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Global Trends and Collaborations in Dengue Virus Research: A Scientometric and Bibliometric Overview (1872–2019)

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ABSTRACT

Dengue virus, a paramount public health concern, prompts ample global research. This paper provides a comprehensive overview of global efforts in dengue research, applying bibliometric and scientometric procedures to examine the breadth and depth of this field. Drawing data from the Web of Science (WoS) and Scopus databases, 18,607 publications from 1872 to 2019 were meticulously analyzed using advanced tools such as Mendeley, Biblioshiny, and VoS-viewer for systematic visualization and examination. This research not only charts the trajectory of publication growth but also employs the AutoRegressive Integrated Moving Average (ARIMA) model to predict future trends. A focal point of the study is the geographical distribution of research, highlighting key activity regions. Besides, the collaborative networks amongst researchers, institutions, and countries are investigated in detail, showing noteworthy contributions from entities such as Mahidol University, the University of Malaya, and the National University of Singapore, with publications totaling 1,070, 505, and 443. The analysis further demonstrates that the mean citation count for the top 15 articles stands at 1,213, illustrating the high impact of these contributions. An essential finding is the prevalence of multi-authorship, with approximately one-fifth of the articles containing nine or more authors. The research highlights the strong interconnection between authors and institutions, reflected in co-authorship patterns. This comprehensive overview provides a valuable resource for researchers, offering insights into the evolution and current state of global dengue virus research and serving as a basis for future investigations.

1. INTRODUCTION

Dengue fever is caused by the dengue virus (DENV) and is a member of the Flavivirus genus, a family of viruses within the Flaviviridae [1]. It is a severe worldwide health issue characterized by high fever, muscle pain, headache, and rash. The disease can also present more severe symptoms. Dengue is globally prevalent, which makes it difficult for adequate control.

Bibliometric analysis [2, 3] assesses scientific research patterns through various types of metadata, such as publication years, document types, countries, journals, impact factors (IF), institutions' citation numbers, h-index, and international collaborations in global trend studies of specific fields [4]. This method uses mathematical and statistical techniques to assess scientific publications on journal indexing databases, such as Web of Science (WoS) and Scopus. These databases were particularly selected due to their extensive coverage. Moreover, these databases have articles on dengue covered from different perspectives, e.g., the clinical studies of dengue and public health awareness studies.

Bibliometric analysis is a widely used approach for scientific research trend delineation. It helps analyze the scientific output on a specific topic regarding the publication years, institutes involved, countries, journals, collaborations, and several bibliometric measures [4]. This analytical method has been increasingly applied to evaluate scientific endeavors in other arboviral diseases, including chikungunya, malaria, yellow fever, and Zika virus [5, 6].

Bibliometric methods are the cornerstone of quantitative analysis of academic literature and are intricately linked to the broader field of informetrics and the more specific field of scientometrics. These methods facilitate a comprehensive assessment of specific literature published within a subject-specific area. The integration of statistical tools into bibliometric analysis is a significant advance. Initially, it primarily involved bibliographic surveys of scientific works or

collections of extensively referenced publications. These surveys were broken down into lists detailing author outputs and national or subject-specific bibliographies.

The scope of bibliometric analyses often extends to various general or specialized subjects, encompassing aspects such as publishing trends. This includes examining geographical and institutional factors, performance indicators, and the evolution of research over different time periods, subject areas, types of literature, and author contributions. The bibliometric analysis used in this research includes descriptive analysis that describes scientific collaborations, authors and their contributions, impact factor analysis of most active journals, countries, institutes' cooperation, and citation counts. Using bibliometric analysis, we identify all research work done in dengue research, growth trends, the leading countries, key organizations and institutes, leading authors, leading sub-fields, and journals in dengue research that accumulate all information in a single paper. This analysis helps new researchers to analyze the research domain and identify sub-fields that require more attention.

In addition, predictive analysis, utilizing the ARIMA model, forecasts publication trends over the next five years, indicating an anticipated increase in research output. This predictive aspect is crucial for understanding both past and present trends, and it offers projections on the future trajectory of dengue research. These insights are pivotal for funding agencies, researchers, and stakeholders in resource allocation and strategic planning.

This article fills a gap in dengue research by providing a comprehensive bibliometric analysis, predicting future trends, and demonstrating collaboration networks. This study enhances understanding by providing insights into global research patterns and collaboration dynamics, serving as a valuable resource for developing future dengue-related initiatives and research agendas.

The rest of the paper is structured as follows: Section 2 introduces the research aims and objectives; Section 3 reviews the current state of the art; Section 4 describes the methodology; Section 5 describes the experiments and results; Section 6 concludes the paper and outlines the future research directions.

2. RESEARCH AIM AND OBJECTIVES

The main objective of this research is to conduct a comprehensive bibliometric review of dengue-related academic works covering a broad time frame from 1872 to 2019. The aim is to trace the development trajectory, breadth, and collaborative framework that characterizes dengue. Specific goals are outlined next:

(1) Classification of Publications: Classify publications according to document type and publishing language. This classification helps understand the diversity and accessibility of dengue research.

(2) Assessment of Research Volume and Trends: Quantify the volume of literature published on dengue-related tasks, such as detection, identification, and vaccine production. The aim included a thorough review of publication trends since 1872, the year of the oldest dengue-related publication recorded in Scopus. The study highlights the relatively limited number of publications available during this period.

(3) Forecasting Publication Trends: Employing the AutoRegressive Integrated Moving Average (ARIMA) model to discern the momentum of dengue research and forecast potential publication trends in the forthcoming biennium. This predictive analysis is critical for understanding the evolving landscape of dengue research.

(4) Authorship and Collaboration Analysis: The objective is to have influential authors pinpointed and the networks of collaboration mapped out, thereby allowing for the dissection of the patterns of joint authorship and partnerships that underpin dengue research.

(5) Journal Productivity Assessment: To identify the most productive journals in dengue research, they were ranked based on the number of dengue-related articles published. The study also reports on changes in SCImago Journal Ranking (SJR) and Impact Factor (IF) trends.

(6) Institutional and Geographical Collaboration: To identify collaborative efforts in dengue research among various institutions in different geographical regions to identify the most productive institutions contributing to dengue research.

(7) Citation and Co-citation Analysis: To perform a detailed citation analysis, including information on the most-cited documents, total citations, country and journal of publication, the first author of the paper, and the IF (2019) and SJR (2019). The study also explores the co-citation of references in dengue literature articles.

(8) Term Analysis using VoS-viewer: VoS-viewer graphs will be used to identify commonly used terms in dengue research, enabling the examination of terminological trends and their signifiance in the field.

3. Literature Review

This section concisely reviews bibliometric analyses focusing on infectious diseases and viruses, highlighting key research contributions in this domain.

3.1 Bibliometric analysis of coronavirus research

Lou et al. [7] conducted a bibliometric study on COVID-19, utilizing data from PubMed. The analysis features 183 publications written after the virus first broke out. The findings show that a large proportion of these publications (25 out of 183) were in the Journal of Medical Virology, with epidemiology emerging as the primary keyword. In addition, the study highlights China's significant contribution to COVID-19 research.

In a related vein, the distribution of research capabilities among countries and institutions, as well as the research frontiers in coronavirus studies over the last two decades, were examined by Zhai et al. [8] utilizing the WoS core database. Their work involved the analysis of 11,036 documents related to COVID research, covering the period from 2003 to 2020. The developmental trajectory of COVID-19-related studies was shown through this research.

A noteworthy contribution by Zyoud [9] focused on research trends within the coronavirus literature. The analysis focuses on assessing the keywords used in coronavirus research, distinguishing between keywords assigned by authors and those assigned by the publishers. Zyoud's study also highlights collaborative efforts on coronavirus research, pointing to central hubs that demonstrate the international scope of these research efforts.

Halstead [1] provides a critical review of Middle East respiratory syndrome coronavirus (MERS-CoV)-related literature indexed in the Scopus database from 2012-2015 [1].

The review focuses on this specific strain of coronavirus, paying particular attention to its first isolation in 2012 and its outbreak in multiple regions around the world.

3.2 Bibliometric analysis of dengue virus research

As discussed, dengue has proved to threaten human life and is a concern for global health organizations. Many research teams have put their efforts surrounding dengue from different perspectives. In this section, we provide a bibliometric analysis of the research done in this field.

Zyoud [4] performed a detailed bibliometric analysis of dengue, highlighting it as a significant health concern for the general public. This study was limited to the Middle East The research focused on the work done by Middle Eastern research teams. Zyoud [4] found out that dengue fever is spread in over 128 countries

In study [10], the authors focused on the spread of dengue fever. The study focused on the research's quality, quantity, and reliability in addition to other bibliometric measures, such as the h-index and i-index. The findings revealed that dengue fever severely affected Vietnam, while the most negligible impact was observed in India.

Furthermore, a study [11] identified a correlation between dengue and scientific research through bibliometric analysis. An examination of 7,746 dengue-related articles from the SCI-EXPANDED database (1991–2014) revealed an exponential increase in dengue research since 2000. The analysis also highlighted that 96% of these articles were published in English, with other languages contributing minimally. This language dominance could influence global research directions, while non-English publications, though rich in localized knowledge, may gain less visibility in the global scientific community.

An insightful review presented by Maula et al. [12] performed a bibliographic analysis of dengue virus research, offering a comparative study between Indonesia and Southeast Asia (SEA). Drawing data from PubMed, this research focused on the bibliographic patterns and information organization about dengue in Indonesia compared to SEA, covering 2007 to 2016.

Ramakrishnan et al. [13] extracted the data related to dengue from MEDLINE database for the 2008-2017 decade. According to this study, 2016 was the peak year in which most of the literature was published. The US, England, and the Netherlands were the main contributors to research in this decade.

Similarly, in study [14], the authors performed a study for the same period but limited to 5 years. The data was collected from the PubMed database, the primary focus of the study remained on author patterns, degree of association, annual distribution, languages used, book types and geographical distribution of books.

Comparing our work with existing works, our research offers a far more extensive study from 1872 to 2019. We provide a detailed historical perspective of the topic, which gives a substantial dengue-related research research pattern.

3.3 Miscellaneous studies

This section reviews a selection of miscellaneous bibliometric studies that have explored various infectious diseases, further demonstrating the diversity and depth of this research approach.

Al-Jabi [15] undertook a hybrid bibliometric analysis of the West Nile Virus (WNV), a mosquito-borne infectious disease increasingly recognized as a global public health issue. This bibliometric study considered 4,729 publications obtained from Scopus that have been published from 1943 to 2016. This comprehensive review highlighted the evolution and current state of research on WNV.

In another research endeavor [16], the authors delved into the expansion of literature related to Dry Eye Disease (DED) over the past decade. The study aimed to discern the most active journals, countries, and authors in DED research using bibliometric analysis. An aggregate of 5,522 survey papers was considered, published in 821 unique journals separated from the WoS Core Collection. The USA emerged as a leading contributor, accounting for 34.53% of the total articles and 46.10% of all references, indicating a significant impact in DED literature.

A similar bibliometric study [17] conducted a statistical analysis of Diabetic Retinopathy (DR) research. The analysis encompassed 7,706 documents published between 1980 and 2014, retrieved from the WoS database. The USA contributed the most, with 24.38% (1,840) of the publications, surpassing England and Japan. Notably, Iceland demonstrated the most significant relative increase in publications. A strong correlation was observed between the volume of publications and the 2014 Gross Domestic Product (GDP) rankings of 81 countries.

In the context of Polio research, a bibliometric study cited in research [2] reviewed literature published between 2011 and 2015. The study analyzed 2,118 records from the PubMed database, initially in XML format and subsequently converted to Excel. The analysis employed both MS Access and MS Excel. It was found that 7,556 authors contributed to the polio literature in 18 languages across 688 journals, encompassing 13 types of documents. An important observation was the higher prevalence of single authorship papers compared to multiple authorship ones.

While these bibliometric analyses provide significant insights into various infectious diseases, they also indicate an important gap: the underrepresentation of non-English publications. This limitation confines the reach and impact of such studies beyond specific linguistic communities, as opposed to the more widely accessible English-language publications. Future bibliometric research should address this disparity by adopting a more inclusive process that integrates publications in different languages. This emphasis would guarantee a more exhaustive and globally representative understanding of research trends in infectious diseases. Moreover, including advanced text mining and network analysis techniques in bibliometric methodologies could offer deeper insights into collaboration patterns, emerging research themes, and the general evolution of research in these fields.

4. Methodology

Here, we summarize the methodology used for the bibliometric analysis of dengue-related studies. In June 2019, a comprehensive dataset was developed, including literature on dengue. Nine thousand six hundred sixty-four documents were retrieved from the WoS, and 30,604 were retrieved from the Scopus database. After merging these datasets, 8,117 duplicates were identified and subsequently removed. This

process of adaptation resulted in a pooled dataset of 32,150 publications.

Further analysis revealed that 13,543 of these publications covered diseases and viruses other than dengue, such as arbovirus, chikungunya virus, Zika virus, and West Nile virus, and these articles were excluded from the analysis. As a result, the final dataset consists of 18,607 publications, each including title and abstract, dating from 1872 to 2019. The retrieved documents include 14,669 articles (78.84%), 168 book chapters, 635 conference papers, 4 data papers, 203 editorials, 161 errors, 878 editorials, 251 conference abstracts, newsletters, reviews, reprints, and brief reviews. The following basic information associated with the retrieved publications was recorded for analysis: publication date, names of authors, their affiliations, titles, abstracts, journal names, and keywords. A total of 18,607 scientific publications from 1872 to 2019 were considered.

The researchers have used many visualization and analysis tools, including Mendeley, Biblioshiny, and VoS-viewer. VoS-viewer's visualization abilities are particularly noteworthy, simplifying the examination of intricate networks and clarifying connections within large datasets. Its ability to make visually exciting maps of bibliometric data is beneficial. The easy-to-use interface of VoS-viewer makes it easier to explore connections, like when terms appear together or articles cite each other. Furthermore, VoS-viewer's compatibility with various software platforms extends its analytical utility.

5. Experiments and Results

This section details the outcomes of a detailed bibliographic analysis focused on dengue research literature.

5.1 Growth trend of annual publications

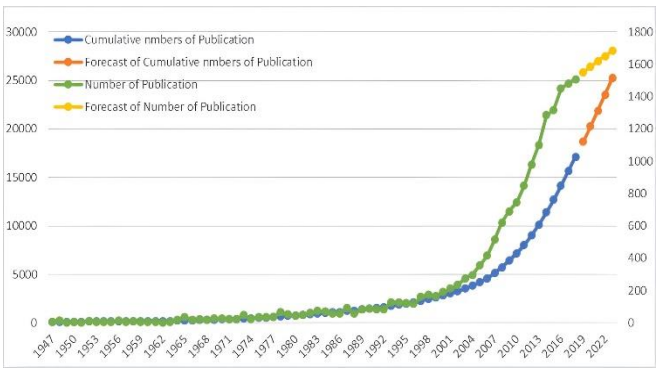

Figure 1. Increase in the number of publications over the last 40 years with forecast for 2023

The total number of documents related to dengue disease was 18,607, published from 1872 to 2019. It was observed that the number of publications increased in the last four decades, with the statistics given as 646 publications during 1980–1989, 1253 during 1990–1999, 3,810 during 2000–2009, and 10,714 during 2010–2018. It was also concluded that the maximum number of publications, 1,507 (8.1%), were published in 2018, followed by 1,482 (8%) in 2017, 1,466 (7.8%) in 2015, 1,450 (7.7%) in 2016, and 1,318 (7%) in 2013. Figure 1 explains how publications have dramatically increased in the last four decades. A drastic increase in research publications from 2000 to 2019 resulted in a publication count of 15,990 (85.94%). The number of publications was forecasted utilizing the most accurate statistical model based on mean error and mean square error. The ARIMA model (2:1:1) [18] emerged as the optimal fit. The projection for the anticipated number of publications was calculated for the next five years (including 2019) and found 1,550, 1,583, 1,619, 1,651, and 1,683 publications, respectively. Cumulative growth and the exponential increase indicate the importance of the dengue disease and its associated subject.

5.2 Classification of documents by document type and language

The dataset of 18,607 publications was classified according to document type and language. It was observed that 79% (14,625) of these were original research articles, 5.99% (1,115) were reviews and surveys, 4.72% (878) were editorial letters, and 3.41% (635) were conference proceedings. Notably, a minority of 9.47% (1,763) of the documents were published in languages other than English. This distribution, illustrated in Figure 2, offers insight into the predominance of English-language publications in dengue research and the relatively limited representation of other languages.

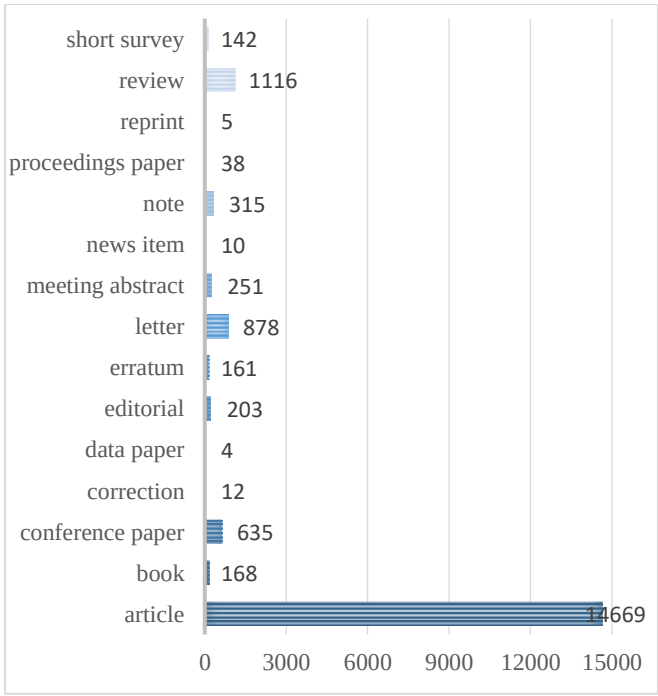

Figure 2. Classification of studies by document type in dengue research

5.3 Authors and their contribution

Upon analyzing the author-article nexus within the 14,625 articles, 33,464 distinct authors were identified. The analysis revealed that a majority (62.92%; n=21,057) of these authors contributed to only one article. A smaller fraction, 15.91% (n=5,323), contributed to two articles, while 6.67% (n=2,232) were associated with three articles. Notably, 14.5% of authors were credited with four or more articles. Table 1 elucidates the top five most prolific authors in terms of their article output, highlighting 'Harris' from the University of California, USA, as the leading contributor with 158 published articles. The total citations garnered by these authors varied significantly,

reflecting the diverse impact of their work. 'Nisalak' attained the highest number of total citations (14,146), closely followed by 'Halstead S.' (12,371) and 'Harris' (10,146), indicating their prominent influence on dengue research.

Table 1. Top five most-productive authors by publishing articles in dengue research

Author (Institute, Country)	No. of Articles	Total Citations	Avg. Citation per Article	No. of Articles as 1st Author
Harris E, University of California, Berkeley, USA	158	10,146	642	5
Nisalak A, Armed Forces Research Institute of Medical Sciences, Thailand	150	14,146	943	3
Kurane I, National Institute of Infectious Disease, Japan	139	5,101	36.7	21
Lin Y, National Cheng Kung University, Taiwan	138	5,489	39.5	11
Halstead S, Uniformed Services University of the Health Sciences, USA	128	12,371	96.7	57

Table 2. Top ten journals publishing the articles associated with dengue research

Journal	No. of Publications	SJR (2019)	IF (2019)	Subject Category (SJR)
American J. Tropical Medicine and Hygiene	698	1.18	2.15	Immunology and Microbiology Medicine Medicine, Infectious Diseases
PLOS Neglected Tropical Diseases	608	2.15	3.885	Public Health, Environmental and Occupational Health, Pharmacology Toxicology and Pharmaceutics
PLOS ONE	448	1.02	2.74	Multidisciplinary, Multidisciplinary
J. Virology	347	2.41	4.01	Agricultural and Biological Sciences Insect Science, Immunology, Virology, Microbiology
Southeast Asian J. Tropical Medicine and Public Health	223	0.26	0.35	Medicine, Infectious Diseases Medicine (miscellaneous), Public Health Environmental and Occupational Health
Virology	207	1.27	2.819	Immunology and Microbiology, Virology
Dengue Bulletin	203	NA	NA	Immunology and Microbiology Virology, Medicine, Infectious Diseases
Emerging Infectious Diseases	197	2.72	6.259	Medicine, Infectious Diseases Microbiology and Epidemiology
Vaccine	188	1.68	3.143	Biochemistry, Genetics and Molecular Biology immunology and Microbiology, Medicine, Veterinary
J. Infectious Diseases	181	2.95	5.045	Medicine, Infectious Diseases, Allergy and Microbiology

A noteworthy aspect is the average citation count per article. 'Halstead' exhibited an exceptionally high average citation count (96.7), suggesting that each of their articles tends to garner more citations compared to others on this list. The role of an author as the first author in publications indicates their leadership or primary contribution to the research. For instance, 'Halstead' was the first author of 57 articles, underscoring their significant leadership role in these studies.

The average number of articles per author stood at 0.437, with 0.137 articles lacking specific authorship details. Single authorship was evident in 6.85% (n=1,002) of the articles, while 9.49% (n=1,388) had two authors. Approximately 13.85% (n=2,025) featured three authors, 13.00% (n=1,902) had four authors, and 11.71% (n=1,713) comprised five authors. In addition, 10.58% (n=1,547) of articles had six authors, 8.13% (n=1,189) had seven, 6.69% (n=979) had eight, and the remaining 19.7% comprised nine or more authors, with a maximum of 31 authors per article. The cooperation patterns among authors were visualized using VoS-viewer (refer to Figure 3). The size of the circles in the visualization represents the volume of articles by each author, while the curved lines denote the collaborative links between authors. The color scale in the visualization highlights distinct collaboration clusters, with the author clusters divided into 16 discernible segments in the cooperation network.

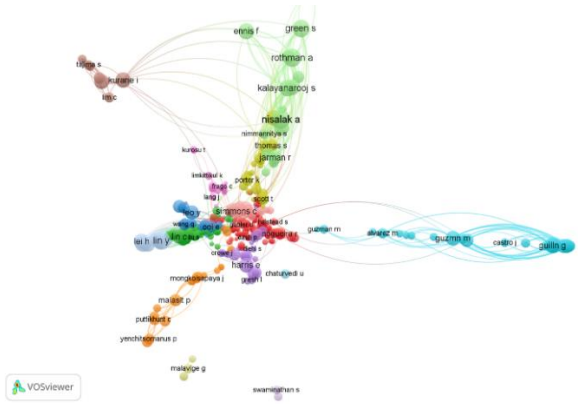

Figure 3. Author cooperation network in dengue virus research

5.4 Journal publishing on dengue research

An analysis of the 18,607 articles related to dengue virus research revealed that they were published across 3,042 journals. Among these, 1,579 journals (51.91%) published a single article. Approximately 481 journals (15.81%) published two articles, and 239 (7.86%) contributed three articles each. Furthermore, 468 journals (15.38%) published between four and ten articles, while about 275 journals (9.04%) were more prolific, publishing between 11 and 698 articles on dengue. Table 2 details the top ten journals regarding their productivity in dengue research. These rankings are based exclusively on the number of dengue-related publications.

The analysis of the journals, utilizing the SJR, revealed a wide array of subcategories under which dengue research is published. Most publications fell within the domains of "Medicine, Infectious Diseases, Medicine (miscellaneous), Public Health, Environmental and Occupational Health," followed by "Immunology and Microbiology, Parasitology, Virology and Biochemistry, and Genetics and Molecular Biology." This diversity in subject categories, encompassing Immunology and Microbiology, Medicine, Infectious Diseases, Public Health, and Virology, underscores the interdisciplinary nature of dengue research.

Among these journals, "Emerging Infectious Diseases" was found to have the highest IF of 6.259. This journal was followed by the "Journal of Infectious Diseases" with an IF of 5.045, the "Journal of Virology" with an IF of 4.010, and "PLoS Neglected Tropical Diseases" with an IF of 3.889. Figure 4 depicts the publication frequency by year for the top five journals with the most significant impact. It was noted that some journals, like the "Southeast Asian Journal of Tropical Medicine and Public Health," tend to have a regional focus, while others, such as "PLOS Neglected Tropical Diseases" and "Vaccine," demonstrate a more global reach.

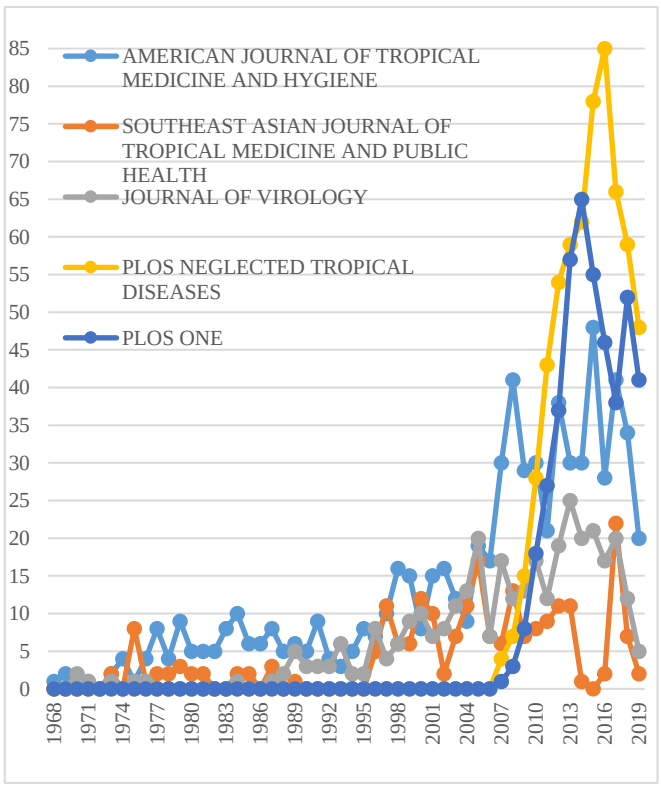

Figure 4. Top five most-active journals by year in dengue virus research

5.5 Geographical, institutional distribution, and cooperation

Upon analyzing the affiliations and addresses provided in the WoS and Scopus databases, it was found that a substantial majority (approximately 93%) of the 18,607 dengue-related publications were affiliated with specific regions or countries. However, 1,212 publications lacked regional affiliation data. The nature of academic collaboration often entails multiple affiliations per publication, resulting in a diverse geographical and institutional spread. All author affiliations, encompassing various countries and institutions, were meticulously examined.

5.6 Countries and territories

A thorough assessment of the publications disclosed associations with 119 regions or countries. The distribution of these publications is varied: European institutes contributed 28 publications; Asia, 30; Africa, 26; North America, 15; South America, 11; and Oceania, 9. Figure 5 visually represents this global distribution, offering insights into the international scope of dengue research. Notably, 40.3% (48) of countries or territories produced fewer than ten publications, while 31.1% (37) contributed between 11 and 50 publications. Additionally, 13.45% (16) of countries published between 51 and 200 articles, and 10.9% (13) produced between 200 and 1000 significant publications. Remarkably, five countries were identified as having generated more than 1000 publications each, with US universities and medical research groups leading in publication volume. Figure 6 delineates the top 15 most prolific countries and territories in dengue research.

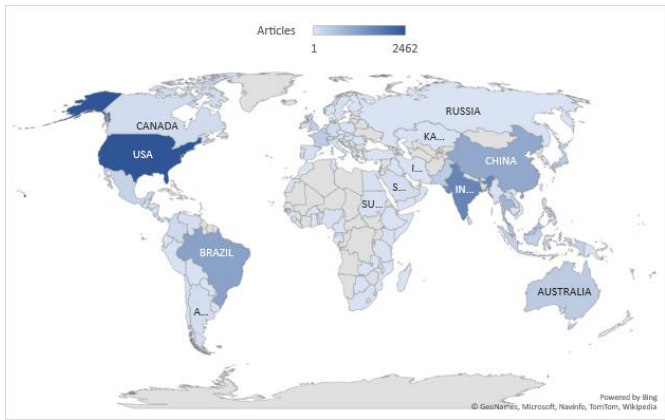

Figure 5. World Map to show the geographical distribution in dengue virus research

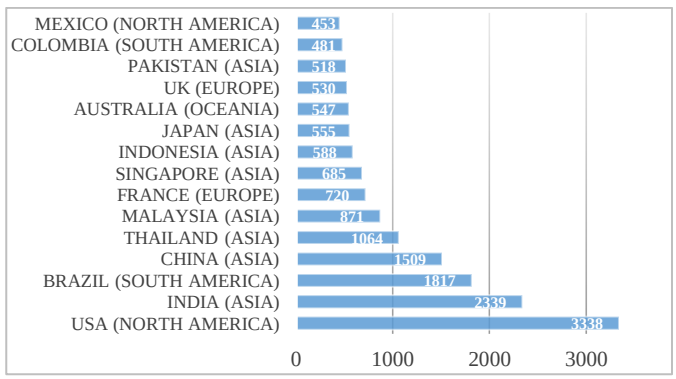

Figure 6. Top 15 most-productive countries or territories publishing in dengue research

Economically developed nations, including G7 group countries, alongside the USA, India, Brazil, China, Thailand, Malaysia, and France, were prominent in the top 15 research-oriented countries regarding dengue virus research. Figure 7, leveraging VoS-viewer software, illustrates the intricate cooperation network between countries and their research outputs. The network highlights countries with ten or more publications, with the circle size corresponding to the volume of publications.

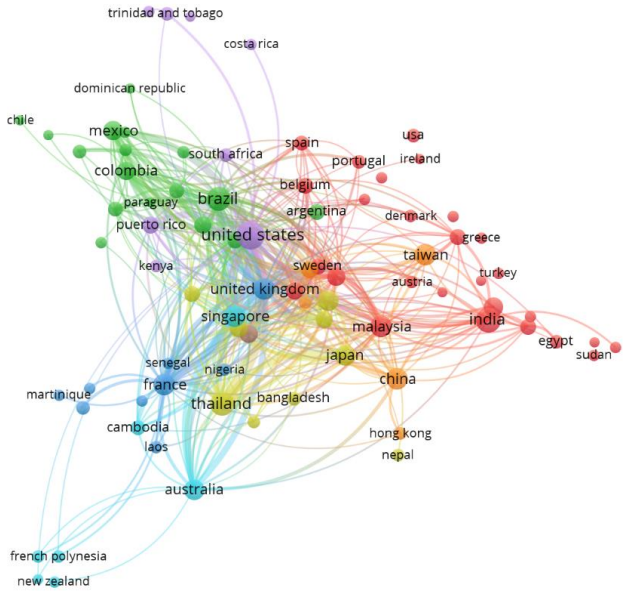

Figure 7. Countries co-operation network in dengue virus research

The links depicted in the network signify collaborative associations among countries. Seven primary clusters related to dengue research were identified. The first cluster, centered around the USA, is the most prolific regarding publications (purple group). The second cluster associates India and Germany (red group), while the third represents Brazil (green group). The fourth cluster, comprising the United Kingdom and France, is illustrated in the lower left corner (blue group). The fifth cluster, representing Japan and Thailand, is at the bottom (yellow group). The sixth cluster, denoting collaboration between Australia and Singapore, is indicated in the sky blue group. Lastly, the seventh cluster encompasses China, Canada, and Taiwan (orange group). The analysis also revealed specific collaborative patterns; for instance, Indian research groups strongly collaborate with Turkey, Malaysia, and Egypt. USA shows a global outreach in its research collaborations, whereas Japan predominantly associates with other Asian countries. Singapore and New Zealand, on the other hand, collaborate extensively with Australia. Brazil maintains robust research ties with Mexico and Colombia.

5.7 Institutions

Out of 13,269 research institutions involved, a detailed analysis revealed that 48.62% (8,458 institutions) participated in only one publication. Furthermore, 11.36% (1,976 institutions) contributed to two publications, while 12.4% (2,157 institutions) published between three and ten articles. A smaller percentage, 2.06% (359 institutions), collaborated on 11 to 20 publications, and 1.77% (308 institutions) were associated with 21 to 200 publications. Notably, 11 institutions have produced 200 or more publications each.

Table 3 presents data on dengue research's top 15 most productive institutions. These institutions account for 5,082 papers, which is 27.31% of the total, averaging 338.8 publications per institution. The geographic distribution of these leading institutions highlights the global scope of interest and engagement in dengue research. Mahidol University, for instance, has contributed over 1,070 publications, underscoring its significant role in this field.

Most of the top contributing institutions are government universities, which indicates their capacity to secure financial grants for research. Notably, the top three universities, originating from Thailand, Malaysia, and Singapore, are situated in regions with tropical climates - a factor that may influence the prevalence and study of dengue. In addition to these universities, private organizations, research centers, and institutes also contribute significantly to dengue research. Figure 8 illustrates the cooperation network among various institutions.

Table 3. Top fifteen most-productive institutions according to the number of publications

Institutions	Country	No. of Publications
Mahidol University	Thailand	1,070
University of Malaya	Malaysia	505
National University of Singapore	Singapore	443
University of California	USA	406
National Cheng Kung University	China	395
Institute Pasteur	France	349
University of Oxford	UK	277
Nagasaki University	Japan	250
University of Texas Medical Branch	USA	221
Walter Reed Army Institute of Research	USA	215
Kaohsiung Medical University	Taiwan	211
London School of Hygiene and Tropical Medicine	UK	188
Nanyang Technological University	Singapore	188
National Taiwan University	Taiwan	184
Centers for Disease Control and Prevention	USA	180

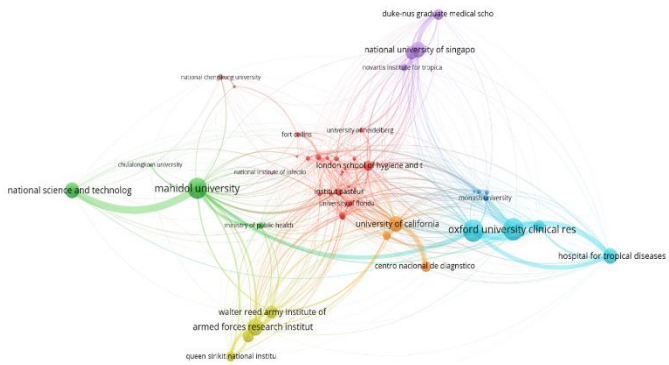

Figure 8. Co-operation among institutions in dengue virus research

5.8 Citation analysis

This segment explains the impact of dengue research publications through comprehensive citation analysis, drawing upon data from the WoS and Scopus databases.

The 18,607 publications relevant to dengue research compiled for this study have been cited 427,047 times in other scholarly works as of the data extraction date. This results in an average citation count of 22.95 per publication. Notably, 18.3% (n = 3,405) of these articles have been cited at least once. This figure slightly surpasses the findings of Zyoud [4], who reported an average of 18.0 citations per publication in his bibliometric analysis of dengue research, covering the period from 1872 to 2015.

Delving deeper into citation frequencies, we found that 8.48% (1,577) of the publications were cited only once, while 6.1% (1,132) received two citations. A substantial portion, 25.2% (4,696), were cited three to ten times. Furthermore, 13.6% (2,524) of the articles garnered eleven to twenty citations. The analysis also shows that 17.00% (3,157) of the articles were cited up to 50 times, and 7.00% (1,295) reached up to a hundred citations. Remarkably, approximately 4.4% (821) of the publications were cited more than one hundred times, demonstrating their significant impact in the field.

The average citation count for the top 15 most-cited dengue research articles is 1,213. Table 4 details the five most-cited publications in dengue research, highlighting their influential role in shaping understanding and advancements within this area of study.

Table 4. Top five most-frequently cited publications

Title	References	Category SJR	TC per Year	TC	Journal, IF, SJR	Institution	Country
The Global Distribution…	Bhatt S. (2013)	Multidisc.	479.12	3,833	Nature, 42.778, 14.05	University of Oxford	UK
Dengue and Dengue Hemorrhagic...	Gubler D.J. (1998)	Immuno, Microbio Medicine & Infections	86	1,978	Clinical, 18.130, 8.66	Fort Collins	USA
Rapid Detection and…	Lanciotti R.S. (1992)	Medi. & Microbi, History & Phil, and Multidisc.	43.13	1,251	Journal of Clinical Microbiology, 4.59, 2.6	Fort Collins	USA
Pathogenesis of Dengue…	Halstead S.B. (1988)	Arts and Humanities	36.27	1,197	Sciences, 41.845, 13.11	Division of Health Sci.	New Zealand
Dengue Viremia Titer…	Vaughn D.W. (2000)	Medi. Immuno, Allergy & Infect. Diseases	51.85	1,089	Journal of Infectious Diseases, 4.730, 2.95	Walter Reed Army Inst. of Research	USA

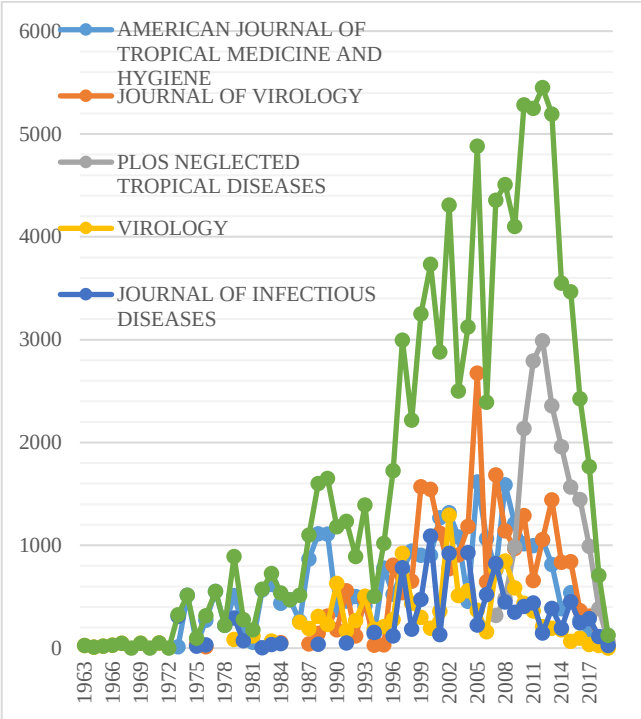

Figure 9. Top five most-active journals in citation per year

Regarding the first-author publications, the USA leads with nine articles, followed by England, Australia, New Zealand, and Vietnam. The authors Gublerd J., Guzman M.G., and Modis Y., each appear twice in this esteemed list. The journals 'Cell' and 'Nature' feature prominently in terms of publication frequency, with three and two articles, respectively, and are published bi-monthly. These publications predominantly fall under the SCImago Journal categories of "Medicine, Infectious Diseases, and Microbiology," "Biochemistry, Genetics, and Molecular Biology (miscellaneous)," and "Immunology". Additionally, four of the journals encompass topics labeled as "Multidisciplinary".

Regarding the citation impact of the 3,042 journals involved in dengue research (of which 2,135 journals have more than one citation), 20.97% (638 journals) received no citations, and approximately 8.84% (269 journals) were cited only once. About 26.98% (821 journals) have publications cited 2 to 10 times, while 22.72% (691 journals) garnered 11 to 50 citations. A further 12.23% (372 journals) achieved 51 to 200 citations, and 5.95% (181 journals) were cited between 200 and 1000 times. Remarkably, 2.30% (70 journals) have amassed over a thousand citations each.

The 'American Journal of Tropical Medicine and Hygiene' leads in citations, contributing significantly (n = 31,676 / 427,047) to the total citation count. Following this are the 'Journal of Virology,' 'PLOS Neglected Tropical Diseases,' 'Virology,' 'Journal of Infectious Diseases,' 'Proceedings of The National Academy of Sciences of the United States of America,' 'PLOS One,' 'Emerging Infectious Diseases,' 'Journal of General Virology,' and 'Nature,' collectively accounting for 34.21% (146,110) of the total citations. Figure 9 illustrates the top five journals most frequently cited by other articles.

5.9 Co-citation analysis

The analysis was based on 358,161 references used across the retrieved 18,607 publications, averaging 23 references per document. However, it was noted that 2,873 cited references were missing from these articles. Focusing on the 15,734 available cited references, only those used more than 20 times were considered. Consequently, out of 269,563 references, 467 documents met this criterion and were included in the co-citation analysis.

The co-citation analysis, visualized using VoS-viewer and depicted in Figure 10, employs circles to represent the frequency of citations, with the proximity between circles indicating the extent of the relationship among the studies. This network encapsulates the research activities of five distinct groups.

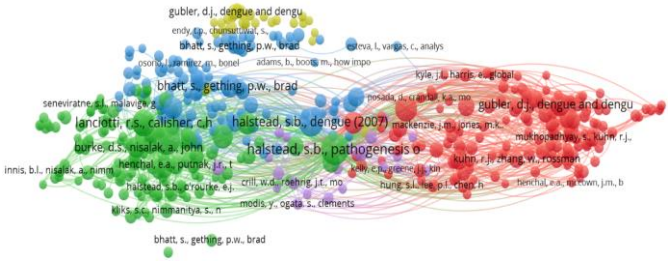

Figure 10. Co-citation analysis

In the co-citation map, the green cluster indicates medical studies, primarily focusing on clinical aspects of dengue. The red group encompasses epidemiological analyses related to the spread of the dengue virus. Meanwhile, the yellow and blue clusters are associated with public health concerns, risk factors, and dengue's social and economic implications. The most frequently co-cited articles delve into the risk factors associated with the dengue virus in humans. Significant works in this realm include Gubler (1998), Lanciotti (1992), and Modis Y. (2004), which offer critical insights into these aspects. Additionally, the comprehensive review by Kyle and Harris (2008) and Bhatt (2013) on the global spread and distribution of the dengue fever virus stands out for its high co-citation rate. These articles provide a detailed survey of the dengue virus, including future projections, and underscore the pressing nature of dengue as a public health issue, highlighting increasing infection rates, disease severity, and mortality.

5.10 Terms analysis

This part of the analysis focuses on the terms frequently used in dengue research publications, offering insights into the evolving trends and focal areas in this field.

Utilizing VOS-viewer, a comprehensive terms analysis was conducted, encompassing authors' keywords, keywords from databases, and keywords-plus. For this analysis, terms appearing in at least ten publications were included. As a result, 500 terms were selected to construct an effective network, depicted in Figure 11. In this visual representation, circles represent the occurrence of terms, and their proximity indicates the extent of their correlation. The frequency of co-occurrence determines the strength of the relationship between terms, leading to four distinct clusters.

The red cluster (left) primarily represents medical aspects such as virus replication, antibodies, human cells, immunology, and vaccines. In contrast, the green cluster (right) focuses on clinical aspects like fever, blood sampling, case studies, disease severity, and clinical articles. The blue cluster (down) encompasses terms related to dengue transmission, including mosquitoes, Aedes species, larvae, virus transmission, and risk assessment. The yellow cluster pertains to serotype classification, isolation and purification, and evolution.

The most frequently used words in the analyzed literature were 'dengue,' 'dengue virus,' 'antibodies,' 'female,' 'Aedes,' 'mosquito,' 'virus replication,' 'adult,' 'epidemic,' and 'dengue vaccine.'

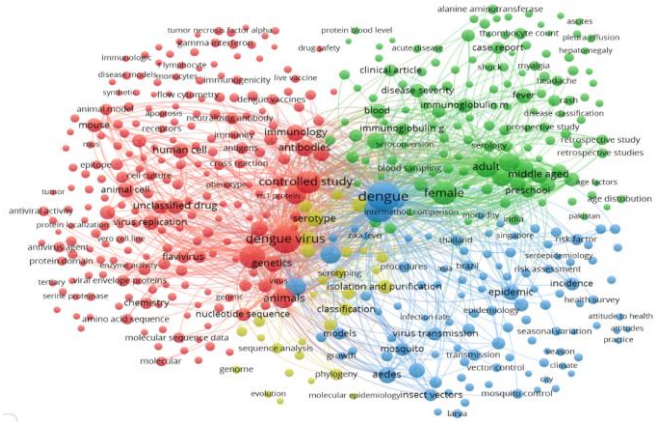

Figure 11. Terms analysis

Figure 12 illustrates the temporal correlation among terms, with color coding representing the average publication period of related publications. The prevalent terms were mainly used between 2008 and 2014, with blue hues indicating earlier usage and yellow denoting more recent terms. According to the color intensity and circle sizes, the most frequent terms emerged predominantly between 2010 and 2014. Clusters featuring contemporary terms are associated with recent developments such as antiviral activities, anti-virus agents, fever, headache, risk factors, classifications, procedures, and transmission methods. Meanwhile, the cluster related to medical aspects corresponds to older terms like antibodies, human cells, antigens, immunity, and virus protein.

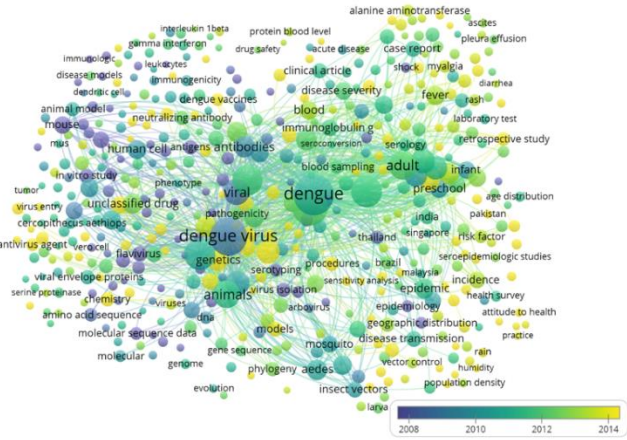

Figure 12. Terms analysis with time information

6. CONCLUSIONS

This paper's comprehensive bibliometric analysis has provided a detailed overview of global research on the dengue virus from 1872 to 2019. A total of 18,607 publications were identified, with a pronounced increase in output observed over the last four decades (1980–1989: 646; 1990–1999: 1,253; 2000–2009: 3,810; 2010–2018: 10,714). This escalation in research activity coincided with a surge in dengue incidence, as reported by the CDC, USA, in 2019 compared to 2018. This correlation between the volume of publications and the increase in disease incidence merits further investigation.

The analysis revealed that 2018 witnessed the highest number of publications at 1,507 (8.1%), followed by 1,482 (8%) in 2017, 1,466 (7.8%) in 2015, 1,450 (7.7%) in 2016, and 1,318

(7%) in 2013. Projections for the coming five years (including 2019) suggest a steady increase in publications: 1,550, 1,583, 1,619, 1,651, and 1,683, respectively. Among these, 79% (14,625) were original research articles, with 5.99% (1,115) being reviews or surveys and 4.72% (878) editorial letters. Notably, 90.57% (16,844) of the literature was published in English. Harris E., from the University of California, USA, emerged as the most prolific author with 158 publications.

"The American Journal of Tropical Medicine and Hygiene" was the leading journal in terms of publications, with 698 works. Mahidol University, the University of Malaya, and the National University of Singapore, all situated in tropical climates, were identified as the most active institutions in dengue research.

Regarding citation impact, the top 15 articles had an average citation of 1,213, with "The Global Distribution and Burden of Dengue" being the most cited article, accumulating 3,833 citations. A network visualization map revealed the most prevalent terms in dengue research, including 'dengue,' 'dengue virus,' 'antibodies,' 'female,' 'Aedes,' 'mosquito,' 'virus replication,' 'epidemic,' and 'dengue vaccine.'

This study's reliance on specific databases may have overlooked non-indexed publications, potentially limiting the scope of analysis. Furthermore, bibliometric metrics might not fully encompass recent dengue research advancements beyond our study period.

As of 2023, over five million cases and more than five thousand dengue-related deaths have been reported from 86 countries, emphasizing the critical need for continued research and resource allocation within the biomedical field. Future endeavors will focus on a more region-specific analysis, particularly in India and Pakistan, to further enhance the understanding of dengue research trends and impacts in these areas.

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