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Bibliometric Analysis of Trends in Human Vaccine Development, Law, and Ethics

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ABSTRACT

Introduction: The global health crisis triggered by COVID-19 in 2020 placed unprecedented emphasis on the rapid creation and worldwide dissemination of vaccines, while also bringing ethical and legal questions to the forefront of public and academic debate.
Methods: Using a bibliometric framework, this study analyzes scholarly publications addressing vaccination in relation to ethics and law over the period 1970–2024, drawing on records indexed in the Scopus database. Research productivity and collaboration patterns were assessed based on publication year, authorship, country of origin, institutional affiliation, and document type. Network visualization performed with VOSviewer revealed five dominant thematic clusters shaping the vaccine research landscape.
Results: The findings demonstrate a pronounced expansion in publication volume, particularly in the post-pandemic period, with the United States emerging as the most influential contributor.
Conclusion: This analysis highlights the critical role of cross-national collaboration and offers evidence-based insights to support the advancement of ethical governance, legal regulation, and public health policy in vaccination research.

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INTRODUCTION

The COVID-19 epidemic has rapidly disseminated globally since its inception in 2020, impacting social relationships, public health, and economic structures (1). Governments worldwide have implemented several measures to alleviate these effects, notably through vaccination initiatives, with the development and distribution of COVID-19 vaccines being a prominent strategy (2).

The history of vaccination in Indonesia dates back to the 19th century in East Java, an area that frequently saw epidemics of diseases like smallpox, cholera, and malaria. The "separated vaccination system," a groundbreaking strategy comprising repeated inoculations starting from infancy, was one of the first coordinated public health responses at that time (3). Vaccination is now considered to be one of the most economical and successful methods of stopping the spread of infectious diseases (4). Vaccines protect people from a variety of diseases that can be prevented by vaccination by inducing the body's immune system to produce particular antibodies (5).

Vaccination improves community immunity by lowering overall disease transmission in addition to providing individual protection. Vaccines have historically been essential in preventing disease, disability, and early mortality (6,7). Effective vaccination campaigns and the creation of cutting-edge vaccines have significantly raised vaccination rates and avoided innumerable cases of illness and death (8).

Vaccine resistance is still a problem, though. Parental reluctance and the emergence of anti-vaccine movements have increased public worries about possible adverse effects, which has led to a decline in vaccination rates and an increase in diseases that can be prevented (9,10). Concerns about safety, false information, and mistrust of public health officials are common causes of vaccine reluctance (11–13). Despite overwhelming evidence to the contrary, a 1998 publication that mistakenly asserted a link between vaccines and autism further muddled matters (14). Underfunded health systems in many developing nations exacerbate these obstacles to vaccine adoption, making childhood immunization programs less successful (15,16).

By providing insights into research trends, author productivity, institutional and national contributions, and citation networks, bibliometric analysis offers a methodical approach to analyzing scientific production across time (17). These studies are useful instruments for helping funding agencies, researchers, and politicians make well-informed decisions, especially in fields like public health and medicine where evidence-based practices are crucial (18).

METHOD

The publication data included in this study, covering the years 1970–2024, was sourced from the Scopus database. To ensure relevant outcomes related to the study question, the search strategy was executed using the term "Vaccine" in the TITLE-ABS-KEY field. To make the search even more specific, Boolean logic was utilized using keywords like "Vaccine development," "Vaccine law," and "Vaccine ethics." The criteria for inclusion were limited to peer-reviewed works published in Scopus-indexed journals that discussed the ethical, legal, and medical aspects of vaccination. The investigation encompassed English-language literature pertaining to human immunizations; studies lacking original data or papers deemed unrelated to the context were excluded from the analysis.

This search found a total of 219 documents. The papers in this study appeared in peer-reviewed journals indexed by Scopus, which guarantees higher reputation and research quality; hence, they are considered to have undergone thorough evaluation (19).

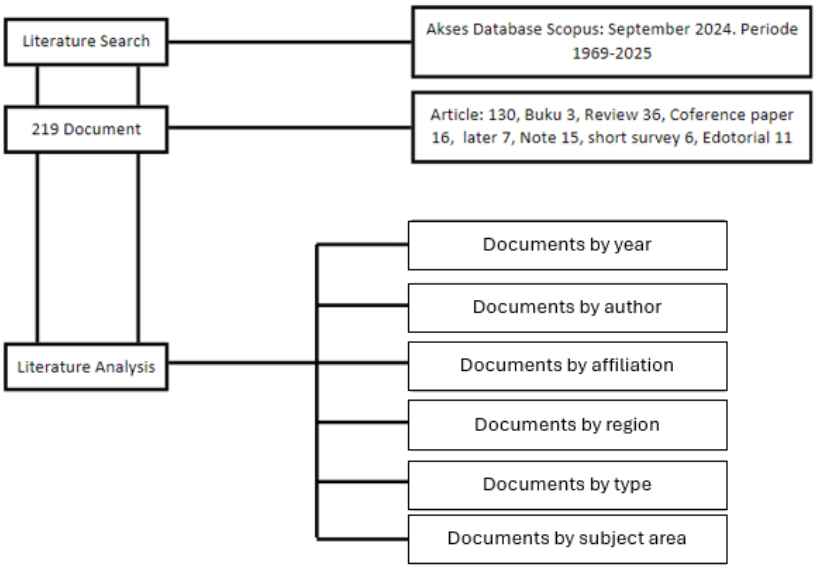

Figure 1. Research Method

To make network analysis and visualizations based on bibliographic data, VOSviewer was used to look at the data. To ensure methodological transparency, all relevant analytical parameters are provided. These include the type of analysis (co-authorship, co-occurrence, citation, or bibliographic coupling), the counting method (full or fractional), threshold values, normalization techniques, and the software version used. To facilitate replication by other researchers, repeatable supporting materials are provided, encompassing raw CSV data and VOSviewer configuration files.

Figure 1 presents an overview of the bibliometric workflow employed in this study. Publication trends were examined through the analysis and visualization of multiple parameters, including research fields, document categories, countries or regions, institutional affiliations, authorship, source titles, and year of publication. To facilitate the identification of research patterns and relationships, this study utilized VOSviewer software, a widely adopted tool for bibliometric mapping. VOSviewer enables the construction of network and visualization maps based on bibliographic data, allowing for the exploration of connections among authors, institutions, and dominant research themes (20).

RESULTS AND DISCUSSION

Documents by Year

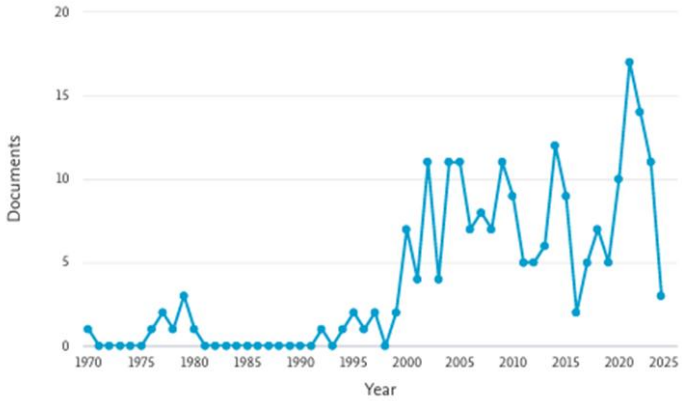

Figure 2. Percentage of Documentation by Year (Scopus data analysis, 2024)

The observed publication trajectory reflects a long period of limited scholarly activity followed by a rapid expansion beginning in the late 1990s. This sharp increase, culminating in the highest number of publications in 2024 and a projected peak in 2025, suggests growing academic recognition of the importance of the field. The acceleration in research output may be attributed to heightened global attention to vaccination-related challenges, particularly those involving ethical, legal, and public health considerations. These findings indicate a shift from marginal academic interest toward a more established and dynamic research domain.

The observed surge in publication output is likely shaped by a complex interaction of structural and contextual factors rather than a single causal driver. While advances in information and communication technologies have undoubtedly improved the speed and reach of scholarly dissemination, they have also contributed to increasing publication pressure and volume-driven research practices. Similarly, global health crises most prominently the COVID-19 pandemic have stimulated intensified academic engagement with vaccination-related ethical, legal, and policy issues, though this acceleration may reflect reactive research agendas rather than sustained long-term inquiry. Heightened public awareness of the societal implications of scientific research has further amplified demand for evidence-informed public health decisions. At the same time, expanded funding from public and private sources has supported increased research productivity, raising important questions about the influence of funding priorities on research focus, scope, and equity in knowledge production.

In 1970, a paper about religion and vaccine law came issued (21). By 2020, there were a lot more papers about vaccines. For instance, Mitilian et al. (2020) wrote an essay that looked at the costs, ethics, safety, and usefulness of controversial vaccination methods in the media (22).

Documents by Authors

Figure 3. Documents by Authors (Scopus Data Analysis, 2024)

Figure 3. Presents the distribution of scholarly output among individual authors. The horizontal axis lists the authors, while the vertical axis represents the number of publications attributed to each contributor. The analysis reveals that Gostin, L.O. and Slack, C. account for the largest share of publications, positioning them as leading figures in research addressing the intersection of human vaccination, ethics, and legal frameworks. One influential study by Slack (2005), titled "Resources and Needs of Research Ethics Committees in Africa: Preparations for HIV Vaccine Trials," explores ethical issues surrounding HIV vaccine trials conducted in resource-limited contexts (23). The paper draws attention to key concerns such as fair recruitment of participants, culturally responsive informed

consent procedures, active community engagement, continuous assessment of social risks, sponsor responsibilities in providing HIV-related care to affected participants, and equitable access to post-trial benefits, institutional capacity strengthening, and effective health interventions. Authors including Opel, D.J., Silverman, R.D., and Strode, A. exhibit comparable publication volumes, indicating a similar level of scholarly engagement within this research domain. Conversely, contributors such as English, A. and MacDonald, N.E. show lower publication outputs, suggesting a more modest presence in the literature. Meanwhile, Andanda, P., Avrett, S., and Barilan, Y.M. record the fewest publications, which may reflect either their recent entry into the field or a research focus on narrower or less frequently examined topics. In summary, this bibliometric visualization highlights variations in individual research productivity and helps identify both dominant contributors and underrepresented authors. Such analysis is useful for mapping the intellectual structure of the field, recognizing influential scholars, and identifying areas where additional academic support or collaboration may enhance future research contributions.

Documents by Country or Region

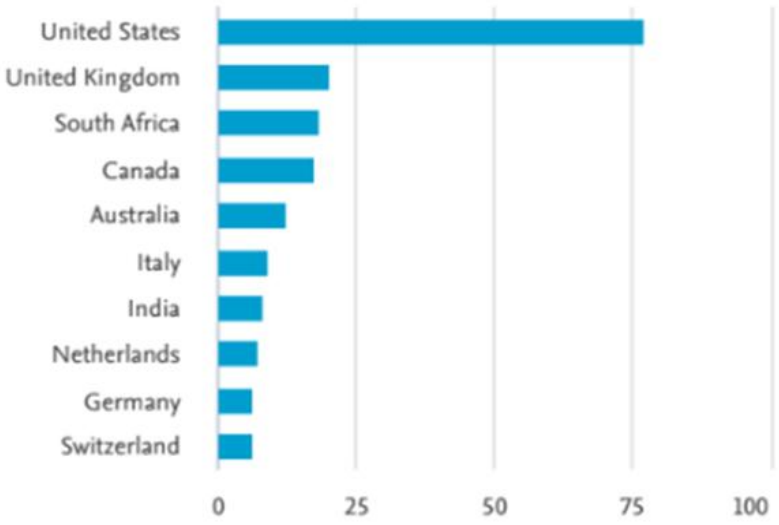

Figure 4. Documents by Country or Region (Scopus Data Analysis, 2024)

The observed geographic pattern underscores a pronounced imbalance in global vaccine-related research production. The dominance of the United States, followed by the United Kingdom, reflects the concentration of research capacity, funding availability, and established academic infrastructures in high-income countries. The presence of contributions from South Africa, Canada, Australia, and Italy suggests increasing engagement beyond traditional research hubs; however, the comparatively lower output from countries such as India, the Netherlands, Germany, and Switzerland indicates uneven global participation. This disparity highlights opportunities for strengthening international collaboration and capacity building, particularly in underrepresented regions, to promote a more inclusive and globally representative research landscape.

Documents by Type

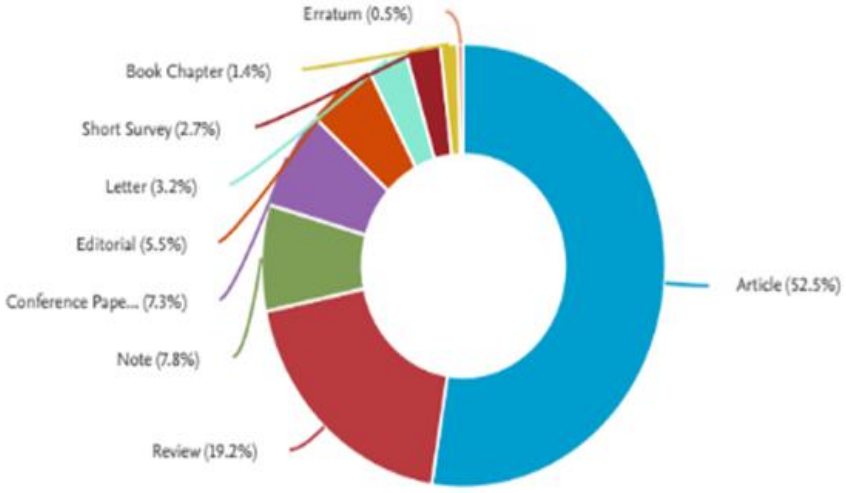

Figure 5. Documents by Type (Scopus Data Analysis, 2024)

The document type analysis shows that most of the contributions are original research and detailed literature reviews. This is because most of the publications are journal articles (52.5%) and review papers (26.2%). Notes (3.8%), conference papers (2.1%), editorials (5.3%), and letters (3.2%) are other types of articles that usually give commentary, new ideas, or early results. Book chapters (0.4%) and errata (0.5%) include more specific or corrective information, while brief surveys (2.7%) give general overviews. This distribution demonstrates that the most common forms of documents in this sector are peer-reviewed research papers and reviews. Other types of documents are used to provide extra information.

Documents by Subject Area

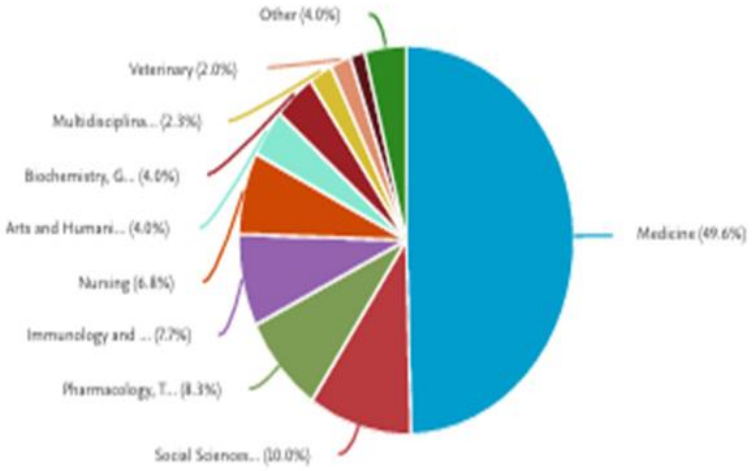

Figure 6. Documents by Subject Area (Scopus Data Analysis, 2024)

The study of the subject area shows that almost half of the publications (49.5%) are in the medical field. This shows how important medical research is for vaccination studies. Next are contributions from the social sciences (20.0%), pharmacology (8.3%), nursing (3.0%), and immunology (2.7%). Veterinary medicine (2.1%), biochemistry and genetics (4.0%), arts and humanities (4.0%), and transdisciplinary research (2.2%) all have lesser shares. Even while most vaccine research is about health, it also looks at legal, moral, and social scientific points of view. For example, Brusa and Barilan (2021) talked about vaccination procedures for children and how they affect the morality of children getting vaccinated on their own (24).

Networking Visualization Results: VOSviewer Collaboration Among Countries

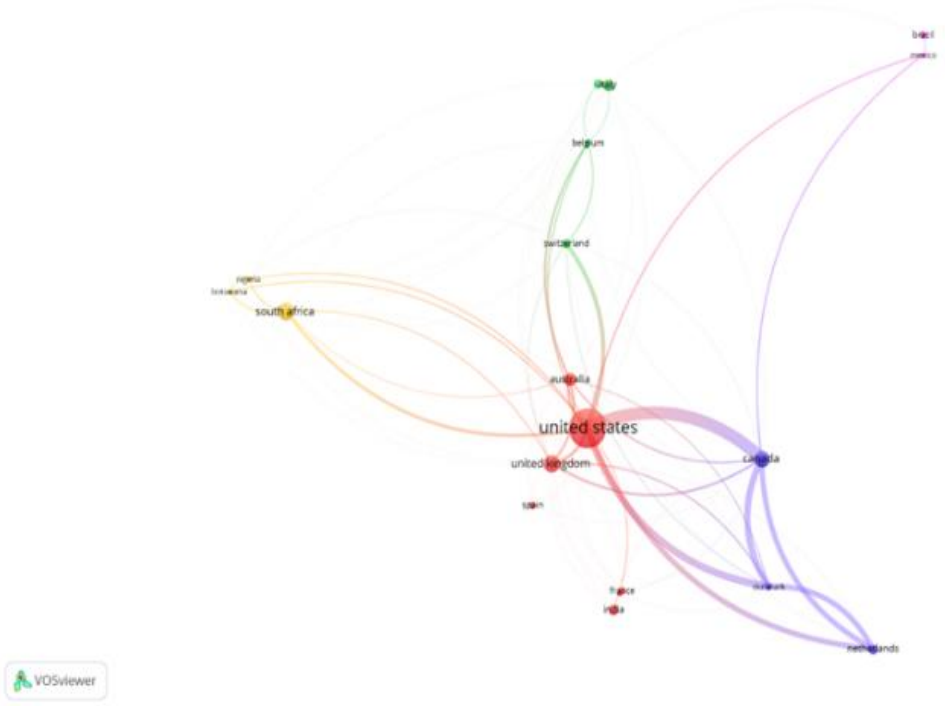

Figure 7. Networking Visualization Results: VOSviewer Collaboration Among Countries

The United States is shown as the major node in Figure 7, which depicts worldwide cooperation in vaccine research. There are 77 publications in this nation that deal with vaccines, and there are 1,683 co-authorship relationships between scholars overall. The idea of having the flexibility to choose vaccinations while being willing to face the risks is covered in one of the American papers (25). The vaccine business in the US and Europe has greatly improved its dependability as a provider during the last ten years. The United States has created the majority of recently authorized vaccinations globally (26). Furthermore, a study by Atwell et al. (2018) examined how recent vaccine mandates were created, introduced, and carried out in six different nations: Australia, France, Germany, Italy, California, and Washington. Five clusters can be seen on the collaboration network map. With seven members in the first cluster (highlighted in pink), the United States has close ties to France, Australia, Spain, India, and the United Kingdom (27). A collaborative article from the UK and India about COVID-19 vaccine reluctance among Indian medical students serves as one illustration (28). Italy, together with Germany, Belgium, and Switzerland, is part of the second cluster, which is shown in green. Canada, Denmark, and the Netherlands make up the third cluster, which is shown in blue. Nigeria, Botswana, and South Africa make up the fourth cluster, which is highlighted in yellow. Brazil and Mexico make up the fifth cluster, which is shown in purple. The first of these five clusters has the greatest level of international cooperation.

Networking Visualization Results: VOSviewer Keyword Analysis

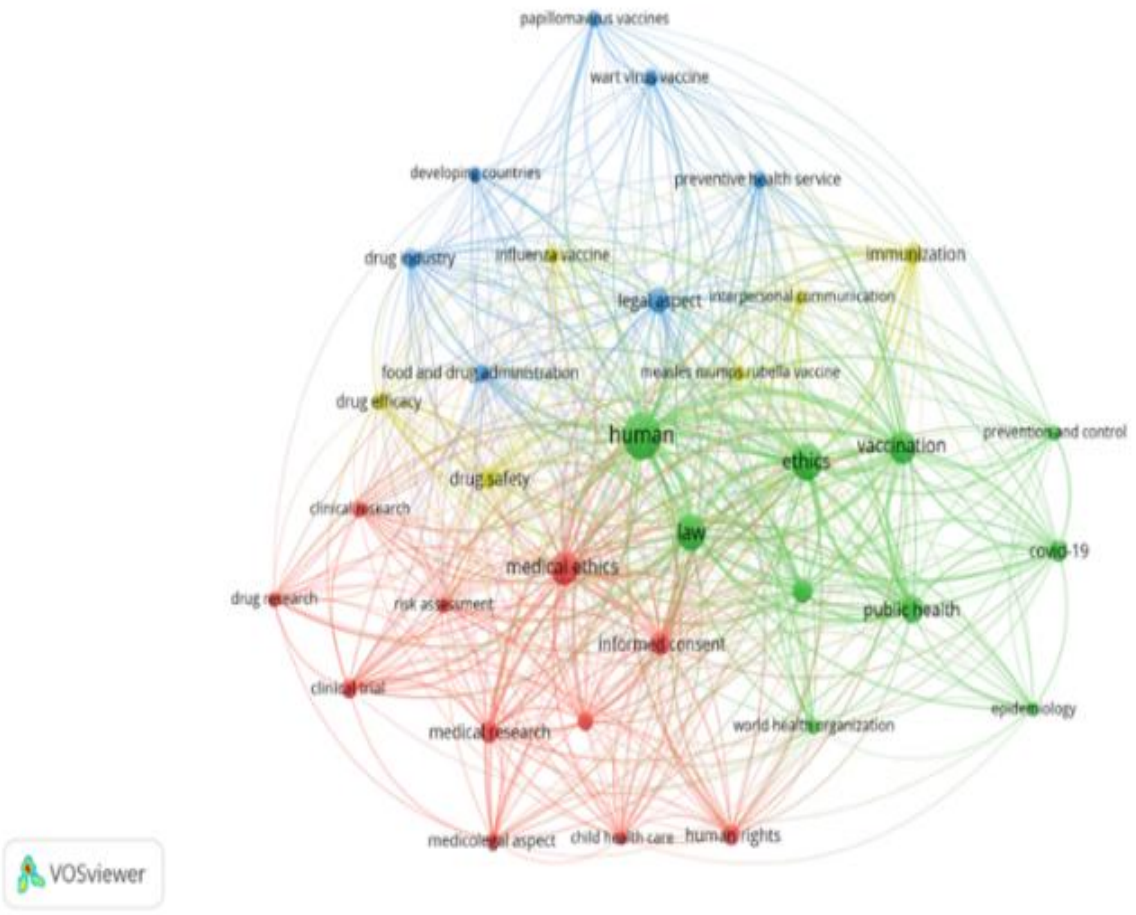

Figure 8. Networking Visualization Results: VOSviewer Keyword Analysis

The keyword network map of vaccine-related research that was indexed in Scopus between 1976 and 2025 is shown in Figure 8, with four clusters. Because they are commonly used together in various publications, keywords that belong to the same cluster show a significant relationship.

With 11 members and a primary keyword of "Medical Ethics" with 79 occurrences and a total link strength of 438, the first cluster is depicted in red. "Human" is the primary term in the second cluster, which is represented in green and has 10 members. It has 194 occurrences and a total link strength of 927, suggesting that other researchers use this keyword frequently. With six members and "Legal Aspect" as the center node, the third cluster, which is shown in blue, has a link strength of 229 and appears 41 times. With "Drug Safety" as the primary keyword, the fourth cluster (highlighted in yellow) has seven members, 26 occurrences, and a total link strength of 178.

Keyword Density Visualization Results: VOSviewer

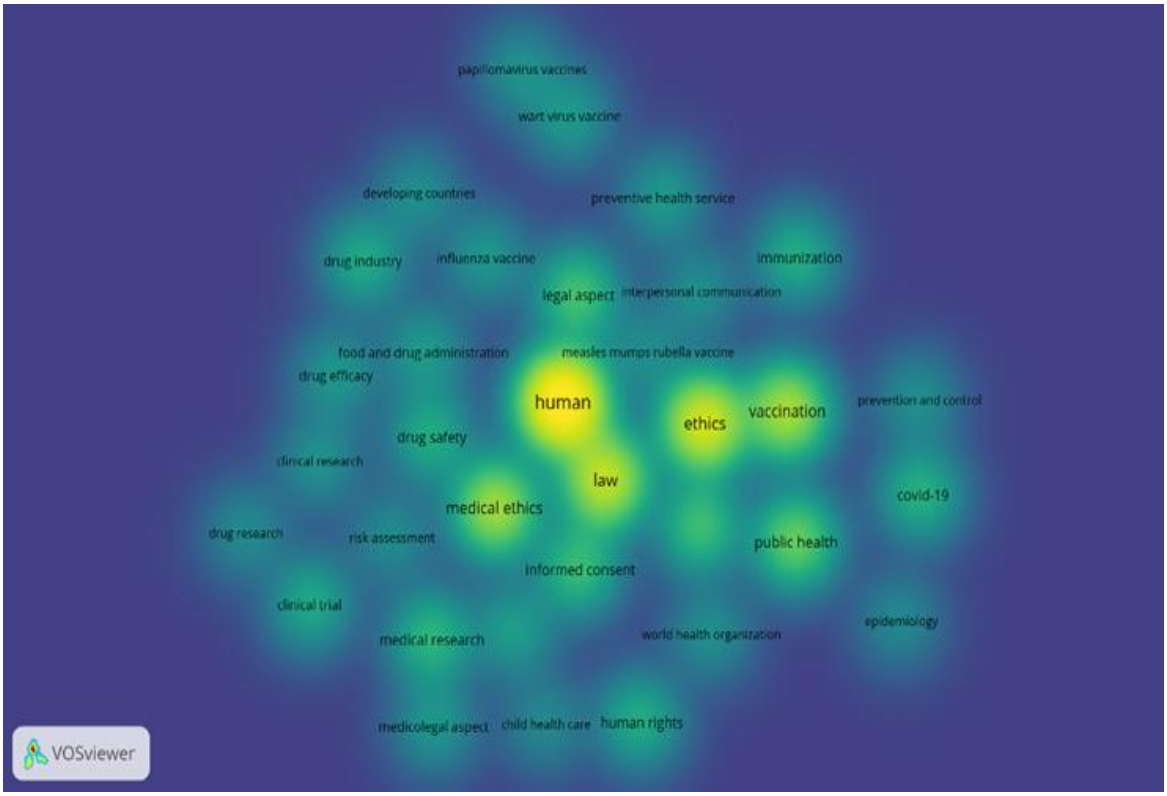

Figure 9. Keyword Density Visualization Results: VOSviewer

The density visualization, which shows the concentration of keywords, is shown in Figure 9. The density level at each item point in the density visualization is indicated by a color. A point's hue changes closer to yellow the more objects surround it and the heavier those objects are.

CONCLUSION

This bibliometric review highlights the growing academic focus on vaccination, particularly regarding its ethical and legal implications, which has intensified in recent decades. Analysis of publication patterns since 1970 shows a consistent upward trajectory, with research output expected to peak in 2025, confirming the fundamental role of vaccines in controlling infectious diseases. The findings also reveal that scholarly production is largely concentrated in the United States and the United Kingdom, indicating an unequal global distribution of research capacity. In addition, international collaboration networks identified through VOSviewer reflect the global interdependence of vaccine research efforts. Taken together, these results underscore the necessity of incorporating legal and ethical perspectives alongside biomedical approaches when addressing vaccination issues. Such an integrated framework can support the development of more inclusive, balanced, and context-sensitive vaccination policies worldwide.

AUTHOR'S CONTRIBUTION STATEMENT

Each author played a significant role in the development and execution of this study. Rika Noviriza contributed to data collection and analysis, manuscript drafting, and overall study conceptualization. Defia Roza assisted with data analysis, literature review, and writing. Elsa Yuniarti, as the corresponding author, led the research design, data analysis, and manuscript drafting. Alfitri participated in the analysis and interpretation of data and provided substantial revisions. Fitra Arya Dwi Nugraha contributed to data collection and statistical analysis, while

Arif Paria Musta focused on the legal and ethical sections of the study. Lastly, Yulia Susanti was responsible for the legal analysis and contributed to the overall manuscript development.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest regarding the publication of this study.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors confirm that no generative AI or AI-assisted technologies were used in the writing or revision of this manuscript.

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