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Global Research Trends on Vaccination in Athletes: A Bibliometric Analysis of Publications from 1965 to 2024

Jonathan Hasian Haposan [1,2,*] and Rahmat Fadhli [3,4]

[1] Dep. Biostatistics, Epidemiology, and Population Health, Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia
[2] Faculty of Medicine, Dentistry, and Health Sciences, University of Melbourne, Parkville, Australia
[3] Dep. Educational Management, Faculty of Educational Sciences and Psychology, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
[4] Faculty of Engineering and Information Technology, University of Melbourne, Parkville, Australia
* Correspondence: jonathan.haposan@ugm.ac.id

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Abstrak:
Pendahuluan: Atlet menghadapi risiko infeksi yang khas akibat sering bepergian, berada dalam lingkungan dengan kontak fisik yang erat, serta aktivitas fisik intens yang dapat menyebabkan penurunan sementara fungsi imun. Meskipun memiliki kebugaran fisik yang tinggi, atlet tetap rentan terhadap penyakit infeksi yang dapat berdampak pada performa dan kesehatan masyarakat secara luas. Imunisasi merupakan strategi pencegahan yang penting, namun riset terkait vaksinasi pada atlet masih terbatas dan kurang terwakili. Penelitian ini bertujuan untuk mengeksplorasi riset tentang vaksinasi pada atlet melalui analisis bibliometrik **Metode:** Studi bibliometrik ini secara sistematis meninjau publikasi dari database Scopus, Web of Science, MEDLINE, dan CENTRAL hingga 15 April 2025. Data dianalisis menggunakan VOSviewer® dan R® (bibliometrix dan biblioshiny). **Hasil:** Setelah mengecualikan studi non-manusia, sebanyak 387 publikasi dianalisis. Output penelitian meningkat tajam setelah tahun 2020, dipicu oleh pandemi COVID-19. Empat klaster tematik utama ditemukan: perawatan klinis dan pencegahan, hasil vaksinasi berdasarkan demografi, epidemiologi global, dan respons imun terkait aktivitas fisik. Amerika Serikat dan Inggris memimpin dalam produktivitas dan kolaborasi, sementara kontribusi negara berpendapatan rendah dan menengah masih terbatas. **Kesimpulan:** Studi ini menyimpulkan meningkatnya minat terhadap imunisasi pada atlet dan pentingnya perluasan riset secara global terutama di negara berkembang.
Kata kunci: Analisis Bibliometrik; Atlet; Immunisasi; Trend Penelitian; Vaksinasi

Abstract:
Introduction: Athletes face unique infection risks due to frequent travel, close-contact environments, and intense physical activity, which may temporarily suppress immune function. Despite their physical fitness, they remain vulnerable to infectious diseases that can impact performance and public health. Immunization is a key preventive strategy, yet research on vaccination in athletes is limited and underrepresented. This study aims to explore research on athlete vaccination using a bibliometric analysis. **Methods:** This bibliometric analysis systematically reviewed publications from the Scopus, Web of Science, MEDLINE, and CENTRAL databases up to 15 April 2025. Data were analyzed using VOSviewer® and R® (bibliometrix and biblioshiny). **Results:** After excluding non-human studies, 387 publications were included. Research output increased sharply after 2020, driven by the COVID-19 pandemic. Four thematic clusters emerged: clinical care and prevention, demographic vaccination outcomes, global epidemiology, and exercise-related immune response. The United States and the United Kingdom led in productivity and collaboration, while contributions from low- and middle-income countries were limited. **Conclusion:** This study underscores the growing interest in athlete immunization and the need for broader global research engagement especially in developing countries
Keywords: *Athletes; Bibliometric analysis; Immunization; Research trends; Vaccination*

1. Introduction

Immunization plays a vital role in protecting overall health, including among athletes, who face unique exposure risks due to the nature of their profession. Professional athletes travel frequently, train in shared facilities, and are in close contact with many people, all of which increase their vulnerability to infectious diseases (1–3). As we know, high-intensity physical activity can result in temporary immunosuppression, referred to as the "open window" period, further increasing susceptibility to infections (3,4). Besides traumatic injuries, such as spleen rupture among athletes, might also increase the risk of infections (5). When infections occur, they can disrupt training schedules and competitive performance, leading to financial losses and health risks that affect not only the individual but the broader sports community as well (2).

Once contracted to a contagious infection, it will be a difficult question to decide who plays and who sits, or the return-to-play decision (6). Even a minor contagious illness might result in potentially disastrous consequences (6). Even the Tokyo 2020 Olympic Games should be postponed until the summer of 2021 due to the potentially disastrous COVID-19 risks with the various mitigation and control measures to be applied, including vaccination prevention during the Beijing 2022 Olympic Games after several COVID-19 vaccines are available (7). Evidence of six British Olympic athletes being positive for COVID-19 after their flight landed in Tokyo that raised fear of other competitors out of the Olympic (8) has underscored the importance of infectious disease prevention, especially vaccination.

Despite being in excellent physical condition, athletes are advised to follow the National Immunization Schedule and receive additional vaccinations based on their travel plans and potential exposure (3,9). Immunizations for influenza, hepatitis, and other travel-related diseases are particularly relevant for athletes (2,9). Encouragingly, studies show that the timing of vaccination does not negatively affect immune responses or increase side effects, allowing athletes to be vaccinated without disrupting their training cycles (10). In addition to individual protection, athlete immunization contributes to herd immunity, helping to reduce the transmission of infectious diseases within teams and the broader community (11). Ultimately, vaccination significantly decreases the incidence and severity of vaccine-preventable diseases among athletes, supporting safer and more secure participation in sports (2,3,9,12).

Based on the preliminary search, there remain gaps where the research on vaccination among athletes is understudied and underrepresented, especially in low- and middle-income countries where most infectious diseases occur. Therefore, this study aims to map the knowledge gap and encourage global researchers to study this area of research using a bibliometric analysis approach. There are some advantages of the bibliometric analysis approach compared to other reviews, where bibliometric analysis can provide the trends of certain topics over time, citations over time, clustering based on keywords or authorship, and many other features (13,14). The findings are expected to inform future research direction and contribute to the development of more robust guidelines and policies related to vaccination in athlete populations. Therefore, this study aims to map global research trends on athlete vaccination by identifying publication trends, visualizing thematic patterns, and identifying the most active journals and contributing countries.

2. Methods

This study employed a bibliometric analysis to map the global landscape of vaccination in athlete literature. Bibliometrics analysis is defined as the quantitative evaluation of academic literature to uncover patterns in publication, authorship, and thematic development (15). A comprehensive literature search was conducted in four major databases: Scopus, PubMed, CENTRAL, and Web of Science (WoS) to ensure comprehensive coverage and reduce database-specific bias. The search was performed during April 2025, using tailored keyword strategies for each database to maximize the retrieval of relevant studies related to athlete vaccination. The search strategy combined keywords related to vaccination (e.g., vaccin*, immuniz*) and athlete populations (e.g., athlete*, sportsman, sportsperson). The inclusion criteria for the study are: 1) peer-reviewed journal or conference

proceedings, 2) focused on topics of athlete vaccination, 3) were published in English, and 4) the year of publication is 1965 to 2024.

All retrieved records (n = 915) from Scopus (n = 515), Web of Science (n = 212), PubMed (n = 173), and CENTRAL (n = 15) were imported into Covidence software. This software helps researchers to manage records, facilitate duplicate removal, and streamline the screening process based on inclusion criteria. After removing 328 duplicates, a total of 586 studies were screened based on the title and abstract. Irrelevant studies, such as non-human populations, were excluded from the analysis. As a result, 387 studies are included in the bibliometrics analysis. The screening process was presented in the PRISMA Flowchart as follows in **Figure 1**:

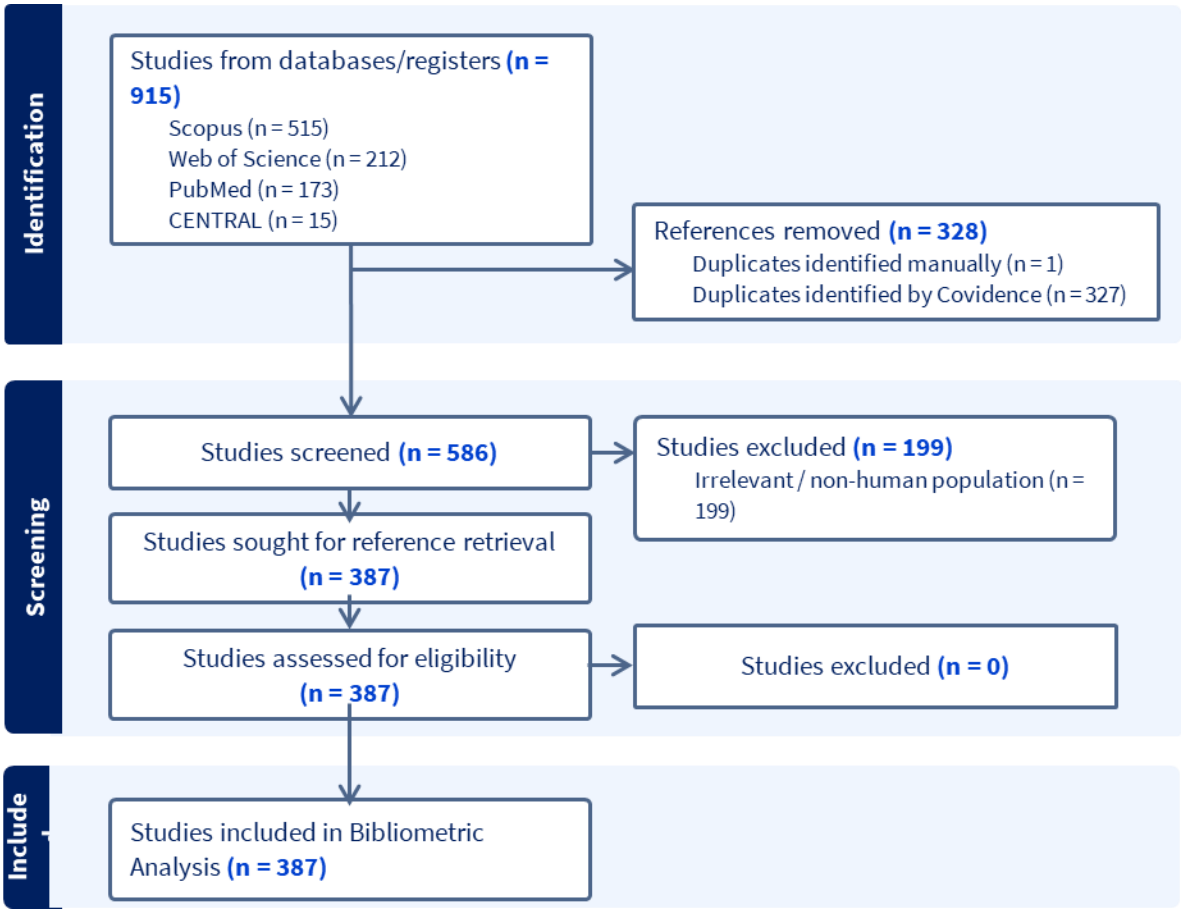

Figure 1. PRISMA Flowchart

The included data were exported to Microsoft Excel for further bibliometrics analysis. VOSViewer software and Biblioshiny were utilized for this study. VOSviewer is widely used for visualizing bibliometrics networks, such as co-authorship, co-occurrence of keywords, and citation patterns, through its strength in generating intuitive and interpretable maps (16). Meanwhile, Biblioshiny software is an interactive web interface of the Bibliometrix R-package that offers comprehensive tools for descriptive analysis, trend mapping, and thematic evolution (17). By combining these tools, the study leveraged both robust visual network mapping and in-depth descriptive analytics to ensure a more nuanced understanding of the research landscape. The output analysis included keyword co-occurrence networks, overlay visualizations, country-level publication mapping, and source (journal) analysis.

The records exported in Microsoft Excel were then subjected to data cleaning to ensure all the metadata of the included records was complete. A total of 20 records were removed from the analysis due to incomplete metadata such as the author's name, keywords, year of publication, and relevant data. Therefore, 367 publications were analyzed for bibliometric analysis. The cleaned dataset was subsequently analyzed using VOSviewer to generate network and overlay visualization based on keyword co-occurrence. To minimize the bias arising from keyword variations, the researchers standardized the keywords by merging semantically equivalent terms into a

single unified keyword. For instance, 'Coronavirus', 'SARS-CoV-2', and 'Coronavirus 19' were grouped under 'Covid-19'. Following this, for co-occurrence analysis, researchers visualized keywords using both network visualization and overlay visualization functions. A minimum threshold of eight occurrences was applied to ensure conceptual relevance. Irrelevant or generic keywords such as controlled study, review, or high-quality journal were excluded from the visualization to improve thematic clarity.

Moreover, Biblioshiny software was also employed to complement the visualization by providing insights into the most relevant sources, like journals, and mapping author collaboration patterns based on country affiliations. This allowed the identification of dominant publication spots and geographic trends in research contributions. In addition, due to the nature of the bibliometric analysis using the available secondary data from several databases and using the aggregated data, the study is considered to have no ethical concern and no need for ethical clearance.

3. Results

Figure 2 presents the annual distribution of publications on vaccination in athletes from 1965 to 2024. The data were extracted from four major databases (Scopus, Web of Science, PubMed, and CENTRAL) and visualized using Python to generate a bar chart illustrating longitudinal publication trends in this topic.

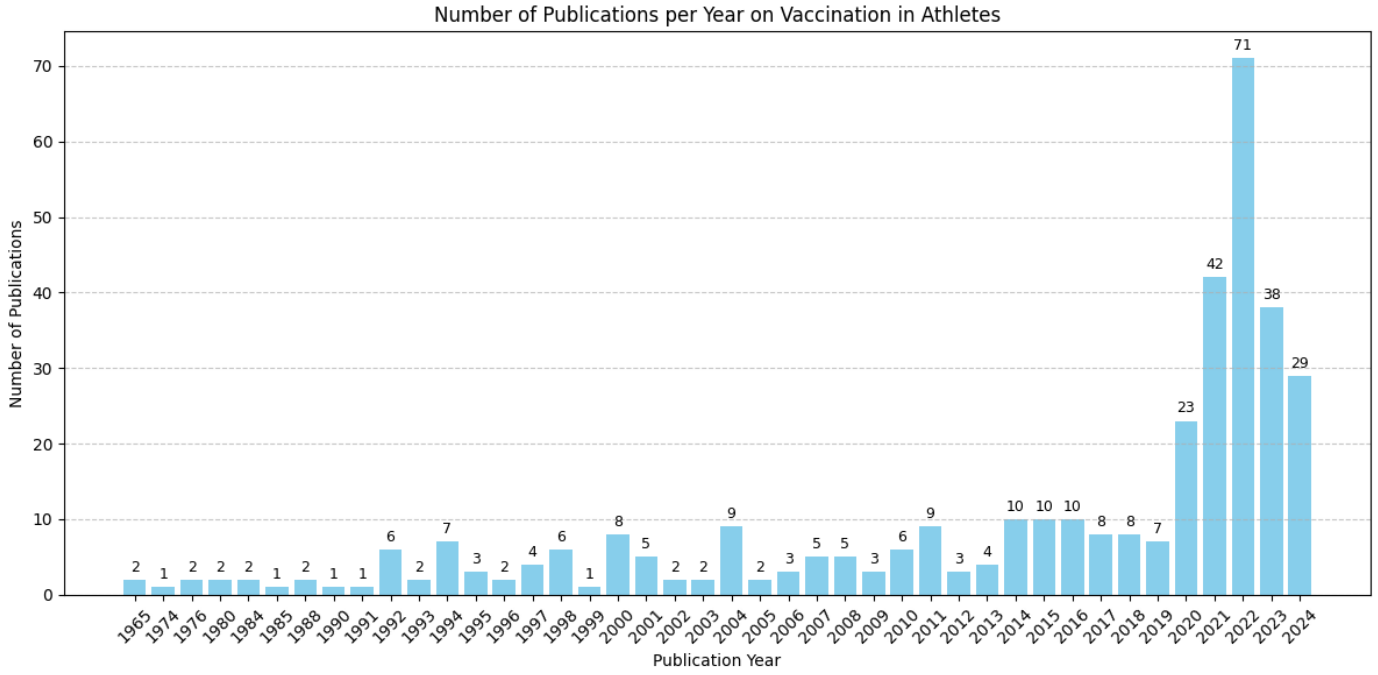

Figure 2. Publication trends by published year in vaccination in athletes between 1965 to 2024

The number of publications remained low and relatively stable from 1965 to 2019, generally not exceeding 10 publications per year. A substantial increase began in 2020, with a sharp peak in 2022 (71 publications), likely reflecting heightened scholarly attention during the COVID-19 pandemic. While there was a slight decrease in subsequent years, the trend indicates sustained academic interest in vaccination among athletes, particularly concerning global health concerns.

3.1 Co-occurrence analysis

Co-occurrence analysis is a bibliometric technique used to identify how often specific terms (e.g., keywords) appear together within a set of documents, which helps reveal patterns and thematic relationships in the literature. For the network analysis, **Figure 2** presents the network visualization of keyword co-occurrence generated using VOSviewer. This visualization maps the intellectual structure of research on vaccination in athletes by identifying frequently co-occurring keywords and their relationships across publications. Each node represents a keyword, with node size reflecting its frequency and link thickness indicating the strength of co-occurrence between terms.

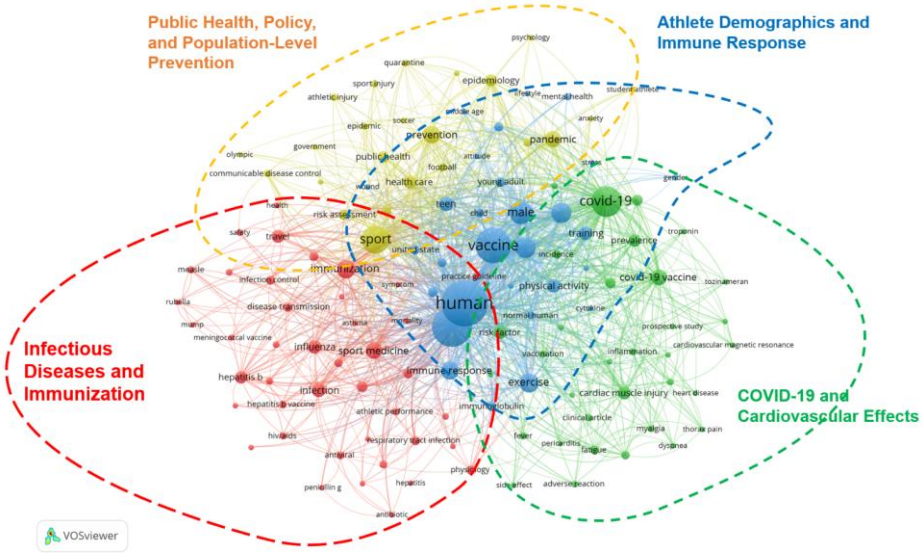

Figure 3. Network visualization

The network reveals four major clusters representing distinct thematic areas: infectious diseases and general immunization (Cluster 1, red), COVID-19 and its cardiovascular effects (Cluster 2, green), demographic and physiological aspects of athletes (Cluster 3, blue), and public health or population-level prevention efforts (Cluster 4, yellow). The keywords *athlete*, *human*, and *vaccine* appear as central nodes, suggesting their pivotal role in linking these research themes. This visualization highlights the multidisciplinary nature of the topic, spanning clinical, physiological, and public health perspectives. To further illustrate the content of each cluster, **Table 1** provides a brief overview of its dominant themes, key terms, and example articles.

Table 1. Summary of Thematic Clusters Identified

Cluster	Thematic Focus	Representative Keywords	Publication Examples
Cluster 1 (Red)	Infectious diseases and immunization	Immunization, influenza, hepatitis B, infection	1. Krzywański, J., Nitsch-Osuch, A., Mikulski, T., Krysztofiak, H., Pokrywka, A., Kanecki, K., ... & Brydak, L. (2018). Antibody response to trivalent influenza vaccine in the northern and the southern hemisphere in elite athletes. *Current Trends in Immunity and Respiratory Infections*, 49-54. 2. Kordi, R., & Wallace, W. A. (2004). Blood borne infections in sport: risks of transmission, methods of prevention, and recommendations for hepatitis B vaccination. *British journal of sports medicine*, *38*(6), 678-684.
Cluster 2 (Green)	COVID-19 and cardiovascular effects	COVID-19, COVID-19 vaccine, myalgia, inflammation	1. Daems, J. J. N., van Hattum, J. C., Verwijs, S. M., Bijsterveld, N. R., Groenink, M., Wilde, A. A., ... & Jorstad, H. T. (2023). Cardiac sequelae in athletes following COVID-19 vaccination: evidence and misinformation. *British journal of sports medicine*, *57*(21), 1400-1402. 2. Shah, A. B., Rizzo, S. M., Finnoff, J. T., Baggish, A. L., & Adams, W. M. (2024). Cardiovascular safety of the COVID-19 vaccine in Team USA athletes. *Sports Health*, *16*(4), 504-506.
Cluster 3 (Blue)	Athlete demographics and immune response	Athlete, exercise, immune response, gender	1. Chastin, S. F., Abaraogu, U., Bourgois, J. G., Dall, P. M., Darnborough, J., Duncan, E., ... & Hamer, M. (2021). Effects of regular physical activity on the immune system, vaccination and risk of community-acquired infectious disease in the general population: systematic review and meta-analysis. *Sports Medicine*, *51*, 1673-1686. 2. Rosic, I., Malicevic, S., Medic, S., & Vlasich, C. (2008). Immune response by athletes to hepatitis B vaccination. *Vaccine*, *26*(26), 3190-3191.
Cluster 4 (Yellow)	Public health, policy, and population-level prevention	Public health, prevention, epidemiology, student-athlete	1. Daly, P., & Gustafson, R. (2011). Public health recommendations for athletes attending sporting events. *Clinical Journal of Sport Medicine*, *21*(1), 67-70. 2. Brito, J. (2015). Vaccination in elite athletes: a call to action to develop guidelines for all infectious diseases. *Sports Medicine*, *45*(3), 447-448.

Moreover, this study also generated an overlay visualization of keyword co-occurrence using VOSviewer to explore the temporal evolution of themes in the literature (See **Figure 4**). This visualization represents the average publication year of keywords, with colors ranging from dark purple (older topics) to yellow (more recent ones), thereby allowing us to observe emerging trends and shifts in scholarly focus over time.

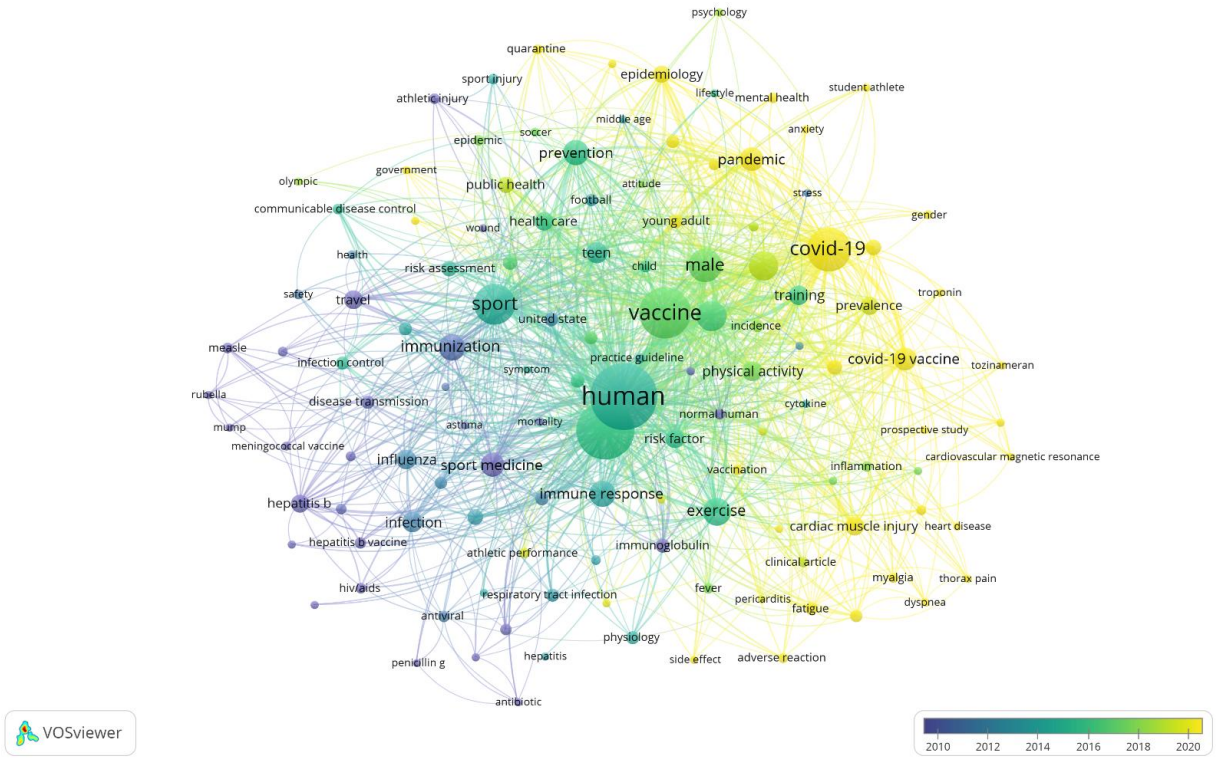

Figure 4. Overlay visualization

As shown in **Figure 4**, early research in this field primarily focused on general immunization topics such as hepatitis B, influenza, and infection control, indicated by darker purple tones. In contrast, recent studies highlighted (in yellow) concentrate on COVID-19, the COVID-19 vaccine, adverse reactions, cardiac muscle injury, and public health responses. This pattern reflects a temporal shift in scholarly attention, with the COVID-19 pandemic significantly reshaping the research landscape on vaccination in athletic populations.

3.2 Geographics and Source-Level Distribution of Research

To examine the geographical distribution of research on vaccination in athletes, a country-level analysis was conducted. **Figure 5** presents a world map visualization generated using Biblioshiny, displaying the scientific production by country in bar charts and geographical maps. For the geographical map, the intensity of the blue shading reflects the number of publications, with darker shades indicating higher outputs. For the bar chart, Orange represents a group of countries with high co-authorship connections, while blue indicates a group with lower collaborations.

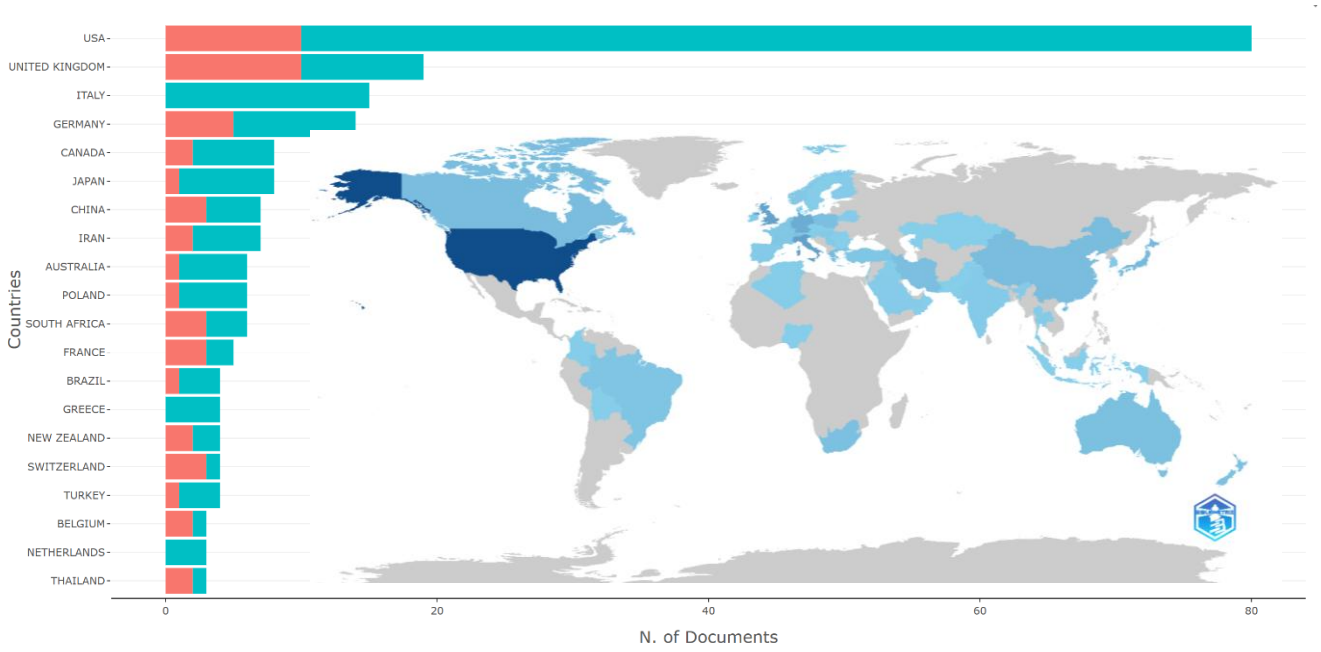

Figure 4. Distribution of most publication countries (combined geographics and bar chart)

As shown in the map, the United States leads the global scientific output in this field, contributing 84 publications. This is followed by the United Kingdom (19), Italy (15), and Germany (14). High contributions are also observed from Canada, Japan, China, Iran, Australia, and Poland. These results indicate that research on vaccination in athletes is predominantly concentrated in North America and Europe, although growing contributions from Asia are also evident. The global spread of authorship highlights the transnational interest in this topic, particularly in the context of pandemic-related health concerns. Furthermore, to identify the primary outlets for research on vaccination in athletes, an analysis of the most relevant sources was conducted using Biblioshiny. **Figure 5** presents the top journals ranked by the number of publications indexed in the dataset, highlighting the key platforms that are frequently published in this field.

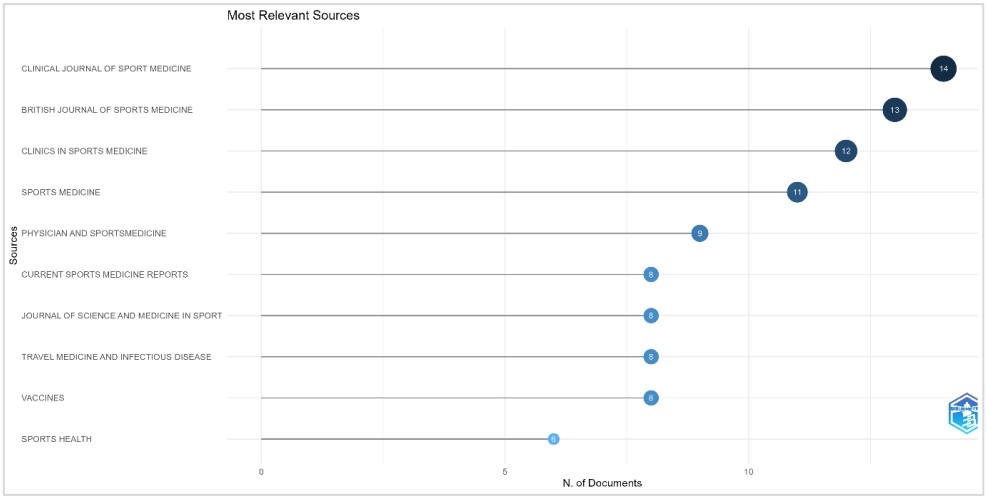

Figure 5. The journal publishers with the most publications

As illustrated, the *British Journal of Sports Medicine* and the *Clinical Journal of Sport Medicine* are the two most prolific sources, each contributing 14 and 13 documents, respectively. Other high-ranking journals include *Clinics in Sports Medicine* (12 publications), *Sports Medicine* (11), and *Physician and Sports Medicine* (9). These findings indicate that the topic is predominantly discussed within specialized sports and exercise medicine journals, though general medical sources such as *Vaccines* also play a role in bridging clinical and athletic health perspectives. This distribution reflects the interdisciplinary nature of the subject, spanning both sports science and public health domains.

4. Discussion

Immunization is important among professional athletes and sports players to prevent them from their high risk of infectious diseases due to their frequent travel, close contact with many people, and the nature of their training environments. This bibliometric analysis aimed to analyze the patterns and trends of publication in the field of vaccination in athletes from the Scopus database between 1965 and 2025. The findings provided insight into the research field, explored the knowledge gaps, and identified potential emerging topics for future research.

The bibliometric analysis showed the exponential growth in the number of publications related to vaccination after 2020 when the COVID-19 pandemic occurred and the global COVID-19 vaccinations were mandated. Before that, the field of vaccination in athletes was considered understudied and very limited. Similar to the findings from the bibliometric analysis on sport-associated infections, the increasing interest and publications are most likely due to the COVID-19 pandemic, which had a significant impact on sports and athlete health (18). Based on our findings, we categorize the most co-occurrence terms into 4 cluster topics regarding the vaccination in athletes, including "Infectious diseases and immunization", "COVID-19 and cardiovascular effects", "Athlete demographics and immune response ", and "Public health, policy, and population-level prevention". We also found the emerging topics that were researched in recent publications, including the pandemic-caused infectious diseases (COVID-19/SARS-CoV-2, long COVID), pandemic-related vaccination, and side effects.

We also found that the United States produced the most publications on vaccination in athletes, followed by the United Kingdom, Italy, Japan, and Australia – all are from high-income countries based on World Bank status. The researchers from these countries led the research productivity and contributed to global research collaborations in the field of vaccination in athletes. Similar findings were also found from the bibliometric analysis on sport-associated infections, where the United States and the United Kingdom were the countries to produce publications on the topic (18). The study findings highlighted the limited number of studies of vaccines in athletes among low- and middle-income countries (LMICs). This can be explained because of the limited capacity, infrastructure, workforce resources, financing, and regulatory issues in conducting vaccine research in LMICs (19).

Although professional athletes are not clinically immune-deficient, it is found that small changes in some immune parameters may compromise the protection against common minor infections, such as upper respiratory tract infections, among athletes (20). Gartner and Meyer (2014) even encouraged the special vaccination guidelines for elite athletes to protect against tetanus, diphtheria, pertussis, influenza, hepatitis A, hepatitis B, measles, mumps, and varicella due to the risks of travel to endemic areas (12). Vaccination among athletes is considered cost-effective with the potential benefits that it may provide (12). Unfortunately, given the potential risk among athletes, the vaccination guidelines for athletes still follow the same recommendations for the common populations, which are diverse across countries and change over time (12,21).

Based on the findings from this bibliometric analysis, several topic areas are recommended for future studies on vaccination in athletes. Our study found that the emerging topics are related to pandemic-related vaccinations, vaccine hesitancy and misinformation in athletes, and vaccine safety evaluation among athletes (**Figure 4**). Control measures and vaccine research to prepare for disease X, which can cause future pandemics, have become a priority across the world (22). Furthermore, the misinformation and hesitancy towards vaccination influenced by athletes as public figures have also become important topic areas to be addressed for future qualitative research (23,24). Research on the potential side effects of future vaccines among athletes seems to be an important topic due to the needs of athletes for good performance, especially before the competitions. It seems that the growing concern and misinformation about cardiac-related side effects due to COVID-19 vaccinations among athletes have been addressed in several systematic reviews and meta-analyses (25–27), where the incidence is very low and the benefit of vaccination outweighs the risk.

It is important to acknowledge the concern about the limited studies among low- and middle-income countries. The findings of this study highlighted the importance of collaboration among researchers, especially from high-income countries, to support and build the capacity of researchers from low- and middle-income

countries, where the most infectious disease burdens and highest risks occur. The findings from the Asia-Pacific Vaccine Research Networks recommend the importance of conducting collaborative efforts and networks regionally or internationally to tackle the challenges in the research-related resources and to support the conduct of vaccine research in LMICs (19).

While the findings demonstrate the increasing interest in this research area, it is important to acknowledge the limitations of this study. This bibliometric analysis was based on four databases, it may not capture other literature from other databases and grey literature. This bibliometric analysis also only captured the trends and patterns from the titles, abstracts, and keywords, along with other citation information that might not capture the whole picture of the contexts and contents of the publications that were not indexed by the four databases that were used in this study.

Despite the limitations of this study, to the best of our knowledge, this is the first bibliometric analysis being studied in the field of vaccination in athletes until 15 April 2025 we searched. The findings from this study might provide the initial foundation of knowledge and ideas for further research in this field. This field area might contribute to the wider research area, especially sports medicine, preventive medicine, and public health. We identified some research gaps with limited publications regarding vaccine acceptance among athletes, vaccine response during the “open window” syndrome, risk factors or predictors of breakthrough infections post-immunizations, comparative studies of vaccination guidelines in athletes across countries, and many other topics.

5. Conclusion

In conclusion, research on vaccination in athletes remains limited and underexplored, particularly in low- and middle-income countries where the burden of infectious diseases is often highest. Nevertheless, this bibliometric analysis highlights a growing global interest in this field, especially in response to emerging public health challenges. The findings underscore the need for further investigation to address existing gaps and support the development of evidence-based vaccination strategies tailored to athletes. Emerging topics such as pandemic-related vaccinations, vaccine hesitancy and misinformation, and vaccine safety evaluation among athletes might need to be further studied.

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