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The Double Burden: A Bibliometric Analysis on Tuberculosis with Diabetes Mellitus Comorbidity

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Abstract

Many studies have been conducted independently and collaboratively to find effective ways to control TB. However, the prevalence of TB continues to increase, especially in low- and middle-income countries. This study highlights the breadth of research conducted worldwide and collaborative networks over the past decade. Between 2003 and 2023, 410 research articles on TB with comorbid diabetes were analyzed using the Scopus database, with an annual growth rate of 7.18%, reaching its peak in 2022. The keywords "tuberculosis" and "diabetes mellitus" were found to have a total link strength of 2895 and 3101, respectively. The most published articles on TB-DM were published in the International Journal of Tuberculosis and Lung Disease (23). Babu, Subash (23) authored the most TB-DM article publications. The National Institute for Research in Tuberculosis is the most productive affiliation (12), making India the country with the most published articles. Still, the Netherlands led in average article citations (32.8%), and the United States has the most collaborative link country (324). Visualization of the co-occurrence and co-authorship networks was conducted using R-Studio and VOS-Viewer. The study highlights the rising tuberculosis and diabetes incidence, identifies research trends, disparities, and bidirectional control innovations, providing valuable insights for policy recommendations.

Introduction

The co-epidemic of diabetes mellitus (DM) and tuberculosis (TB) is a significant worldwide health concern, especially among countries with low to middle incomes where the incidence of both exceeds high (GBD & Diabetes Collaborators, 2023). The number of tuberculosis-related deaths increased dramatically between 2019 and 2021, with 1.6 million tuberculosis-related deaths reported. The WHO End TB Strategy's first success was a 5.9% decline in infections between 2015 and 2021. 10.6 million cases were reported in 2021, an increase of 4.5% from 2020. The 2% annual decline in incidence was reversed by a reduction in the incidence of TB by 2%. An increase of 3.6% (WHO, 2022).

The World Health Organization (WHO) has not achieved its target of reducing the death rate by 35% and the TB infection rate by 20% by 2020, despite a decrease in the annual death rate and global incidence rate. The target is to reduce the death rate by 90% or the TB incidence rate by 80% by 2030 (IDF, 2022; WHO, 2022). The endemicity of tuberculosis (TB) in developing countries is expected to increase the number of people with type 2 diabetes by 51% to 700 million in 2045, and the proportion of new TB cases with diabetes mellitus to 33.3% in 2050 (Awad *et al.*, 2019; IDF, 2022; McMurry *et al.*,

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2019). Diabetes mellitus ranks fourth among all causes of death, with an estimated 6.7 million cases globally in 2021. Together with HIV and malnutrition, people experiencing DM are more likely to get active TB or have latent TB reactivated, which is one of the main risk factors for TB, worsening treatment outcomes, and premature death. According to the International Diabetes Federation (IDF), roughly 45% of DM sufferers worldwide are undiagnosed, with Type 2 DM causing 90% of all DM cases. In Indonesia, 19.5 million people suffer from DM, and 73% of them are undiagnosed (Eckold *et al*., 2021; Indonesian Ministry of Health, 2018; Magliano D. J & Boyko E. J, 2021; Ngo *et al*., 2021; Verma *et al*., 2021).

Bibliometric analysis is a technique of analyzing published information and associated metadata, which is often used in systematic literature reviews and involves quantitative analysis to describe relationships between published articles (Akmal *et al*., 2020; Chen *et al*., 2020; Yang *et al*., 2021). Bibliometric analysis differs from systematic and scoping reviews in providing additional information about research activities. Bibliometric analysis is a brief overview of both domestic and foreign contributions to the literature. It usually uses a single database to provide background data, pinpoint research gaps, and conduct precise quantitative evaluation of the literature that constitutes the basis for subsequent research and funding (Donthu *et al*., 2021; Ninkov *et al*., 2022). However, bibliometric analysis excludes grey literature, which is prevalent in systematic reviews. The strength of this bibliometric approach lies in its comprehensive and detailed coverage (Linnenluecke *et al*., 2020) Increased development and accessibility of software that utilizes quantitative algorithms and techniques, such as VOSviewer (Center for Science and Technology Studies, Leiden University, Leiden, The Netherlands) and scientific databases (Scopus, PubMed, Web of Science, Crossref, Google Scholar, Semantic Scholar) makes bibliometrics has become very popular in recent years as a form of large-scale data analysis. Official guidelines exist for systematic reviews, but the coverage and depth of bibliometric methods in these guidelines remain inadequate. Bibliometric analysis is regarded as a scholarly approach for gathering and combining published research on a fixed subject, notwithstanding its drawbacks (Donthu *et al*., 2021; Passas, 2024). There are many accessible systematic reviews with varying research focuses regarding TB, DM, or TB-DM. However, there are not many systematic reviews that apply bibliometric analysis. In this study, we gathered research articles indexed in the Scopus database between 2013 and 2023 that dealt with the co-morbidity of TB and diabetes and then analyzed and visualized them bibliometrically.

Method

The bibliometric analysis was applied from 2013 to 2023, employing the SciVerse Scopus database, which provides various benefits compared to different databases. Due to its easy-to-use interface, Scopus provides more global coverage than Web of Science and more precise data analysis than Google Scholar or PubMed (Beovich *et al*., 2021; Keighobadi *et al*., 2021). Scopus-indexed data collected by over 25,000 active titles and 7,000 publishers, all of which have been extensively verified and approved by a third-party assessment council. Scopus uniquely merges an exhaustive, highly managed abstract and citation database with enhanced data and connected academic literature spanning several fields (https://elsevier.international/en-gb/solutions/scopus.html). Scopus was selected due to its all-encompassing perspective on worldwide research productivity in medical science, technology, arts, humanities, and behavioural sciences. It provides tools for tracking research trends, publication year, document type, analysing citations, computing h-index (Hirsh-index), journal name, authors, affiliations, mapping keywords, and collaborating on international research (Sweileh, 2018).

Data collection was carried out on November 16, 2023. A comprehensive search was carried out on Scopus data collection to retrieve data of original research publications on the topic of TB with comorbid DM. This bibliometric study began with identifying sources and establishing inclusion and exclusion criteria. However, the most significant consideration is keyword selection,

since it has a direct effect on the discoveries and outcomes (Sweileh, 2018). In the initial data collection process, according to keywords, 715 articles were collected. Furthermore, data cleaning is required to remove duplicate articles and articles published in the period 2013 to 2023. Only full-text original articles published in English and final stage are considered to meet the inclusion criteria; all other types of documents, articles with unprovided English translations, and unrelated articles are excluded. The results of data extraction produced a total of 505 articles. The data search method in the Scopus database involves combining the terms TITLE ("tuberculosis" OR "lung tuberculosis" OR "pulmonary tuberculosis" AND diabet* AND "diabetes mellitus" OR "diabetes") AND ABS ("tuberculosis" AND "diabetes mellitus") AND ALL ("tuberculosis" AND "diabetes mellitus")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYP, "j").

The data gathered was applied to figure out the number of original research publications by year, subject area, journals, authorship, institutions, countries, research funding, co-occurrence networks, and co-authorship networks. Data from Scopus regarding 15 journals, 15 authors, 15 institutions, and 15 active countries—which are thought to contribute the most scientifically to the literature—are exported into an Excel spreadsheet (Microsoft® Excel® for Microsoft 365 MSO Version 2405). All subsequent data will be analyzed after exporting to ".csv" (comma-separated values) format. The number of articles given to every country may overlap since Scopus determines the entire articles for every country by considering the author institutions, irrespective of the author's rank on the author roster. Direct assessment or quantification of a publication's quality is challenging. As an indirect indicator of publication impact or quality, one can look at the overall number of citations obtained, the mean count of articles cited, the Hirsch index (h index), and the proportion of mostly cited articles (Aksnes *et al*., 2019; Thelwall & Sud, 2022).

A construct and visualized bibliometric map was produced using Biblioshiny (R studio version 2023.12.0–369) software applied to map country production, article language, and the most cited countries. VOSviewer (version 1.6.20) visualization to showcase the authors who have published the most papers and the collaboration networks between authors. The most popular subjects were found using title analysis and co-occurrence network visualization. The link strength in a map was strongly correlated with the size of the node and the line that connected the authors. Visualized maps were also generated to provide insight into the scope of worldwide collaboration. Based on the thickness of the connecting lines and the quantities of articles, VOSviewer determines the degree of partnership involving two or more countries. The link strength is supplied by the software; hence, the author does not compute it. In terms of the quantity of co-authored articles in comparison to those in other countries, the greater the collaboration between the two countries, the greater the link. VOSviewer is also useful for determining how a scientific area is organized and pinpointing potential avenues for further inquiry.

Result and Discussion

Through bibliometric analysis of research findings, we looked at 410 publications from various viewpoints published in 222 journals and featured 2175 authors. The trend in years of publication of original research articles on TB and DM has increased over the past ten years. A total of 23 research articles published in 2013 were indexed in the Scopus Database. However, from 2014 onwards, there were more than 100 publications. The study has steadily expanded since 2017 (32 documents) until it reached its peak in 2022 (58 documents). Overall, research interest in TB and DM has begun to grow over the last decades with an annual growth rate of 7.18%. Even though the increase in research annually insignificant, the number tends to increase. There has been a drastic spike in the last two years (2021 – 2022). This increase in the number of publications is in line with the increasing prevalence of tuberculosis and diabetes mellitus globally, both in developed and developing countries (IDF, 2022; WHO, 2022).

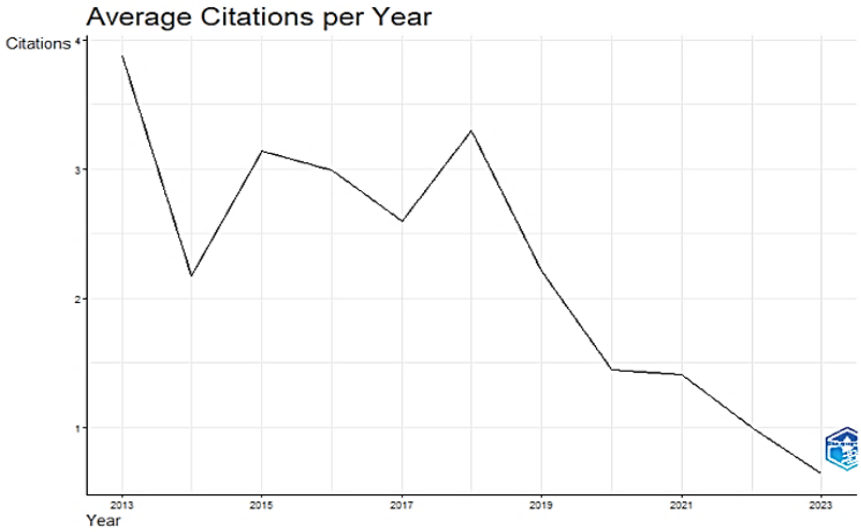

FIGURE 1. Annual citations of original research articles on TB – DM publications per year.

The average annual citation of documents is displayed in Fig. 1. The graph clearly illustrates an inverse link, where the frequency of citations swings with a high tendency from 2013 to 2018, peaking at 46.48 cited publications in 2013, then declines even further from 2019 to 2023. The average number of citations for published articles is decreasing, with average citations per article of 14.86%, although the number of publications is increasing. It suggests that the influence of publications is waning, even though several research paths are being explored in the field of TB and DM. In addition, there were social and economic difficulties brought on by the COVID-19 pandemic, which struck in 2019 and continued until 2021. Worldwide emphasis was mostly focused on COVID-19 research, which contributed to a decline in the amount of attention devoted to TB research overall (Delardas *et al*., 2022; Mofijur *et al*., 2021).

A total of 410 original articles on TB and DM published by authors affiliated in 83 countries; The top 15 countries publishing TB articles with DM comorbidity, including India (n = 86, Total citation = 929) taking the top spot, followed by the United State (n = 78, Total citation = 893), China (n = 67, Total citation = 710), United Kingdom (n = 39, Total citation = 118), and Indonesia (n = 31, Total citation = 77) in fifth position. The subsequent countries listed in sequence are Mexico (n = 24), Netherlands (n = 21), South Korea (n = 20), Taiwan (n = 17), France and South Africa (n = 16), Brazil (n = 15), Tanzania (n = 14), Denmark and Thailand (n = 12). The Netherlands led the world in average article citations (32.8%), followed closely by the United States (31.9%), the United Kingdom (23.6%), and Mexico (23.1%). Due to the vast quantity of publications and relatively low quality of those articles, India has substantially lower average article citations, even though overall citations are more than in other countries/regions. Interestingly, the three Asian countries with the highest TB caseloads are included in "The Big Five" (India, Indonesia, and China). It reveals a clear correlation between "high burden TB-DM countries" and research contributions, as evidenced by the most published articles. Research on TB itself is increasing, and controlling its spread has become one of the main health priorities in the world, with the United States, United Kingdom, India, and China dominating research in this field (Abdullah *et al*., 2022; Garrido-Cardenas *et al*., 2020). Similar results to the bibliometric analysis of DM (Kong *et al*., 2023). Bibliometric analyses of TB and DM, although separately, report similar results regarding the most contributing countries.

Fig. 2 depicts the worldwide collaboration cluster network of linked countries and regions. These data were used to create eleven clusters. At least one publication was released by 46 nations or territories, and 32 of those were linked together to create a cooperative network. The United States was the most collaborative

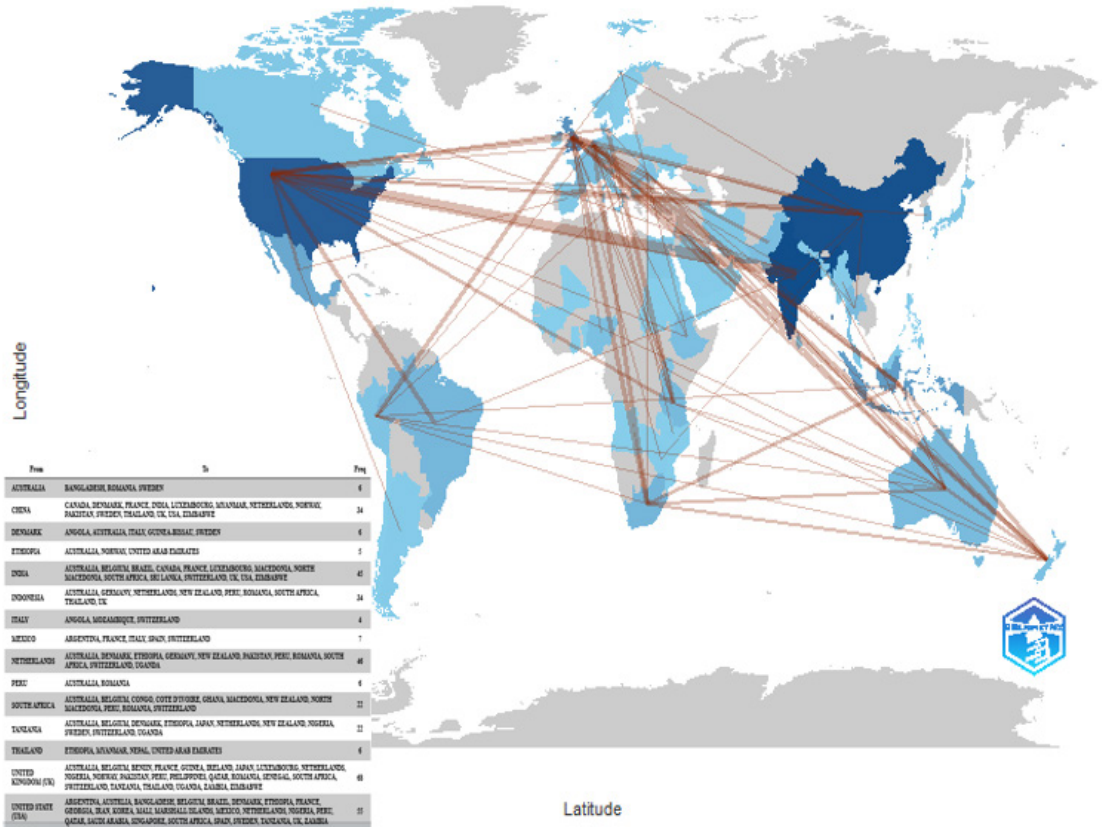

FIGURE 2. Countries' Partnership World Map.

country with the highest total link strength (TLS = 324), followed by the United Kingdom (TLS = 232), the Netherlands (TLS = 94), China (TLS = 78), and India (TLS = 70). Indonesia (TLS = 17), on the other hand, is a member of the red cluster and collaborates with nine other nations/territories, both inside and outside of its cluster. The countries that collaborate with Indonesia the closest include Australia, the Netherlands, New Zealand, South Africa, and the United Kingdom. Thus, Indonesia must strengthen the influence of publications and global collaboration in the areas of diabetes and TB, in light of both quantity and quality.

The original articles gathered for the present research have been published in open-access journals of various categories, including all open-access (n = 302), gold (n = 233), green (n = 149), bronze (n = 28), and hybrid gold (n = 16). Original research articles published in 161 peer-reviewed publications were included, and the top 15 journals are listed in Table 1, along with their associated 2023 CiteScore, frequency of articles published in each journal, and their citations. CiteScore 2023 is determined by dividing the total number of citations received in 2020–2023 for articles, reviews, conference papers, book chapters, and data papers published in 2020–2023 by the total number of publications created in 2020–2023. The International Journal of Tuberculosis and Lung Disease is the journal with the most published articles (n = 23) related to the topic of TB-DM, while Plos One is in the second place, has the highest number of citations (TC = 653). Meanwhile, the highest 2023 CiteScore is the International Journal of Infectious Diseases (18.9), which reflects the highest annual average number of citations to recent articles published in that journal.

Firstly, the h-index was developed for individual scientists or academics, act as an author-level indicator that assesses the productivity and citation effect of publications.

The most frequently referenced papers and citations from other journals serve as its foundation. It has more recently been used with an academic journal's influence and production. The International Journal of Tuberculosis and Lung Disease has grown since 2021 – source details obtained from Scopus – by releasing 23 of 90 TB-DM related publications in 2023 with 12 citations and an h-index of 12. Among the top 15 journals, Plos One had the most citations (TC = 653) and the highest h-index (15) out of 20 publications about TB-DM. The growing trend of research based on numerous published and cited documents related to TB cases with DM comorbidity draws the international spotlight on the spread and control of TB with DM comorbidity factors in two directions since it can have a significant global impact on public health (Bai & Ameyaw, 2024; Villar-Hernández *et al.*, 2023). Original articles on TB and DM, written by a total of 2175 authors, co-authors per document 7.37, and international co-authorship of 37.32%. Fig 3. shows a comparison of the number of published articles and the top five authors with most publications were authored by Babu, Subash S. currently affiliated with the National Institute of Allergy and Infectious Diseases, United States (n = 23; h-index = 14; total link strength = 65; total citations = 613). Those reflect the outstanding standard and significant impact of Babu's publications. Second position is Kumar, Nathella P. who is affiliated in Tuberculosis Research Centre, India (n = 20; h-index = 11; total link strength = 48; total citation = 438), then followed by Kornfeld, Hardy with affiliations in University of Massachusetts Chan Medical School, United States (n = 17; h-index = 11; total link strength = 26; total citation = 488). Critchley, Julia A. is in fourth position affiliated in St. George's

TABLE 1. The 15 Leading Journals by Number of Articles in the Field of Tuberculosis with Diabetes.

Journal	Articles	h-index	g-index	CiteScore 2023	Total citation
International Journal of Tuberculosis and Lung Disease	23*	12	19	4.9	389
Plos One	20	15*	20	6.2	653*
BMC Infectious Diseases	17	9	14	6.5	217
Tuberculosis	12	6	12	4.6	280
Scientific Reports	9	6	9	7.5	241
BMJ Open	8	4	5	4.4	36
International Journal of Infectious Diseases	7	5	7	18.9*	62
Infection And Drug Resistance	6	3	6	5.6	45
International Journal of Mycobacteriology	6	4	6	2.2	57
BMC Health Services Research	5	4	5	4.4	60
Frontiers In Public Health	5	3	3	4.8	15
BMC Public Health	4	3	4	6.5	25
Frontiers In Endocrinology	4	1	3	5.7	12
Immunology	4	4	4	11.9	110
Indian Journal of Public Health Research and Development	4	2	2	Covered discontinued in Scopus	

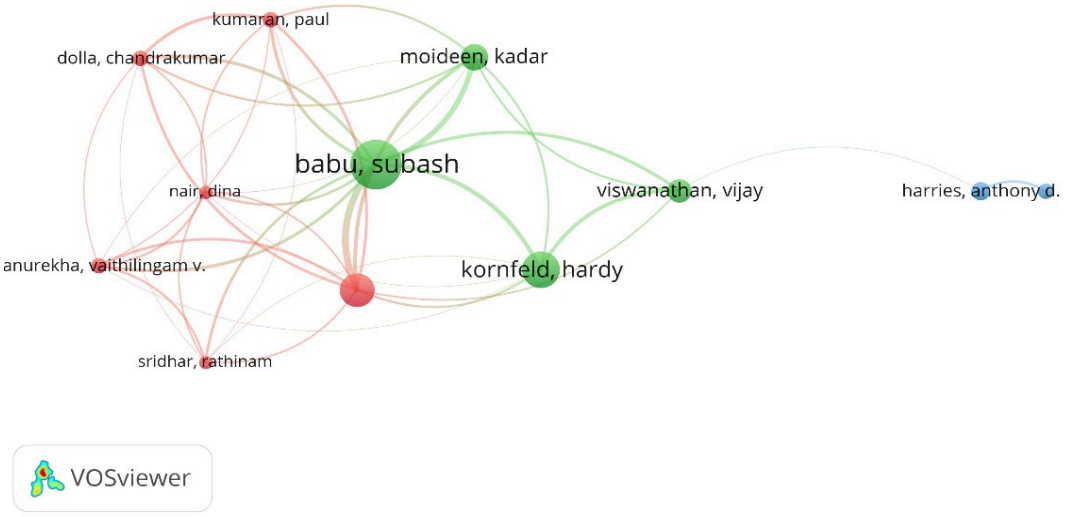

FIGURE 3. Network Visualization Map of Authors' Connections

University of London, United Kingdom (n = 12; h-index = 7; total link strength = 29; total citation = 139), and lastly Moideen, Kadar affiliated in Tuberculosis Research Centre, India (n = 9; h-index = 8; total link strength = 35; total citation = 145). The item weight determines the size of the item label and circle. The item label and circle are larger, the heavier the object is. Fifteen connected authors are displayed in Fig. 3. The item's color is dictated by the cluster it belongs to. Links are shown by the lines connecting the objects. In terms of co-authorship links, the distance between two writers in the graphic generally represents how linked the authors are to one another. Broadly speaking, the stronger the relatedness of two writers, the closer they are to one another.

The three-field plot diagram shown in Fig, 4, consisting of the author, country, and affiliation of the author, aims to highlight the collaboration network of Indonesian researchers in the field of tuberculosis with diabetes comorbidity. In a collaborative study, three authors—Hill PC, Van Crevel, and Critchley J.—focused on Indonesia. London School of Hygiene and Tropical Medicine, University of London, is the organization working with an Indonesian university, in this instance, Padjadjaran University. The Padjadjaran University collaboration network is established by South Africa, the Netherlands, Indonesia, and England.

The three-field plot diagram represents the top 15 affiliates based on the highest number of citations. The top five affiliates include National Institute for Research in Tuberculosis, Chennai, India which is the most productive affiliate (articles = 12; citations = 469; total link strength = 21), followed by Government Stanley Medical Hospital, India (articles = 5; citations = 310; total link strength = 8), Department of Medicine, University of Massachusetts Medical School, United States (articles = 6; citations = 287; total link strength = 16), International Union Against Tuberculosis and Lung Diseases, France (articles = 5; citations = 228; total link strength = 13), and Laboratory of Parasitic Diseases, National Institute of Allergy and Infectious Diseases, NIAID, United States (articles = 3; citations = 177; total link strength = 6). Total link strength within institutions with co-authorship shows the total strength of co-authorship links between researchers from a particular institution and researchers from other institutions. This shows the strength of the collaboration network between institutions and countries. The institutions of Asian countries—particularly Taiwan, Indonesia, and India—seem predominant in the list of top 15 institutions, with Indonesia in 13th place.

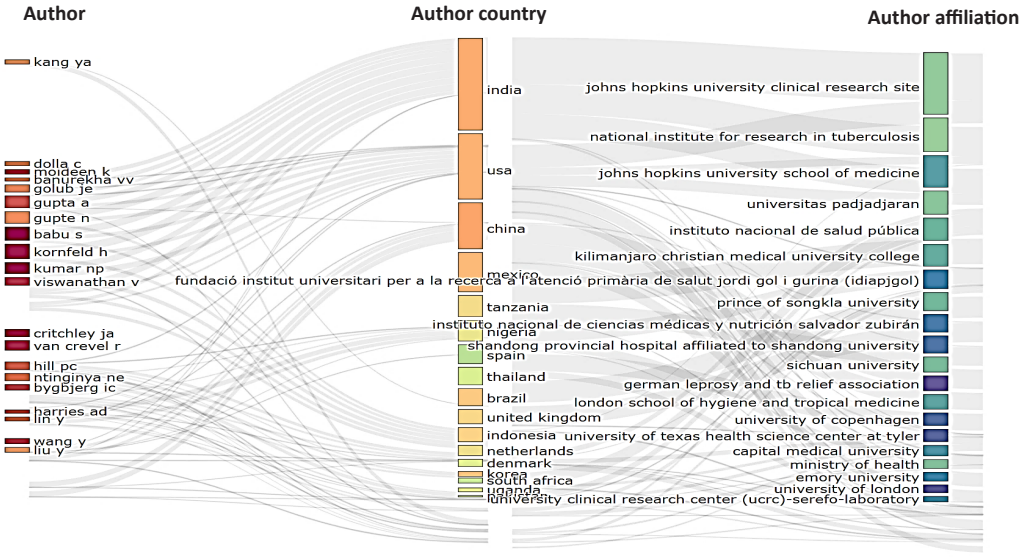

FIGURE 4. Three fields plot of collaboration of the institutions that publish articles about TB and DM.

The trending topics that shift over a ten-year period (2013-2023) are shown in Fig. 5 to compile statistics on keywords that have observed an enormous rise in TB and DM-related research. By displaying the intensity (frequency) and time length, the graph visualizes problems with hot spots. The 30 most popular keywords in the 2013 research featured are "tumor necrosis factor alpha" and "adaptive immunity", which were trending topics until 2014 and 2015 with frequencies of 10 and 9, respectively. Research with the trend topic of "pulmonary tuberculosis" started in 2015 to 2019 (freq = 126), "mycobacterium tuberculosis" started in 2016 to 2021 (freq = 131), and the trend topic of "tuberculosis" only started in 2017 to 2022 with the second highest frequency (freq = 490). Meanwhile, the topic trend of "diabetes mellitus", which also started in 2017 to 2022, has the highest frequency (freq = 504) among the top 30 keywords. Starting from 2022 to 2023, the research trend shifted towards the topics of "metabolomics" (freq = 8), "multivariate logistic regression analysis" (freq = 6), and "bioinformatics" (freq = 5).

Co-occurrence networks visualization and title analysis were performed to reveal the most active topics. To investigate co-occurrence, title keyword analysis was performed. Those terms used at least ten times by the authors within published articles on TB – DM included, and not a single keyword is isolated in the network visualization—all keywords are interconnected. The title field with the minimum number of occurrences of a term is 10 out of 2377 keywords, only 215 of which meet the threshold. The total strength of each keyword's relationship with other keywords will be computed every thirty. The thirty keywords with the highest overall strength of connection will be chosen and split into four clusters. The network visualization displays a line linking the keyword "tuberculosis" (occurrences = 240, total link strength = 2895) and "diabetes mellitus" (occurrences = 256, total link strength = 3101), signifying their link connection. The keyword "tuberculosis" has a larger label, indicating frequent co-occurrence compared to "lung tuberculosis" (occurrences = 164, total link strength = 2240) and "pulmonary tuberculosis" (occurrences = 98, total link strength = 1445). Meanwhile, diabetes mellitus type 2 has occurrences 97 with a total link strength of 1355. The keyword diabetes mellitus type 1 label is not displayed on network visualization, possibly due to low occurrence and total link strength despite being included in the trending topics (Yu *et al.*, 2020).

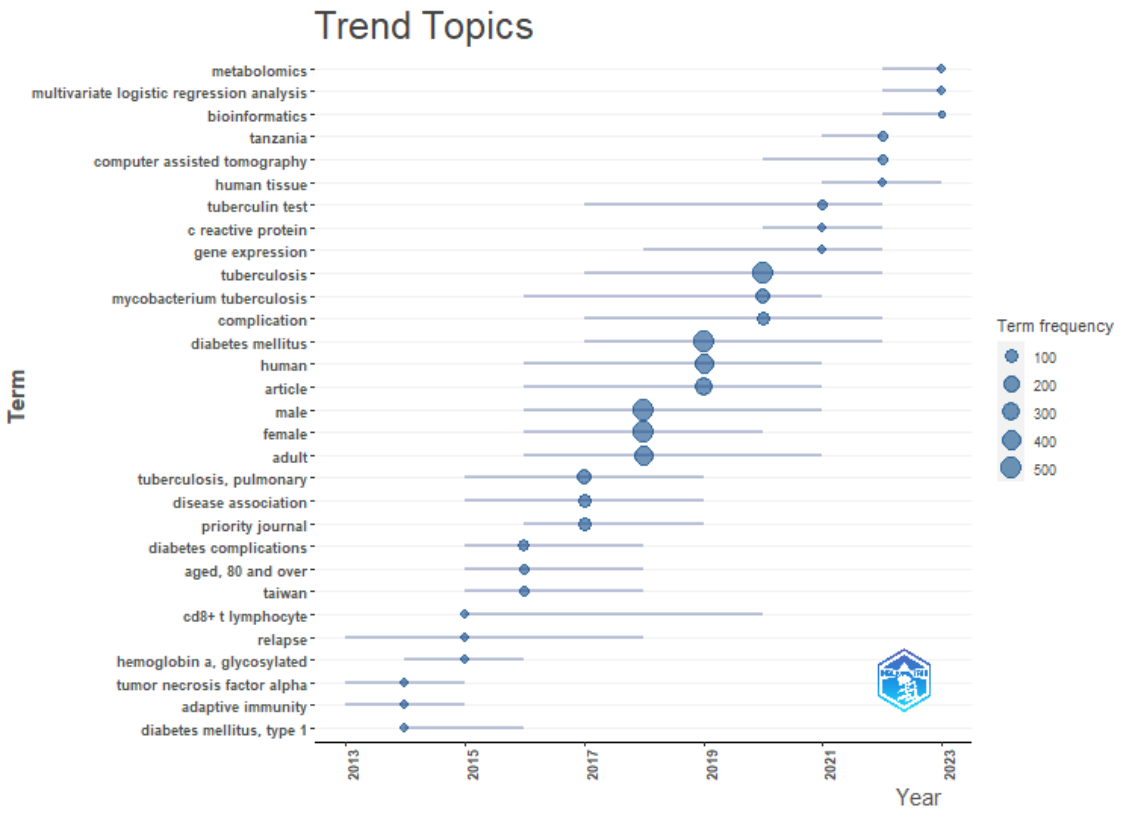

FIGURE 5. Trends Topic on Tuberculosis and Diabetes mellitus.

Conclusion

Research interest in tuberculosis and diabetes mellitus (TB) and DM has grown at an annual rate of 7.18% over the past decades. Beginning in 2014 and peaking in 2022, a batch of studies published and indexed in the Scopus Database has grown rapidly. The average annual citations of documents showed an inverse relationship. The average number of citations per article decreased, but the number of publications increased. Interestingly, authors affiliated with Indonesia are included in the top 15 positions with quite high collaboration link strength. This study provides thorough information to support creative research projects and decision-makers in formulating policy recommendations. The results of this bibliometric analysis will be material for further research entitled "Development of Machine Learning Models to Predict Tuberculosis Disease in Children".

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