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Review

Stem cell research in Indonesia from 2003 to 2022: A bibliometrics analysis

[Investigación con células madre en Indonesia de 2003 a 2022: Un análisis bibliométrico]

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Abstract

Context: Stem cell research has become popular in Indonesia for more than a decade. The scope of research involves *in vitro* to animal studies as well as human trials. However, no evidence proved its trend.

Aims: To analyze the trends and patterns of stem cell research in Indonesia from 2003 to 2022 using a bibliometric analysis of the Scopus database.

Methods: The data for the paper were retrieved from Scopus and then analyzed using bibliometrics. Statistical data analysis was performed.

Results: The results showed that stem cell research in Indonesia has been increasing steadily over the years, with the majority of publications focusing on “Medicine”, “Biochemistry, Genetics, and Molecular Biology” and “Pharmacology, Toxicology, and Pharmaceutics”. It was found that a total of 260 related articles had been published. Rantam was identified as the most productive author, and the authorship network analysis identified nine clusters of authors. The keywords “stem cells”, “culture”, “proliferation”, “differentiation”, and “tissue engineering” were the most frequently used in the publications analyzed.

Conclusions: Overall, this study provides valuable insights into the development of stem cell research in Indonesia and may inform future research and funding decisions in this field.

Keywords: authorship; bibliometrics; biopharmaceutics; stem cell research; Indonesia.

Resumen

Contexto: La investigación con células madre se ha popularizado en Indonesia desde hace más de una década. El ámbito de la investigación abarca desde estudios *in vitro* hasta estudios con animales, así como ensayos con humanos. Sin embargo, no hay pruebas que demuestren su tendencia.

Objetivos: Analizar las tendencias y patrones de la investigación con células madre en Indonesia desde 2003 hasta 2022 utilizando un análisis bibliométrico de la base de datos Scopus.

Métodos: Los datos para el artículo fueron recuperados de Scopus y luego analizados por la bibliométrica. Se realizó un análisis estadístico de los datos.

Resultados: Los resultados mostraron que la investigación con células madre en Indonesia ha ido aumentando constantemente a lo largo de los años, con la mayoría de las publicaciones centradas en "Medicina", "Bioquímica, Genética y Biología Molecular" y "Farmacología, Toxicología y Farmacéutica". En total se publicaron 260 artículos relacionados. Rantam fue identificado como el autor más productivo, y el análisis de la red de autoría identificó nueve grupos de autores. Las palabras clave "stem cells", "culture", "proliferation", "differentiation" y "tissue engineering" fueron las más utilizadas en las publicaciones analizadas.

Conclusiones: En general, este estudio proporciona información valiosa sobre el desarrollo de la investigación con células madre en Indonesia y puede servir de base para futuras investigaciones y decisiones de financiación en este campo.

Palabras Clave: autoría; bibliometría; biofarmacia; células madre investigación; Indonesia.

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INTRODUCTION

Stem cells can self-renew and differentiate into various cell types, making them an attractive candidate for regenerative medicine (Yessentayeva et al., 2022; Zuk et al., 2004). By harnessing the regenerative potential of stem cells, it is possible to develop therapies that can repair, replace, or regenerate damaged or diseased tissues or organs (Brovkina and Dashinimaev, 2020; Omole and Fakoya, 2018). Stem cells can be obtained from various sources, including embryonic stem cells and adult stem cells (Rajabzadeh et al., 2019). However, despite the promising potential of stem cell therapy, many challenges still need to be addressed, such as safety concerns, ethical considerations, and regulatory frameworks, before stem cell therapies can be widely adopted for clinical use (King and Perrin, 2014; Liras, 2010).

In 2018, Indonesia implemented a recent regulatory framework mandating that all forms of cell therapy, including stromal vascular fraction (SVF), stem cells, platelet-rich plasma, and immune cell therapies, must undergo rigorous clinical trials to substantiate their safety and effectiveness. This regulation accelerates the application of stem cells, which leads many research sectors to collaborate to prove their potency, safety, and efficacy from *in vitro* to *in vivo* studies. Due to this opportunity, the number of publications and authors gradually increased year to year. Some funding from the Indonesian government and private companies specified that the criteria focused on stem cell projects only. In just a decade, the number of stem cells reported from bench to bedside and from in vitro to clinical trials has increased. Although the research become popular, the facility to conduct stem cell research is limited. To analyze the region that already runs stem cell research in Indonesia, mapping research is needed. Publication, serving as a pivotal component of scientific research, holds significant value as an indicator of one's contributions to the field of research.

To gain a better understanding of the research trends in stem cell studies, bibliometric studies are commonly used. Bibliometric studies provide qualitative and quantitative analysis of the publication output in a particular field, including authorship, institutional affiliation, and country of origin. The impact factor and published citations of articles are also measured, providing insight into the influence of an article. Online databases and software are necessary to conduct bibliometric studies, and this approach has been widely adopted to analyze research trends across various fields (Hoffmeyer et al., 2023; Hou et al., 2019; Wan et al., 2019).

This paper aims to examine stem cell-related research articles in Indonesia through a bibliometric analysis. The articles were retrieved from the Scopus database and covered various types of articles, such as original articles, reviews, letters, conference papers, editorials, book chapters, and data papers. By analyzing the publication output, this paper aims to provide insight into the research trends related to stem cell therapy in Indonesia over the past two decades.

The findings of this paper are expected to provide valuable information for researchers in the stem cell therapy field. This information can be used to identify potential areas of collaboration and funding, as well as to develop targeted research initiatives to address the challenges facing stem cell therapy in Indonesia. This study was to analyze stem cell-related studies in Indonesia from 2003 to 2022.

MATERIAL AND METHODS

Study design

This study was designed as a literature review under the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Page et al., 2021).

Literature searching

The publication search was done and conducted on March 10, 2023, using Scopus to avoid possible changes in the citation rate. All types of articles were included in the analysis. The search theme was set as "stem cells", the time range was set from 2003–2022, and the country was limited to Indonesia. During the search for articles, terms were used as follows: TITLE-ABS-KEY ((stem AND cell OR stem AND cells) AND Indonesia AND NOT secretome AND NOT exosomes AND NOT vesicles AND (LIMIT-TO (AFFILCOUNTRY, "Indonesia")) AND ((LIMIT-TO (SUBJAREA, "MEDI") OR LIMIT-TO (SUBJAREA, "BIOC") OR LIMIT-TO (SUBJAREA, "PHAR") OR LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "DENT") OR LIMIT-TO (SUBJAREA, "IMMU") OR LIMIT-TO (SUBJAREA, "MATE") OR LIMIT-TO (SUBJAREA, "VETE") OR LIMIT-TO (SUBJAREA, "MULT") OR LIMIT-TO (SUBJAREA, "NEUR") OR LIMIT-TO (SUBJAREA, "HEAL") OR LIMIT-TO (SUBJAREA, "NURS")) AND ((LIMIT-TO (LANGUAGE, "English")) AND ((LIMIT-TO (EXACTKEYWORD, "Mesenchymal Stem Cell") OR LIMIT-TO (EXACTKEYWORD, "Stem Cell") OR LIMIT-TO (EXACTKEYWORD, "Stem Cells") OR LIMIT-TO (EXACTKEYWORD, "Mesenchymal Stem Cells") OR LIMIT-TO (EXACTKEYWORD, "Mesen-

chymal Stroma Cell")) AND ((LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011) OR LIMIT-TO (PUBYEAR, 2010) OR LIMIT-TO (PUBYEAR, 2009) OR LIMIT-TO (PUBYEAR, 2008) OR LIMIT-TO (PUBYEAR, 2007) OR LIMIT-TO (PUBYEAR, 2006) OR LIMIT-TO (PUBYEAR, 2003)).

Inclusion and exclusion criteria

Data entry and collection were verified by the authors. Eligible articles based on inclusion criteria were screened by titles and abstracts (Fig. 1). The inclusion criteria were as follows: (1) the title should indicate stem cells; (2) if there were no term stem cells in the title, the abstract should be analyzed; and (3) all types of papers were included (such as the original article, review, book chapter, letter, data paper, editorial, and conference paper). The exclusion criteria were as follows: (1) duplicates; (2) the titles and/or abstracts were not related to the study; (3) non-English articles.

Study selection, screening, and data extraction

The search strategies for the Scopus database identified a total of 1169 documents. After automatic screening to remove ineligible articles, the records were 493. The documents published by non-Indonesian authors were excluded, yielding a total of 396 documents. Non-relevant studies based on abstracts were excluded. With this search, we recorded 260 data results. Then, the data from Scopus were downloaded and imported into Microsoft Excel (.xls) (Microsoft Corporation, Washington USA) and VOSviewer (.ris) (Leiden University, Netherlands). The data were analyzed qualitatively and quantitatively.

Bibliometrics analysis

Basic information, including the number of articles, citations, funding, affiliation, authors, journals, and subject areas, was recorded from the Scopus database. The number of articles represents the productivity of authors or affiliations, while the citations are considered to influence the degree of the articles.

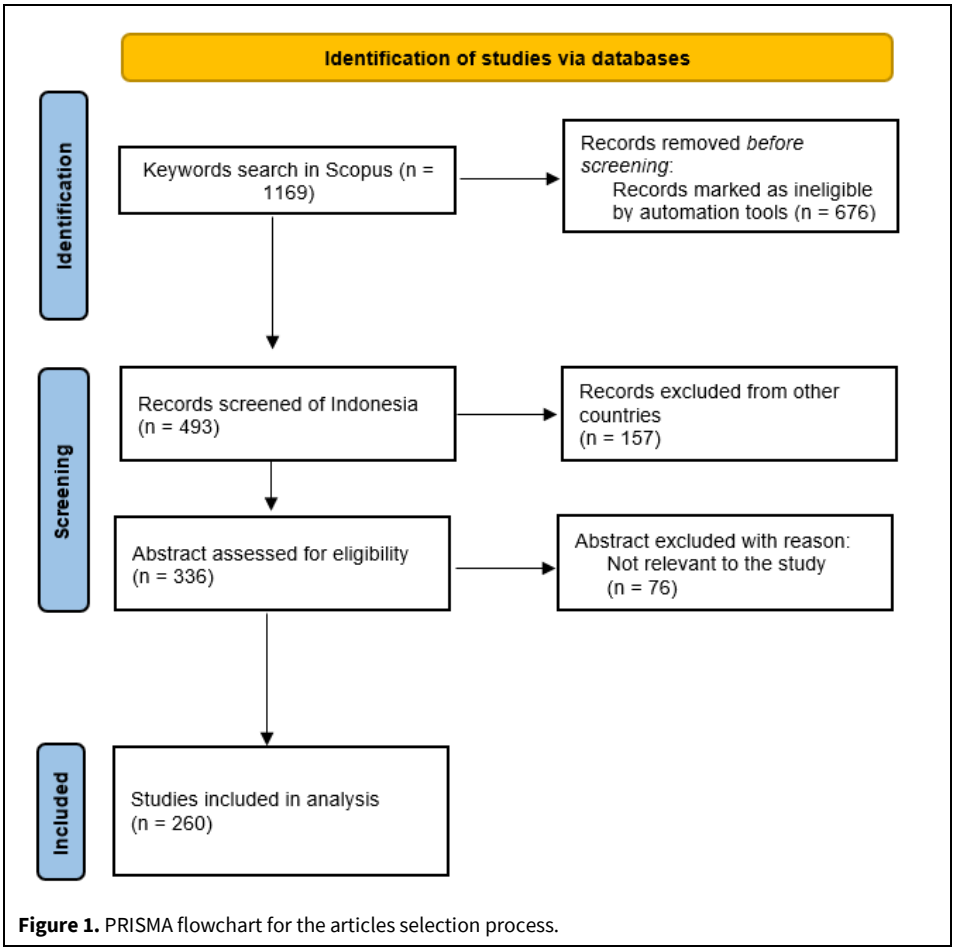


Figure 1. PRISMA flowchart for the articles selection process.

Table 1. Distribution of articles, citations, and total funding.

Articles, citations, funding		Articles per funding ratio	Citations per articles
Total articles	260	2.34	7.23
Original article	222		
Review	23		
Letter	1		
Conference paper	6		
Editorial	4		
Book chapter	3		
Data paper	1		
Citations	1881		
Funding	111		

To visualize the bibliometric network of the authorship and keywords, the VOSviewer (Leiden University, Netherlands) was used. VOSviewer (Leiden University, Netherlands) performed the text mining of co-occurrence networks of important terms extracted from the articles.

Statistical analysis

Microsoft Excel version 2013 (Microsoft Corporation, Washington, USA) was utilized for all statistical analyses. The Spearman rank correlation test was performed to evaluate the correlation. A correlation with an r^2 value less than 0.3 indicated a weak relationship, while an r^2 value ranging from 0.3 to 0.5 represented a low correlation. An r^2 value ranging from 0.5 to 0.8 indicated a significant correlation, and an r^2 value greater than 0.8 represented a high correlation. A positive correlation between two variables was indicated by an r value >0, while a negative correlation was indicated by an r value <0. r value = 0 indicated that two variables are irrelevant. A p-value less than 0.05 was considered statistically significant.

RESULTS

General Information

In this study, 260 articles on stem cells were collected in the Scopus database, of which 222 (85.38%) were original articles, 23 (8.85%) were reviews, and the rest were 15 (5.77%) letters, conference papers, editorials, book chapters, and data papers. The total citations and funding over two decades were 1881 and 111, respectively (Table 1).

Publication outputs number

The number of articles increased during the years from 2003 (n = 0) to 2020 (n = 57) and slightly decreased in 2021 (n = 35), followed by increased again in 2022 (n = 49). The number of review articles increased dramatically from 2003 (n = 0) to 2022 (n = 6) (Fig. 2).

Article, citation, and funding count correlation

The number of articles, funding, and citations showed a similar trend, where the quantity of funding increased, followed by the number of articles and citations. However, when the funding number decreased, the output publications were also the same. The first research was funded in 2006 (n = 1) and increased dramatically until 2020 (n = 26), followed by a decrease in 2021 (n = 12) and a rebound again in 2022 (n = 27) (Fig. 3). The most total citations were shown in 2020 (n = 585), followed by 2022 (n = 278) and 2018 (n = 209).

The highest-cited articles were "Epithelial mesenchymal transition traits in human breast cancer cell lines parallel the CD44HI/CD24lO/-stem cell phenotype in human breast cancer," published in 2010 and co-authored by Blick with citation number 230 (Table 2). No funding was received for this review article. Interestingly, a slightly different Scopus quartile for the journal between 2010 and 2021 was Q1 vs. Q3. The other two articles with the most citations were "Current status of alginate in drug delivery" (n = 73) and "The role of TNF-α-induced MSCs on suppressive inflammation by increasing TGF-β and IL-10" (n = 69), published in 2020 and 2018, respectively. Based on the results, the highest-cited articles involved 2 review articles and 1 original article.

Spearman rank correlation analysis revealed that there was a significant positive correlation between articles and citations ($r^2 = 0.69$, $p<0.001$) and funding to citations ($r^2 = 0.63$, $p=0.002$) while a highly positive correlation was observed between articles and funding ($r^2 = 0.94$, $p<0.001$) (Fig. 4).

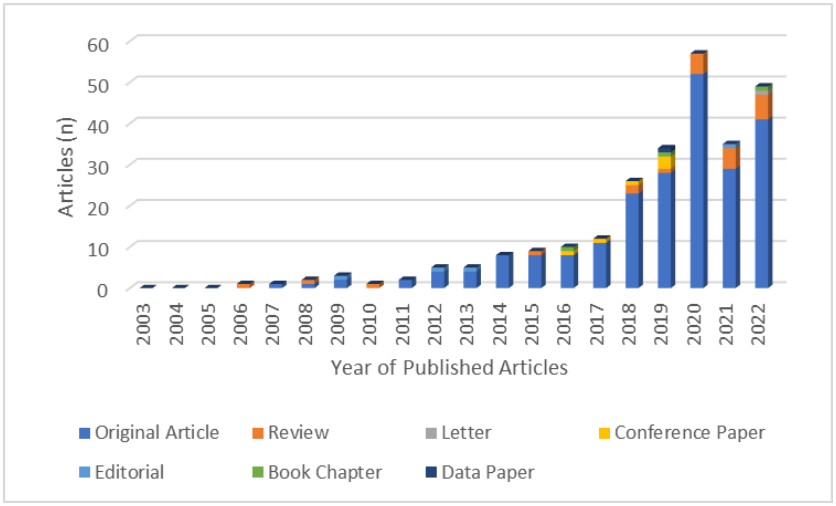


Figure 2. Number of articles from 2003 to 2022.

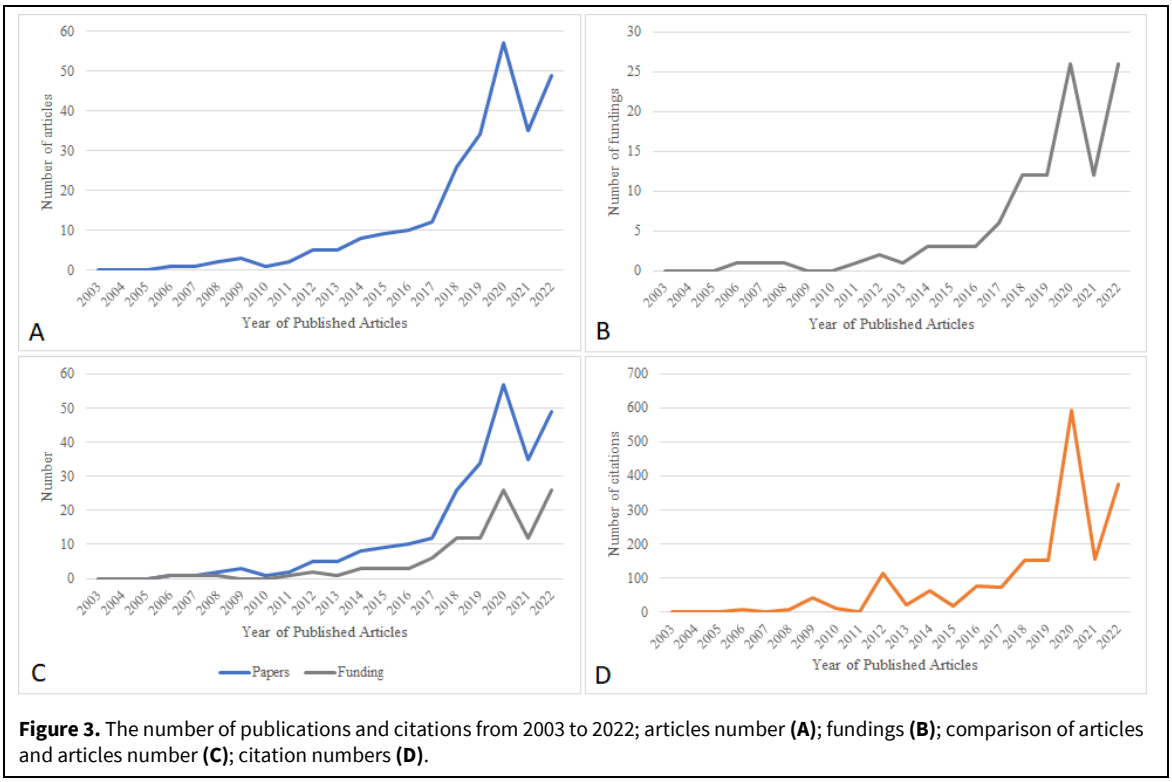


Figure 3. The number of publications and citations from 2003 to 2022; articles number **(A)**; fundings **(B)**; comparison of articles and articles number **(C)**; citation numbers **(D)**.

Journals and subject area

About 19 articles were published in the journal "Biochemical and Cellular Archives," with a total number of citations of 58. The ratio between the article number and citations was 3.05. The second and third journals were "Macedonian Journal of Medical Sciences" and "Medical Journal of Indonesia," with the ratio of articles and citations being 5.59 and 2.92, respectively. Only two journals in the Top 10 with the most articles had a ratio of articles and citations less than 1 (Table 3).

The top 10 subject areas are shown in Fig. 5. "Medicine" was the highest article subject reported, followed by "Biochemistry, Genetics, and Molecular Biology" and "Pharmacology, Toxicology, and Pharmaceutics."

Authorship, affiliation and sponsor

The top 10 cited authors, ranked by the number of articles, are listed in Table 4. These authors have made significant contributions to the field, and their research has been acknowledged by their peers, as

Table 2. Top three most cited articles.

Reference	Authors	Summary	Citations	Funding	Type	IF (2022)	Scopus (Q publication year vs. 2021)	SJR 2021	Publisher	Publisher country
(Blick et al., 2010)	Blick T, Hugo H, Widodo E, Waltham M, Pinto C, Mani SA, Weinberg RA, Neve RM, Lenburg ME, Thompson EW. 2010. Epithelial mesenchymal transition (EMT) traits in human breast cancer cell lines parallel the CD44HI/CD24lO/- stem cell phenotype in human breast cancer. Journal of Mammary Gland Biology and Neoplasia	The cellular product of the EMT with basal B cell lines may improve breast cancer outcomes	230	No	Review	2.31	Q1 vs. Q3	0.6	Springer New York	United States
(Hariyadi and Islam, 2020)	Hariyadi DM, Islam N. 2020. Current status of alginate in drug delivery. Advances in Pharmacological and Pharmaceutical Sciences	Alginate is effective for stem cell culture	73	Yes	Review	N/A	N/A vs Q3	0.25	Hindawi Limited	United Kingdom
(Putra et al., 2018)	Putra A, Ridwan FB, Putridewi AI, Kustiyah AR, Wirastuti K, Sadyah NAC, Rosdiana I, Munir D. 2018. The role of TNF-α induced mscs on suppressive inflammation by increasing TGF-β and IL-10. Open Access Macedonian Journal of Medical Sciences	The 5 ng/mL dose of TNF-α is a sufficient dose for MSCs to suppress the inflammatory milieu	69	No	Original	2.88	Q2 vs Q2	0.79	Open Access Macedonian Journal of Medical Sciences	United States

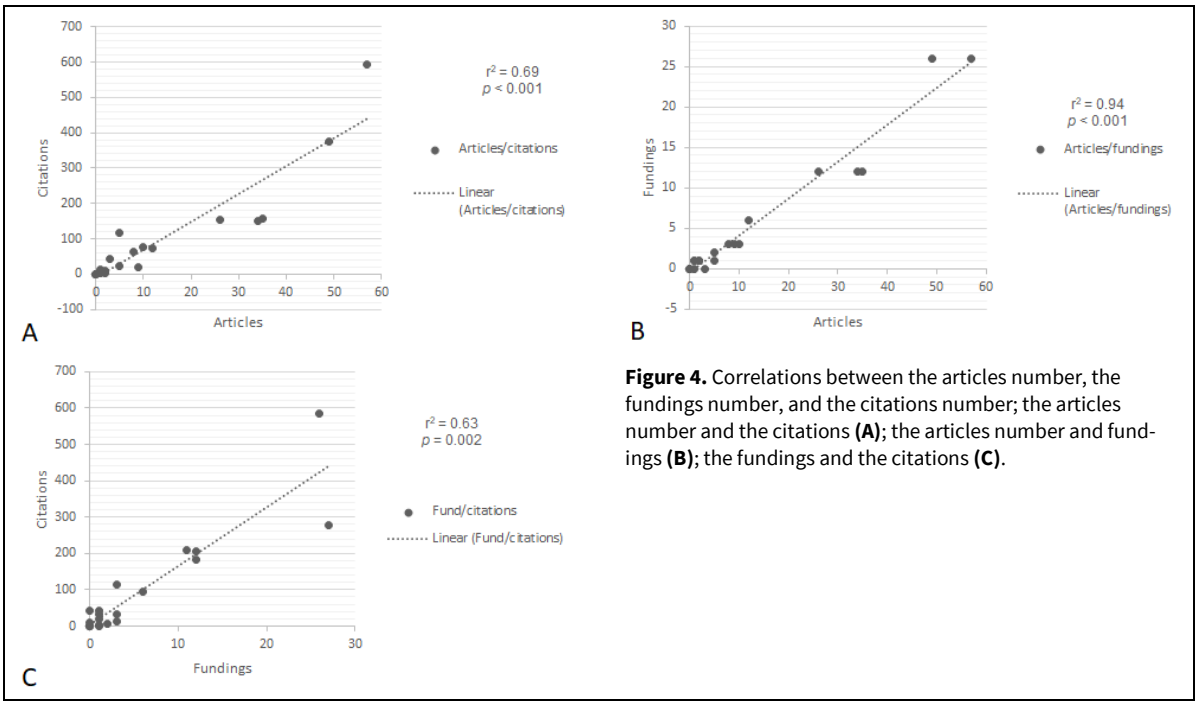


Figure 4. Correlations between the articles number, the fundings number, and the citations number; the articles number and the citations **(A)**; the articles number and fundings **(B)**; the fundings and the citations **(C)**.

Table 3. Top 10 Journals based on article numbers.

No	Journals	Number of articles (1)	Citation (2)	Ratio (2:1)	IF (2021-2022)	Publisher	Publisher country
1	Biochemical and Cellular Archives	19	58	3.05	0.15	DR.P.R.YADAV	India
2	Open Access Macedonian Journal of Medical Sciences	17	95	5.59	0.9	Open Access Macedonian Journal of Medical Sciences	United States
3	Medical Journal of Indonesia	13	38	2.92	0.52	Faculty of Medicine Universitas Indonesia	Indonesia
4	Journal of Biomimetics, Biomaterials and Biomedical Engineering	8	14	1.75	0.81	Trans Tech Publications	Germany
5	Research Journal of Pharmacy and Technology	7	41	5.86	0.68	A and V Publication	India
6	International Journal of PharmTech Research	6	29	4.83	N/A	Sphinx Knowledge House	India
7	International Journal of Applied Pharmaceutics	6	3	0.50	0.76	International Journal of Applied Pharmaceutics	India
8	Medicinski Glasnik	6	12	2.00	0.89	Medical Association of Zenica Doboj Canton	Bosnia and Herzegovina
9	Journal of Global Pharma Technology	5	4	0.80	0.32	Journal of Global Pharma Technology	India
10	Journal of International Dental and Medical Research	5	28	5.60	0.63	Ektodermal Displazi Grubu	Turkey

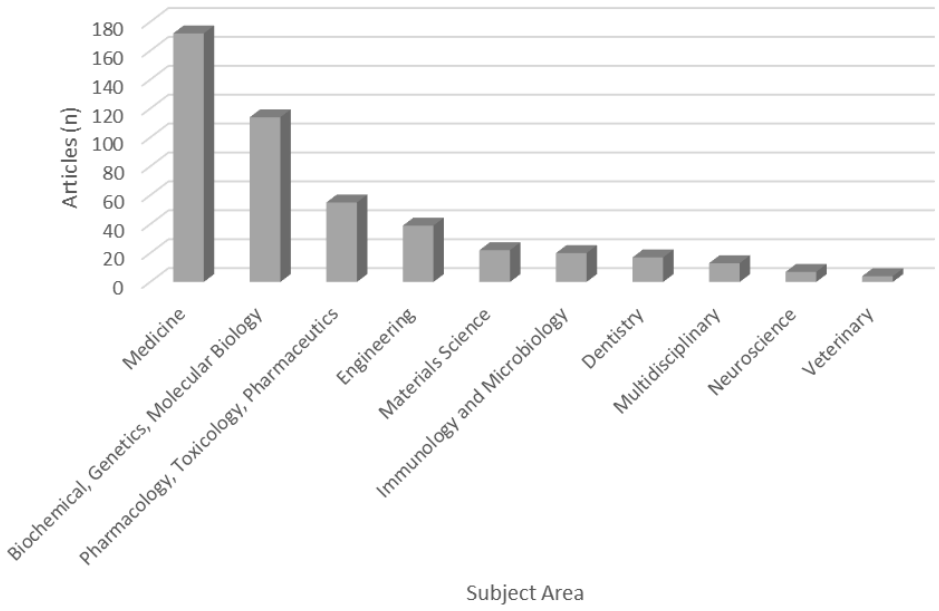
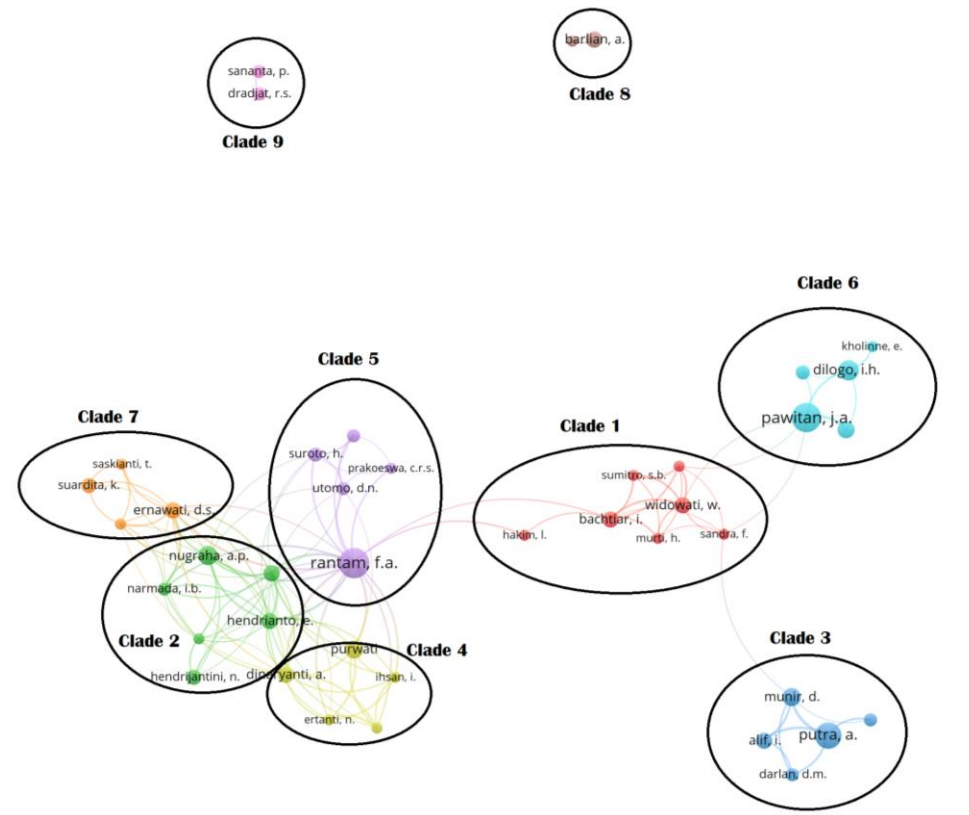


Figure 5. Correlation between the article numbers and subject area.

Table 4. Top 10 authors with the most publications related to stem cells.

Rank	Author	Number of articles	Affiliations
1	Rantam FA	36	Stem Cell Research and Development Centre, Airlangga University, Surabaya, Indonesia
2	Pawitan JA	31	Department of Histology, Faculty of Medicine, Universitas Indonesia; Stem Cell Medical Technology Integrated Service Unit, Faculty of Medicine, Universitas Indonesia; Cipto Mangunkusumo Hospital, Jakarta, Indonesia; Stem Cells and Tissue Engineering Cluster, Indonesian Medical and Education Research Institute, Faculty of Medicine, Universitas Indonesia
3	Putra A	25	Faculty of Dental Medicine, Airlangga University, Surabaya, Indonesia
4	Nugraha AP	15	Department of Orthodontic, Faculty of Dental Medicine, Airlangga University, Surabaya, Indonesia, Stem Cell Research and Development Center, Airlangga University, Surabaya, Indonesia
5	Dilogo IH	14	Consultant of Orthopaedic Trauma and Reconstruction, Department of Orthopaedic and Traumatology; Dr. Cipto Mangunkusumo General Hospital, Faculty of Medicine Universitas Indonesia, Jakarta, Indonesia; Stem Cell Medical Technology, Integrated Service Unit, Dr. Cipto Mangunkusumo General Hospital, Faculty of Medicine Universitas Indonesia, Jakarta, Indonesia; Stem Cell and Tissue Engineering Research Center, Indonesian Medical Education and Research Institute (IMERI), Faculty of Medicine Universitas Indonesia, Jakarta, Indonesia
6	Dinaryanti A	12	Stem Cell Research and Development Center, Airlangga University, Surabaya, Indonesia
7	Hendrianto E	12	Stem Cell Research and Development Center, Airlangga University, Surabaya, Indonesia
8	Munir D	12	Department of Otorhinolaryngology-Head and Neck Surgery, Faculty of Medicine, Universitas Sumatera Utara
9	Purwati	12	Stem Cell Research and Development Center, Universitas Airlangga, Surabaya, 60115, Indonesia, Health Department, Faculty of Vocation, Universitas Airlangga
10	Bachtiar I	11	Stem Cell and Cancer Institute, Jakarta



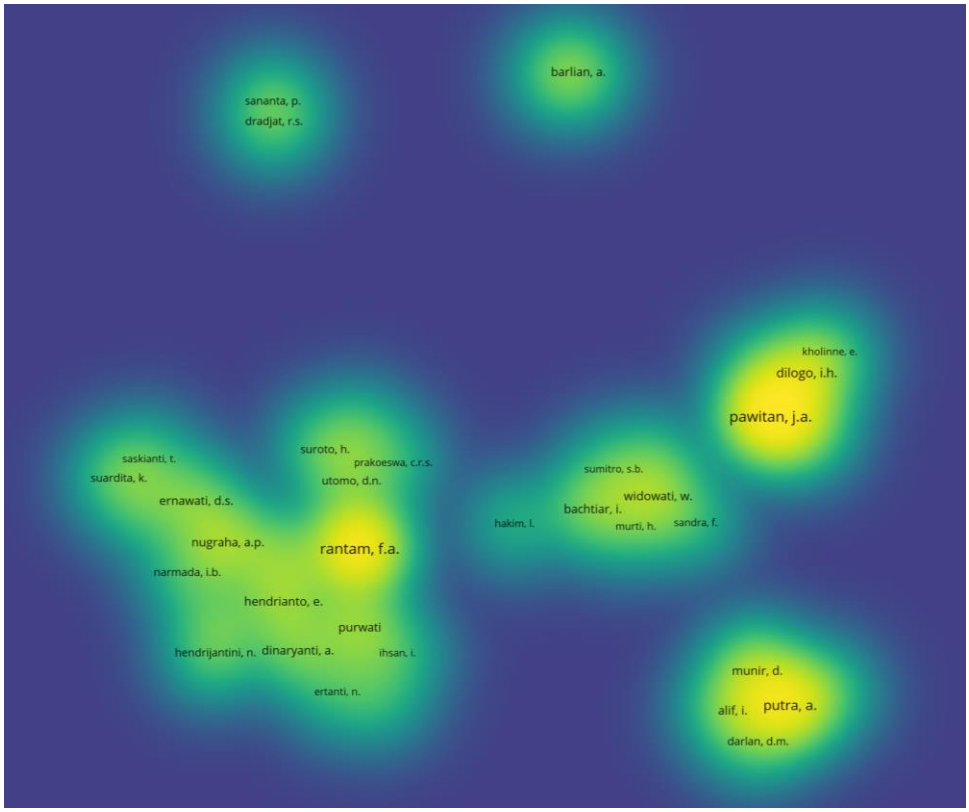


Figure 6. The analysis of authors.

Mapping author network **(A)**; and the density based on articles number **(B)**. Created with VOSviewer software.

Table 5. Top 10 affiliations with the most publications.

Rank	Affiliation	Articles (n)
1	Universitas Indonesia	130
2	Universitas Airlangga	111
3	Brawijaya University	28
4	Universitas Sumatera Utara	25
5	Universitas Islam Sultan Agung Semarang	24
6	Universitas Gadjah Mada	17
7	Universitas Padjadjaran	15
8	Institut Teknologi Bandung	14
9	Universitas Kristen Maranatha	14
10	Hasanuddin University	13

Table 6. Top 10 funding sponsors in Indonesia for stem cell research.

Rank	Funding sponsor	Funding (n)
1	Universitas Airlangga	21
2	Japan Society for the Promotion of Science	17
3	Universitas Indonesia	16
4	Kementerian Riset, Teknologi dan Pendidikan Tinggi	9
5	Japan Agency for Medical Research and Development	6
6	Universitas Sumatera Utara	6
7	Bundesministerium für Forschung und Technologie	5
8	Kementerian Riset Teknologi Dan Pendidikan Tinggi Republik Indonesia	3
9	Lembaga Pengelola Dana Pendidikan	3
10	National Cancer Institute	3

Table 7. Top 10 keywords of stem cells in Indonesia.

Rank	Top relevant keywords	Keywords (n)
1	Mesenchymal Stem Cell	171
2	Controlled Study	146
3	Cell Differentiation	97
4	Stem Cell	97
5	Human Cell	95
6	Stem Cells	92
7	Mesenchymal Stem Cells	88
8	Cell Proliferation	73
9	Cell Culture	70
10	Tissue Engineering	47

evidenced by the citation count. At the top of the list was Rantam, who has published 36 articles on stem cells, making her the most prolific author in this field. Following closely behind were Pawitan with 31 articles and Putra with 25 articles. The remaining seven authors in the top 10 published between 11 and 15 articles each.

Their contributions to stem cell research have been crucial in advancing our understanding of this field. Their works have led to breakthroughs in stem cell therapy and regenerative medicine, which have the potential to revolutionize medical treatments for a variety of conditions.

There were nine clusters of authorship networks based on the minimum number of published articles: 5. There were two clades that did not interact with the others (Barlian, clade 8, and Sananta, clade 9) (Fig. 6A). The highest density of authors showed the most productive authors (Fig. 6B).

The top 10 affiliations with the most publications in stem cell research in Indonesia were identified through bibliometric analysis (Table 5). The University of Indonesia was found to be the most productive affiliation. Other highly productive affiliations include Universitas Airlangga, Universitas Gadjah Mada, and Hasanuddin University. The high number of publications from these institutions highlights the significant research efforts being undertaken in stem cell research in Indonesia and the importance of these institutions in advancing the field.

The top 10 funding sponsors for stem cell research in Indonesia were identified through bibliometric analysis (Table 6). The list includes Airlangga University, Japan Society, Universitas Indonesia, Kementerian Riset, Japan Agency for Medical, Universitas Sumatera Utara, Bundesministerium für Forschung und Technologie, Kementrian Riset Teknologi Dan Pendidikan Tinggi Republik Indonesia, Lembaga Pengelola Dana Pendidikan, and the National Cancer Institute. The presence of various national and international funding sources indicates the growing interest and support for stem cell research in Indonesia. This funding is crucial in facilitating the advancement of stem cell research and its potential applications in regenerative medicine, disease treatment, and drug discovery.

Keywords and research fields

The top 10 keywords identified through bibliometric analysis in stem cell research in Indonesia were mesenchymal stem cell, controlled study, cell differentiation, stem cell, human cell, stem cells, mesenchymal stem cells, cell proliferation, cell culture, and tissue engineering (Table 7). The high occurrence of keywords related to stem cells and human cells indicates the focus of research in the field of regenerative medicine and the potential application of stem cells in human therapy. The inclusion of keywords such as controlled study highlights the importance of rigorous experimental design and the use of animal models in preclinical studies of stem cell therapy.

Bibliometrics analysis provides directions and trends of the research based on keywords. Three clusters were shown in a different color (Fig. 7A). The most used keywords were shown by the highest density (Fig. 7B).

The presence of the keywords stem cells, culture, proliferation, differentiation, tissue engineering, and transplantation in the bibliometric analysis of stem cell research in Indonesia indicates the focus and direction of research in the field (Fig. 8). The inclusion of stem cells and their culture and proliferation reflects the growing interest in understanding the biology and behavior of stem cells *in vitro*. The presence of keywords related to differentiation and tissue engineering suggests the potential applications of stem cells in tissue repair and regeneration. Additional platelet-rich plasma (PRP) is a commonly used supplement in stem cell therapy. The keyword transplantation indicates the potential use of stem cells as a therapeutic option for various diseases and injuries, emphasizing the importance of preclinical studies and clinical trials in establishing the safety and efficacy of stem cell-based therapies.

DISCUSSION

The analysis of Indonesia's publications on stem cells has revealed a rapid increase in quantity year-by-year from 2003 to 2022. This trend indicates the growing interest and investment in stem cell research in Indonesia over the past two decades. The increasing number of publications is also likely to be controlled by advancements in technology and techniques, as well as the availability of funding opportunities and research infrastructure to support stem cell research in Indonesia. This trend is a positive report for stem cell research, as it indicates a strong commitment to advancing the field and improving understanding of the potential applications of stem cells in various areas of medicine and biotechnology.

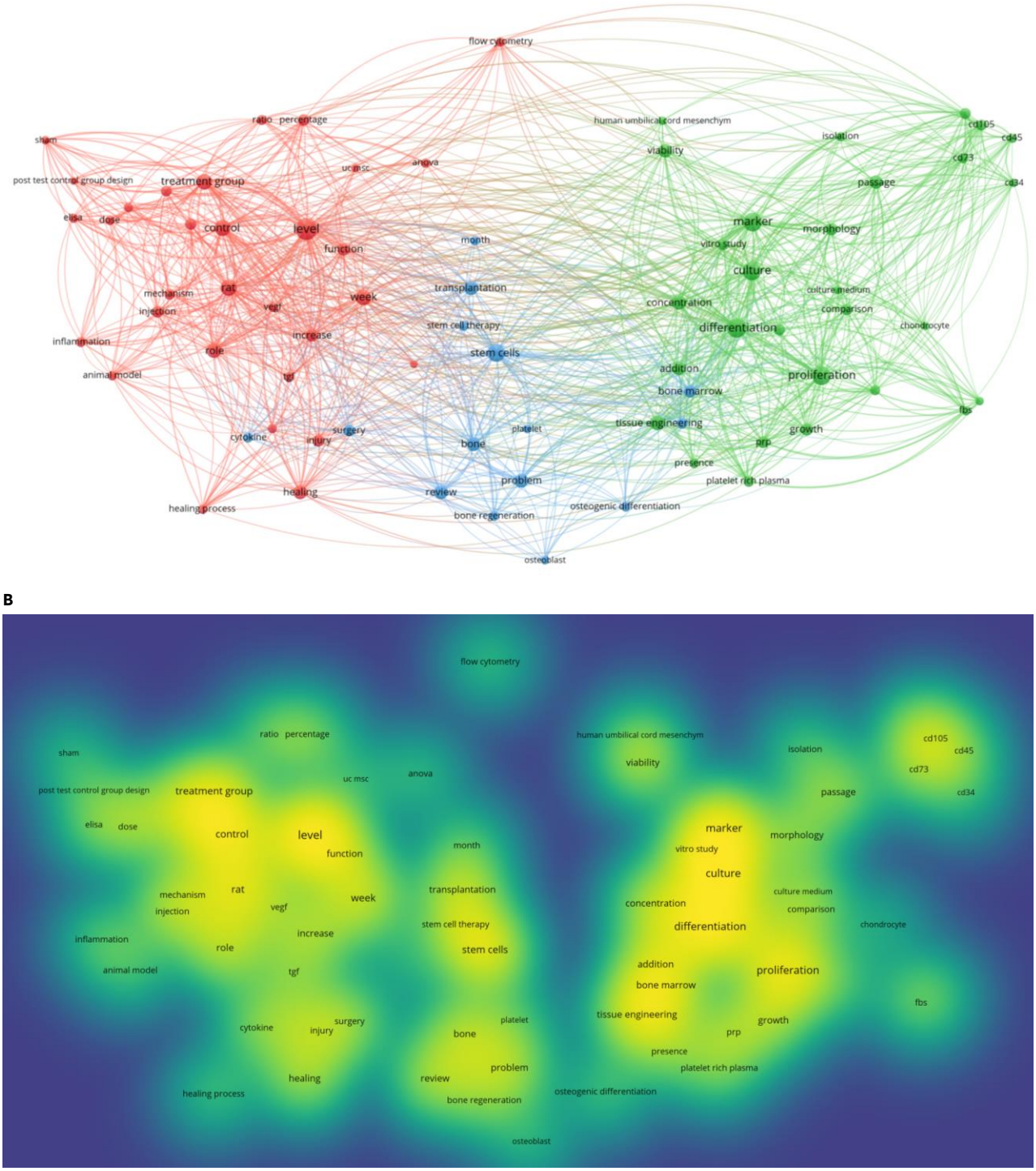


Figure 7. The analysis of keywords, network analysis **(A)**; density analysis **(B)**.
Created with VOSviewer software.

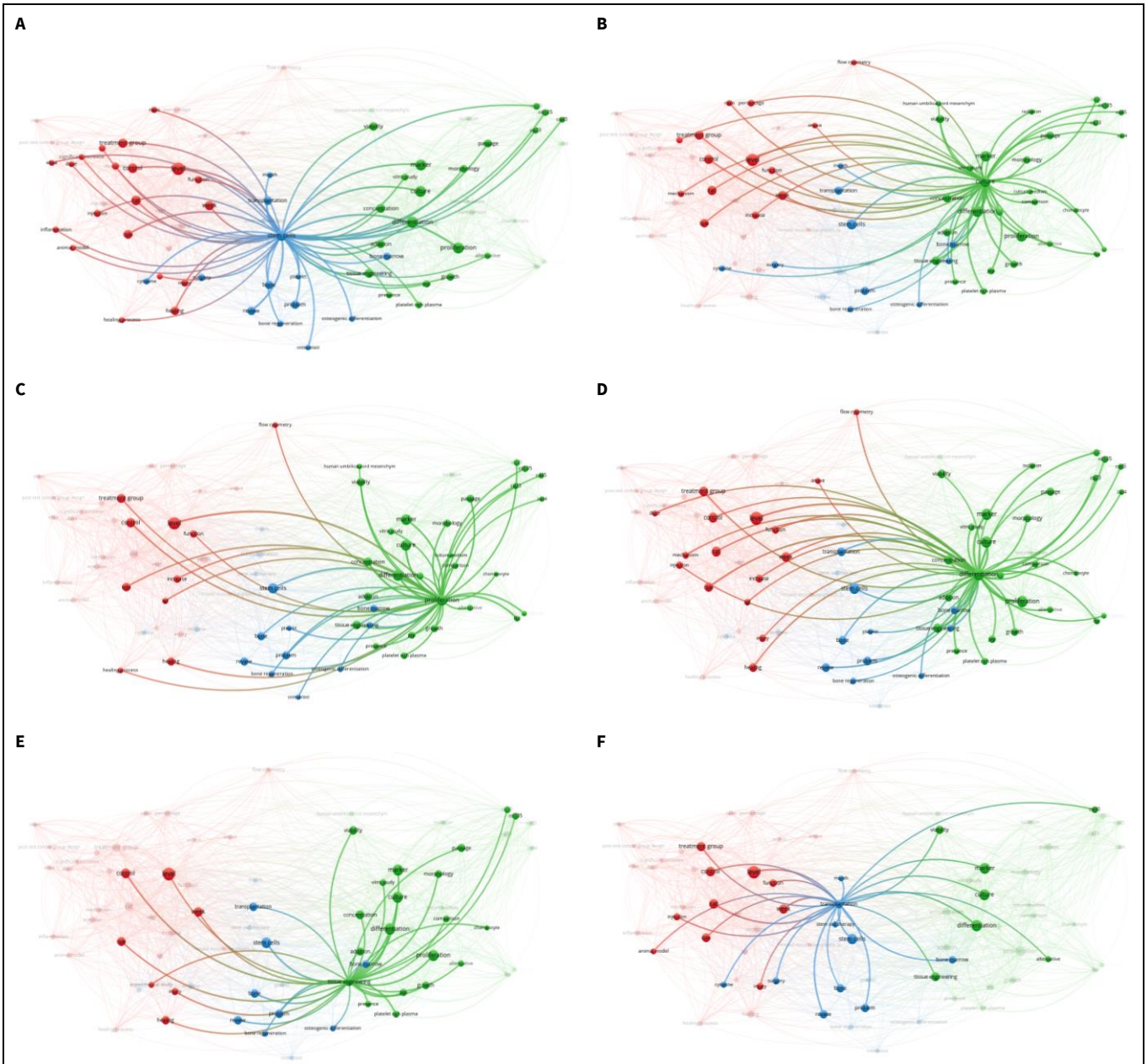


Figure 8. The analysis of specific keywords.
Stem cells **(A)**; Culture **(B)**; Proliferation **(C)**; Differentiation **(D)**; Tissue engineering **(E)**; and Transplantation **(F)**.
Created with VOSviewer software.

As stem cells continue to show significant potential in regenerative medicine and therapeutic interventions (Meiliana et al., 2016), research in this field has become increasingly important, attracting more funding from various sources. The increase in funding for stem cell research has allowed for more comprehensive and impactful studies, leading to an increase in the number of publications in the field. This suggests that funding is a critical factor in advancing stem cell research and innovation. On the other hand, the trend of stem cell-related research in Indonesia can be analyzed using keywords in the bibliometric analysis.

As a keyword, stem cells indicate a significant interest in the biology and potential therapeutic applications of stem cells. The keyword culture suggests the importance of *in vitro* studies in understanding stem cell behavior and differentiation, while proliferation highlights the need to enhance the expansion of stem cells for clinical use. PRP, a commonly used supplement in stem cell therapy, is a keyword that reflects the interest in developing effective and safe stem cell-based therapies for tissue repair and regeneration (Karina et al., 2019). Tissue engineering, another keyword, underscores the potential use of stem cells in creating functional tissues and organs for transplanta-

tion (Kwon et al., 2018). Finally, transplantation as a keyword indicates interest in using stem cells as a therapeutic option for various diseases and injuries, emphasizing the importance of translating preclinical studies into clinical trials to establish the safety and efficacy of stem cell-based therapies.

Stem cells have been applied for orthopedic purposes in Indonesia using bone marrow-derived mesenchymal stem cells (BM-MSCs) (Dilogo et al., 2018). In addition, stem cells can also be used for tendon and ligament repair (Berebichez-Fridman et al., 2017). An Indonesian case report also showed that stem cell administration improved the outcome of chronic spinal cord injury patients (Phedy et al., 2019). Another study in vitro showed that combining human stem cells and hepatocyte-reconstructed liver organoid is important for developing tissue engineering (Sibuea et al., 2020). Several sources of stem cells can be used for research and therapy.

In Indonesia, the most common sources of stem cells were adipose tissue, bone marrow, and the umbilical cord (Kamal et al., 2013; Karina et al., 2020; Pawitan et al., 2015; Wahyuningsih et al., 2020; Widowati et al., 2014). In some studies, researchers have investigated stem cell proliferation and differentiation analysis using PRP. PRP has the potential role of accelerating regeneration and inducing the differentiation of stem cells into chondrogenic or osteogenic lineages (Fibrini et al., 2022; Karina et al., 2019; Rosadi et al., 2019; 2021; 2022). In addition, there has been some research into the potential use of PRP as an adjunctive therapy for treating COVID-19 patients (Karina et al., 2021a; 2021b). Stem cells have been used for COVID-19 treatment in Indonesia (Dilogo et al., 2021). Even though stem cell research and treatment were still reported during the COVID-19 pandemic, the basic research funding numbers have slightly decreased.

It is possible that the decrease in funding for stem cell research has impacted the number of articles and citations in this field, and this decrease may be partly due to the ongoing COVID-19 pandemic. Many fund sponsors may have shifted their focus and resources toward research related to the recovery and prevention of COVID-19, which could have resulted in less funding being allocated toward other research areas, including stem cells.

Mapping author networks and analyzing the density based on the number of published articles can provide insights into research collaborations and productivity within a particular field or discipline. In this context, high density refers to a high number of connections or collaborations between authors who have published a large number of articles (van Eck and Waltman, 2009). A high density can indicate that a particular group of authors has been highly productive and active in their research, often collaborating with one another on multiple projects. This could suggest that this group of authors has a strong research focus and expertise in a particular area. On the other hand, a low density may indicate that authors in the field are less connected and may not collaborate as frequently. This could be due to a number of reasons, such as differences in research interests. It is important to note that while high density may indicate high productivity, it does not necessarily equate to high-quality research. It is important to evaluate the quality of the research and the impact it has on the field, rather than simply focusing on the number of articles published.

In 2018, the Indonesian government implemented a regulation for any cell therapy, including stem cell therapy, to be conducted on the basis of clinical trials to demonstrate its safety and efficacy. This regulation is in line with global efforts to regulate stem cell therapies and ensure that they meet strict standards before they are made available to patients. By mandating clinical trials, the Indonesian government aims to protect patients from potential harm and ensure that stem cell therapies are used appropriately and effectively in the treatment of various diseases and conditions. This new regulation is likely to contribute to the growth and advancement of the stem cell research field in Indonesia by promoting the responsible and evidence-based use of stem cells in medicine.

Overall, the bibliometric analysis of stem cell research in Indonesia provides valuable insights into the trends and directions of research in this field over the past 20 years. It demonstrates that stem cell research in Indonesia is growing in quantity and quality and is well integrated with the international research community. The findings of this study can inform future research directions and policies to further develop and enhance stem cell research in Indonesia.

Although this study provides a detailed analysis of the stem cell research field in Indonesia, there are some limitations to consider. Firstly, our data was collected solely from the Scopus database, which may have resulted in incomplete data collection. Additionally, some researchers do not agree that highly cited research indicates high-quality research, and we did not consider self-citations in our analysis. Despite these limitations, we believe that our comprehensive analysis of a large amount of data is sufficient to represent the development trends in this field. While there may be a small number of potentially missing publications, we are confident that our results are representative of the overall trends in stem cell research.

CONCLUSION

Stem cell research in Indonesia has shown a gradual increase over time and has been recognized by funders as an important area of study. The keywords "stem cells," "culture," "proliferation," "differentiation," and "tissue engineering" have been the focus of research from 2003 to 2022. The keyword "transplantation" is expected to increase in the future due to government support and regulations related to cell therapy, including stem cells. This study provides valuable insights into the trends and developments in stem cell research in Indonesia and highlights the potential for further research and advancements in this field.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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Contribution	Rosadi I	Karina K	Dewi PAS	Az Zahra TF	Barlian A	Kharisma VD	Ansori ANM
Concepts or ideas	x			x	-		
Design	x			x	x		
Definition of intellectual content	x				x	x	x
Literature search	x			x		x	x
Experimental studies	x			x		x	
Data acquisition	x			x		x	
Data analysis	x			x			x
Statistical analysis	x			x			x
Manuscript preparation	x	x	x	x	x	x	x
Manuscript editing	x	x	x	x	x	x	x
Manuscript review	x	x	x	x	x	x	x

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