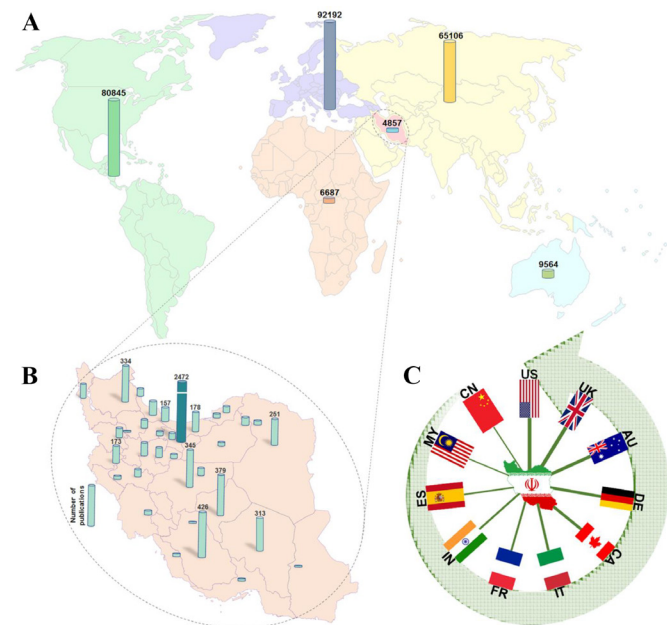


Fig.1: Geographical distribution of all publications in reproductive biomedicine 1990 to the end of 2020. **A.** Global performance in different continents, **B.** National performance in different provinces of Iran, and **C.** The network structure of Iran's scientific collaborations in reproductive biomedicine. The weight of the lines represents the number of collaborative international publications. US; United States, UK; United Kingdom, AU; Australia, DE; Germany, CA; Canada, IT; Italy, FR; France, IN; India, ES; Spain, MY; Malaysia, and CN; China.

In the next step of the study, the quality of the publications was evaluated based on total citations per

country or area, and citations per paper in general. In this analysis, publications from Asia were classified into South-East, Middle-East, North, and Central. Further, publications from the Middle East were divided into Israel, Iran, Turkey, Egypt, Saudi Arabia, and Iraq (Fig.2). The publications were classified into 28 different subjects, the top five of which were medicine, biochemistry, genetics, molecular biology, agricultural and biological sciences, environmental sciences, and social sciences.

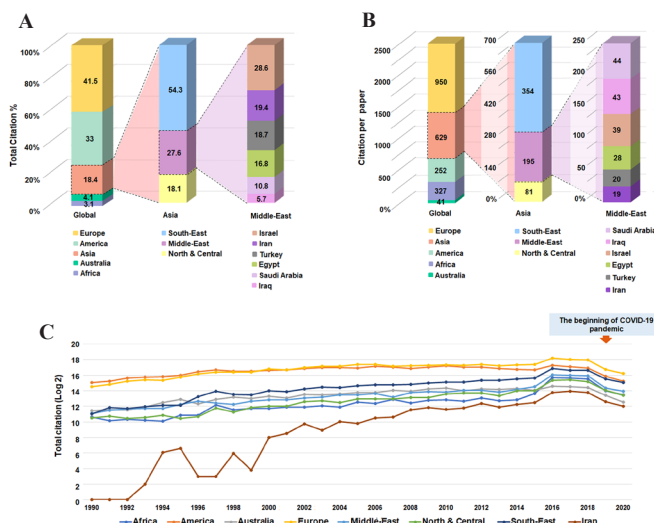


Fig.2: Quantification of reproductive biomedical publications from Iran compared to other countries based on total citations and citations per paper. **A.** The contribution of Iran to the geographical distribution of total citations in reproductive biomedicine publications across five continents (left), Asia (center), Middle East (right), **B.** The contribution of Iran to the geographical distribution of citations per publication in reproductive biomedicine across five continents (left), Asia (center), Middle East (right), **C.** Comparative timeline showing total citations from each continent and Iran. America; US, Canada, Brazil, Mexico, Argentina, Colombia, Chile. Asia; Israel, Iran, Turkey, Egypt, Saudi Arabia, Iraq, India, Pakistan, Russian Federation, China, Japan, South Korea, Taiwan, Singapore, Hong Kong, Malaysia, Indonesia, Thailand. Europe; UK, Germany, Italy, France, Netherlands, Spain, Belgium, Denmark, Switzerland, Sweden, Finland, New Zealand, Norway, Austria, Greece, Poland, Portugal, Ireland, Czech Republic, Romania, Hungary. Africa; South Africa, Kenya, Nigeria, Ethiopia, Bangladesh. Middle East (ME); Israel, Iran, Turkey, Egypt, Saudi Arabia, Iraq.

Further analysis showed that, worldwide, the following scientists had the highest number of publications in reproductive biomedicine; A. Agarwal, C. Niederberger, P. Devroey, A. Pellicer, H. Tournaye, JH. Check, N. Gleicher, Z. Rosenwaks, K. Diedrich, and E. Nieschlag. Presented in order, they are considered the top 10 scientists in this field in the world.

Iran in global and regional reproductive biomedicine research

In terms of quantity, Iranian scientists have contributed to 4,857 publications: 1.1% of publications worldwide, or 4.4% of Asian publications in reproductive biomedicine (Fig.1A). In terms of quality, however, Iran, with an average of 19 citations per paper, accounts for 19.4% of total citations from Asia, while the Middle- East overall accounts for 27.6% of total citations worldwide (Fig.2A, B).

An assessment of international collaborations between Iran and other countries in the field of reproductive biomedicine showed the top five countries were the United States (231 publications), the United Kingdom (147 publications), Australia (111 publications), Germany (106 publications), and Canada (105 publications) (Fig. 1).

At the regional level Israel, Iran, Turkey, and Saudi Arabia are the pioneers in reproductive biomedical research, with Iran the second most important country with 25% of total citations from 1990 to 2020. Also, over the years, Iran has led the region in terms of the total number of publications and the total number of citations. It should be noted here that there has been little fluctuation in the number of citations to Iranian publications.

In this analysis, it was found that the outbreak of the COVID-19 pandemic resulted in a decrease in publications in the field of reproductive biomedicine. This reduction could be due to the shift of research focus to different aspects of this pandemic (Fig.3) (21), although it should be mentioned that Iranian researchers have published many articles on the COVID-19 pandemic and reproductive biomedicine complications (24, 25).

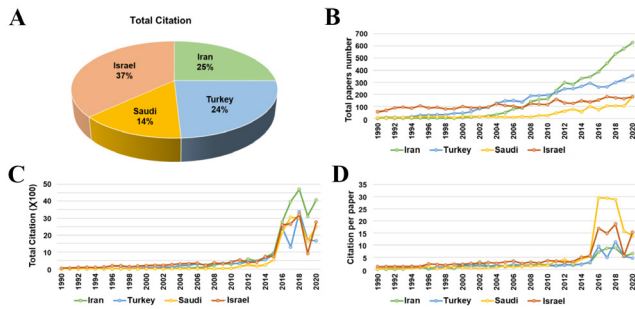


Fig.3: Comparison of the reproductive biomedicine publications from Iran and its regional neighbors based on **A.** Total citations, **B.** Total publications, **C.** Total citations, in the form of a timeline, and **D.** Citation per publication in the form of a timeline.

Reproductive biomedicine research in Iran

The data analysis showed a total of 5298 publications on reproductive biomedicine research in Iran. Of these papers, 4857 were written in English and published between 1990 to 2020. They accounted for 91.68% of the 5298 publications indexed in Scopus, and covered 28 different subjects related to reproductive biomedicine. The top five subjects were medicine (with 3150 publications equal to 65% of the total), biochemistry, genetics and molecular biology (1128, 23%), agricultural and biological sciences (874, 18%), pharmacology, toxicology and pharmaceuticals (293, 6%) and veterinary (255, 5%). The most common types of publication in peer-reviewed journals were original articles (4311 equal to 88.8% of the total), review articles (376, 7.7%), letters (66, 1.4%), conference papers (38, 0.7%) and book chapters (22, 0.5%).

Geographical distribution and top Iranian institutes in reproductive biomedicine research

According to the data analysis, the top five cities active

in reproductive biomedicine research are Tehran (with 2472 publications equal to 50.9% of the total), Shiraz (426, 8.8%), Yazd (379, 7.8%), Isfahan (345, 7.1%), and Tabriz (334, 6.9%). Tehran, as the capital, has the largest number of publications due to the location of many research centers there. In this regard, it was found that the top 10 research centers in reproduction biomedicine are Tehran University of Medical Science (TUMS), the Royan Institute (RI), Shahid Beheshti Medical University (SBMU), Shahid Sadoughi University of Medical Sciences (SSUMS), Tarbiat Modares University (TMU), University of Tehran (UT), Iran University of Medical Sciences (IUMS), Tabriz University of Medical Sciences (TBUMS), Shiraz University of Medical Sciences (SUMS), and Islamic Azad University (IAU). A more detailed analysis revealed that TUMS (with 771 publications equal to 15.9% of the total), RI (594, 12.2%), SBMU (491, 10.1%), SSUMS (334, 6.9%), and TMU (325, 6.7%) accounted for more than 50% of the publications from 1990 to 2020 (Fig.4). According to a recent study by A. Agarwal, an international scientist in reproductive biomedicine, the Royan Institute was recognized as number 9 out of the top ten institutions globally for expertise in male infertility and ART procedures between 2000 and 2019 (12, 15, 26).

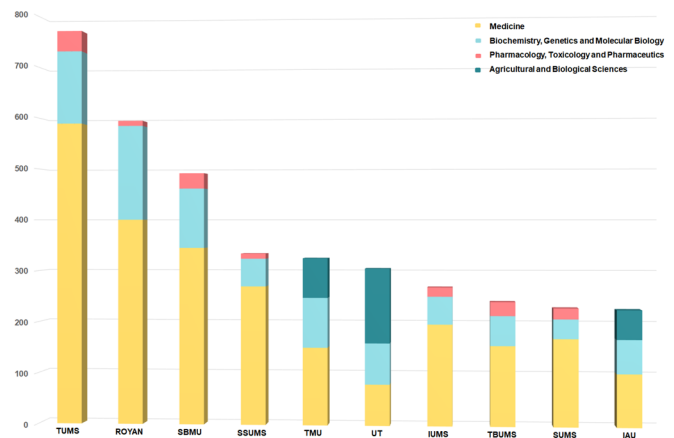


Fig.4: Comparison of the top 10 research centers in reproductive biomedicine in Iran based on the total number publications. TUMS; Tehran University of Medical Science, RI; ROYAN Institute, SBMU; Shahid Beheshti Medical University, SSUMS; Shahid Sadoughi University of Medical Sciences (Yazd), TMU; Tarbiat Modares University, UT; University of Tehran, IUMS; Iran University of Medical Sciences, TBUMS; Tabriz University of Medical Sciences, SUMS; Shiraz University of Medical Sciences, and IAU; Islamic Azad University.

The top Iranian scientists in this field are MH. Nasr-Esfahani (101 publications), MA. Khalili (85 publications), M. Tavalaei (70 publications), H. Gourabi (55 publications), MM. Akhondi (52 publications), MR. Sadeghi (51 publications), A. Aflatoonian (49 publications), and A. Moini (49 publications).

MH. Nasr-Esfahani, M. Tavalaei, H. Gourabi, and A. Moini are affiliated with Royan Institute. MA. Khalili and A. Aflatoonian are affiliated with SSUMS, and MM. Akhondi and MR. Sadeghi are affiliated with Avicenna Research Institute.

Discussion

This analysis of research published over the past three decades has revealed that reproductive biomedical research in Iran has been advancing in parallel with global trends. This progress is particularly evident in the field of male infertility and ART, and is reflected in studies renowned worldwide. The increasing number of these studies has been particularly notable since 2005, resulting in significant achievements in the field of reproductive biomedicine at both national and international levels (12).

In support of this claim, it is important to mention that there are currently 61 registered infertility clinics in Tehran, comprising 24 public and 37 private clinics. This signifies the substantial infrastructure development dedicated to address infertility issues and provide related treatments. Furthermore, it is important to highlight the extensive provision of infertility clinics in other provinces across Iran, emphasizing the widespread effort and commitment to reproductive biomedicine in the country (13). The establishment and expansion of these clinics and research-treatment centers are indicative of increasing attention and investment in this field in Iran. The collaborative efforts of Iranian scientists, clinicians, and researchers have contributed to remarkable progress over recent decades. This growth has not only benefitted Iranians but has also made significant contributions to the global body of knowledge in reproductive biomedicine (14, 15, 21).

However, it is essential not only to highlight the strengths but also the weaknesses that need to be addressed for further improvement. Despite the notable number of and citations to Iranian publications, it is crucial to acknowledge that citations per paper compared to neighboring countries in the region remain relatively low. This signifies the need for improving the quality of articles.

One contributing factor to this discrepancy could be the concentration of research centers primarily in Tehran. To overcome this limitation, there is a pressing need to disseminate knowledge and resources throughout the country. By doing so, the accessibility and availability of expertise and research opportunities will increase, promoting more balanced and comprehensive approaches to reproductive biomedicine across Iran.

Additionally, it is worth noting that the COVID-19 pandemic has had a significant impact on reproductive biomedical studies, leading to a decline in research output. Since SARS-CoV-2 has many unknown pathogenic features, it may have some long-term complications in patients (27, 28). To mitigate these potential effects, it is essential for the Ministry of Health and related associations to establish short- and medium-term plans for the post-COVID period. These plans should aim to create an enabling environment that supports the growth of studies in the reproductive biomedicine field, restoring the conditions observed before the pandemic.

By addressing these weaknesses and implementing the necessary measures, the quality and impact of Iranian research in reproductive biomedicine can be significantly enhanced. Collaboration among researchers, the expansion of research centers beyond Tehran, and the development of strategic plans will help to address the problems of the current low fertility rate in the country and the potential threat of an aging society.

Conclusion

This article has discussed and highlighted national publications in reproductive biomedicine in relation to Iran's position in the region and in the world, as well as in international collaborations in the field. We hope that the information provided can significantly help the authorities to make the right financial and human resource decisions based on the needs of the society.

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Authors' Contributions

Z.H., M.L.; Contributed to data collection and curation. P.A., M.V.; Contributed to conception and design. Z.H.; Contributed to formal statistical analysis, interpretation of data, and drafted the manuscript, which was revised by P.A., M.V., A.V.D. M.V.; Was in charge of overall supervision. All authors read and approved the final manuscript.

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