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A bibliometric analysis of global research performance on tuberculosis (2011–2020): Time for a global approach to support high-burden countries

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Abstract:

BACKGROUND: Tuberculosis (TB) is a persistent public health issue requiring consistent global effort for its eradication and control. Research on the subject plays a vital role in combatting the disease, giving future directions, and meeting the sustainable development goals (SDGs). This study aimed to evaluate the global TB research trends and performance from 2011 to 2020.

MATERIALS AND METHODS: All the data for TB-related research publications from 2011 to 2020 were extracted from the Web of Science database and a comprehensive analysis was performed on the R-bibliometrix package.

RESULTS: An increasing number of publications with an annual growth rate of 6.32% and a plateau in production from 2015 to 2018 was observed. Of 145 countries, the United States of America (USA), China, India, the United Kingdom, and South Africa led and made up half of the global contribution. Out of 91,862 authors, Zhang Y was the most productive with 205 articles and Barry CE had the highest H-index of 45. Only seven of the top 20 authors were from high-burden countries. The University of Cape Town was the leading institutional affiliation, followed by Stellenbosch University and the London School of Hygiene and Tropical Medicine. The most frequent international collaboration was between the USA and South Africa, occurring on 1203 instances. Only five of the top 30 high-burden countries were present in the top 30 collaborations. PLOS ONE, disseminating 2271 articles, was the most productive out of 3500 sources.

CONCLUSION: The past decade has seen a steady increase in global TB research. Prominent authors, affiliations, and countries showed collaborative trends, but publications were found to be mostly from developed, low-burden countries except China, India, and South Africa. To meet the goals set by the SDGs and the WHO End TB Strategy, high-burden countries need to explore feasible opportunities and global support to enhance their expected TB-related research contributions.

Keywords:

Bibliometrics, tuberculosis, Web of Science

Introduction

Tuberculosis (TB) has been of interest to human researchers for a long time; with writings mentioning the disease dating

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as far back as three millennia.^[1,2] In 2019, TB affected 10 million people globally, causing the deaths of around 1.2 million HIV-negative people and an additional 208 000 deaths in HIV-positive persons.^[3] The disease has a predilection for the male

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population, accounting for 56% of the cases, in males over the age of 15.^[3]

Comorbid conditions that increase vulnerability to TB include communicable diseases, such as HIV and noncommunicable diseases, such as diabetes, rheumatoid arthritis, silicosis, and other biological factors affecting the immune system.^[4-6] Socioeconomic factors such as poor housing, malnutrition and lack of access to healthcare, all increase the risk of a TB infection.^[6]

Although TB is a global phenomenon, the region most affected is South-East Asia (44%), followed by Africa (25%), and the Western Pacific (18%).^[3] The top eight high-burden countries make up two-thirds of the global share.^[3] The high-burden countries include India, Indonesia, China, the Philippines, Pakistan, Nigeria, Bangladesh, and South Africa.^[3]

Continuous research on TB plays a vital role in mapping progress, making informed decisions, and devising new strategies to combat the disease. Bibliometrics aims to analyze the contributions of different regions, countries, institutions, authors, and their impact on research. Thus, it identifies the gaps and points toward areas where improvement is needed. Moreover, it helps identify new trends and opportunities for collaborative efforts to reach a goal.^[7] Bibliometric studies significantly contribute to furthering valuable academic knowledge, which is essential to global economic and social welfare.^[8] They look at volume, constituency, and collaboration of research in a specific field and are used to justify the work of a researcher.^[9,10] In recent decades, many bibliometric studies have explored different healthcare issues and public health problems, such as the trends of infectious diseases in general,^[11,12] and more specifically, HIV/AIDS,^[13,14] hepatitis,^[15] and recently, the coronavirus disease.^[16-18]

Although a few studies have explored TB in this context, literature on global TB research trends in the last decade is still limited. The study by Nafade *et al.*, in 2018 analyzed global trends of research before 2016, and the analysis by Igwaran and Edoamodu only targeted Africa; another by Morishita *et al.*, targeted the Western Pacific.^[19-21] A study with a global aspect was, therefore, necessary. This study aimed to perform a bibliometric analysis of TB research from 2011 to 2020 to discover research performance and trends from a global perspective.

Materials and Methods

The databases available to researchers include Scopus, PubMed, Embase, ScienceDirect, and The Cochrane Library, to name just a few. For our study, we used the Web of Science (WoS), as it has been mostly used

for bibliometric analysis by researchers and is more standardized than other databases.^[22-25] WoS, a Clarivate analytics division (Formerly Thomson Reuters), contains over 75 million records and is one of the oldest citation indexes for sciences, without which the development of bibliometrics would have been hindered.^[26] Bibliometric techniques are used to discern trends of data output and provide quantitative measures for the contribution of countries, authors, institutions, funding agencies, collaborations, and more.^[23,24,27,28] Ethical approval was not applicable in this research since the study had no direct involvement of human subjects.

In this study, we planned to describe global TB research trends from 2011 to 2020. For this, we accessed the King Abdulaziz University (KAU) online library and digital resources to retrieve the information. We performed the advanced search on WoS using the following search strategy TI = (TB OR Tuberculosis), from 2011 to 2020 only, document types restricted to article only, and only articles in English. We retrieved 33,088 records. Figure 1 shows the detailed search strategy.

Title (TI) rather than the Topic (TS) was used in the search strategy to be more specific to prevent irrelevant results since TS contains, Title (TI), Abstract (AB), Keywords (AP), and Keywords plus (KP).^[29] Similar search strategies containing TI had been used by other studies, thus supporting our choice.^[21,30] To avoid bias resulting from frequent database renewal, all the records were retrieved on the same day (November 3, 2021).

After the records were extracted in a plain text format, two reviewers independently screened them manually by title to eliminate any that fell outside the scope of the study and resolved any conflicts. Irrelevant articles (2627) beyond the study scope were excluded from detailed analysis, such as articles with "TB" used in the context as an acronym for the element terbium or as unit of data known as terabyte. Using R-Bibliometrix^[31] on the remaining 30,461 articles, a detailed analysis of various bibliometric matrices such as journal, publication year, authors, citations, institutes, countries, sources, and more was done. Collaboration networks of authors, institutions, countries, and top keywords were also observed. Finally, two reviewers independently extracted and rechecked the information to verify the process.

Results

A total of 30,461 articles from 3260 sources were analyzed [Figure 1]. Around 91,862 authors originated from 145 countries, led by the United States of America (USA), China, India, the United Kingdom, and South Africa. Table 1 gives the summary of relevant information.

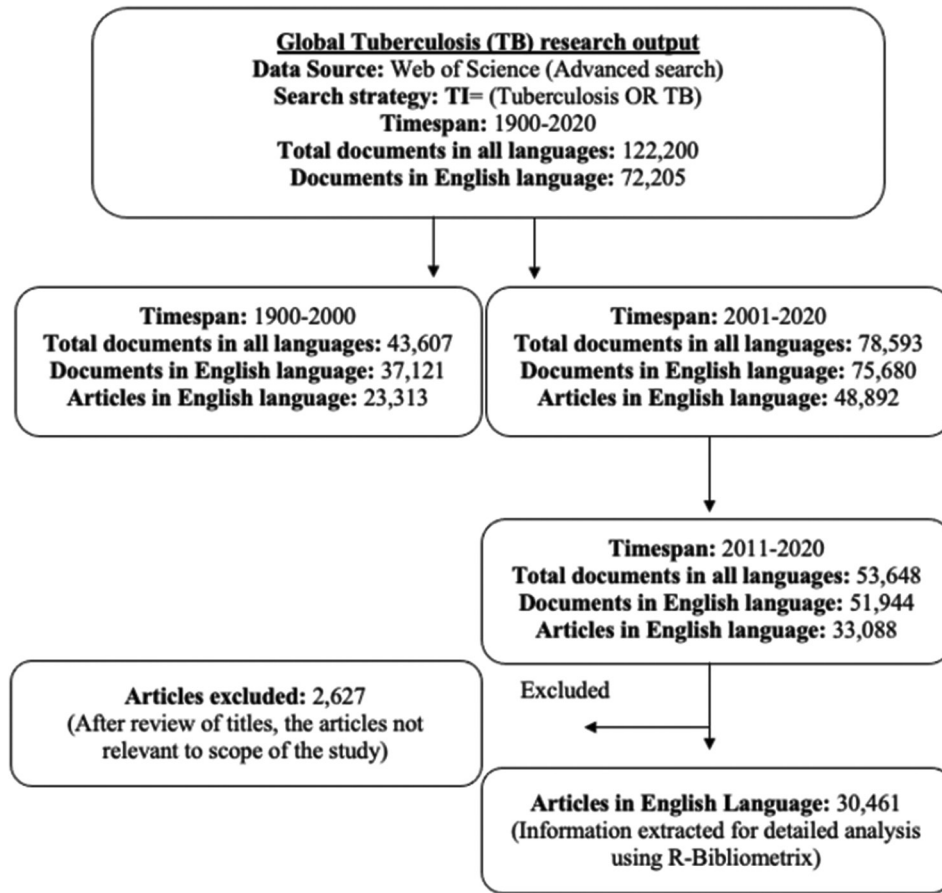


Figure 1: Global Tuberculosis (TB) research output (1900–2020)

The number of articles increased from 2246 articles in 2011 to 3899 in 2020, a 73.6 % increase in yearly production [Figure 2]. The top three funding sources, the United States Department of Health Human Services, the National Institutes of Health (NIH) USA, and the National Institute of Allergy Infectious Diseases, contributed approximately one-third of the funding.

Table 2 shows the 20 most productive authors, led by Zhang Y with 205 articles, and he was the only author with more than 200 articles to his name. Dheda K had the highest share of corresponding author contributions (58%), while Gupta A was the highest contributor as the first author (32%). Barry CE led with the highest h-index (45) and had 6421 total citations. Seventeen out of the 20 authors had h-index ≥ 20 , and 8 of the 20 authors had total citations >3000 . Only three authors had Articles Fractionalized (AF) more than 20. Two authors, Barry CE and Gagneux S, did not contribute as the first authors.

The authors' collaboration network showed that 18 of the top 20 authors collaborated, the most being between Zhan Y and Wang J. Two authors, namely Zhang X and Wang C, did not collaborate with any others or each other.

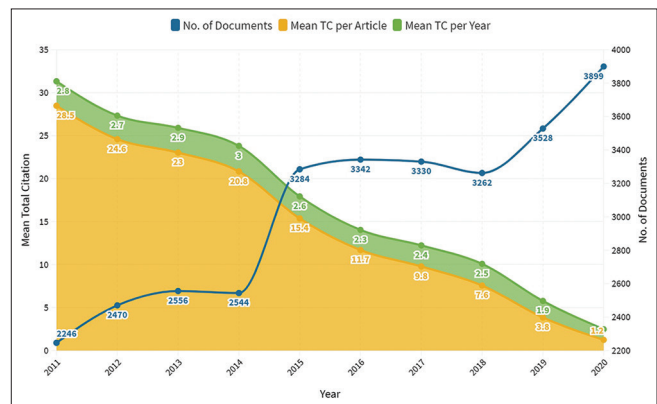


Figure 2: Global TB research publications: Publications, mean total citations per year, and mean total citation per article, 2011-2020

Five countries, including the USA, China, India, the United Kingdom, and South Africa, made 52% of the corresponding author's contribution [Table 3]. The USA led with more than twice as many citations as China, which was in the second place. Switzerland (0.67), the Netherlands (0.65), and the United Kingdom (0.60) had the highest multicountry publication (MCP) ratio, while Turkey had the lowest

MCP ratio (0.07) out of the top 20 countries with corresponding authors [Table 3].

The collaboration world map for countries with ten or more international collaborations showed hotspots in the USA and Europe. Within the top 20 collaborations, the USA collaborated with 12 other countries, making

Table 1: Summary: Global TB research publications 2010-2020

Description	2011–2020
Articles	30,461
Annual growth rate (%)	6.32
Open access (%)	19,615 (64.4)
Sources (journals, books, etc.)	3260
Average years from publication	5.04
Average citations per articles	13.19
Average citations per year per article	1.917
References	375,160
Article contents	
Keywords plus (ID)	21,384
Author’s keywords (DE)	31,246
Authors	91,862
Author appearances	226,836
Authors of single-authored articles	423
Authors of multi-authored articles	91,439
Authors collaboration	
Single-authored articles	499
Articles per author	0.332
Authors per article	3.02
Co-Authors per articles	7.45
Authors’ countries	145
Collaboration index	3.05

it the most collaborative country. The United Kingdom collaborated with seven countries and South Africa with three countries, placing them second and third, respectively, in terms of collaboration. Among bilateral collaborations, the USA and South Africa were leading with 1203 instances.

As shown in Figure 3, the collaboration of institutions shows the largest collaboration cluster (red) dominated by institutions in South Africa. The USA institutional affiliations dominated the other two clusters (blue and green).

The top 10 most frequent affiliations comprised 28.1% (8569) of the total number of articles. The University of Cape Town showed the most frequent affiliation with 1893 articles, followed by the Stellenbosch University with 1117 articles and the London School

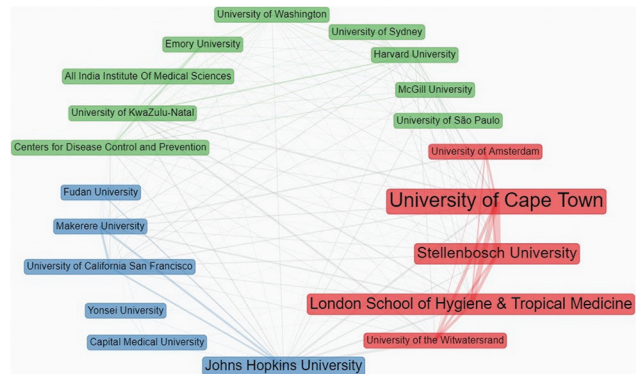


Figure 3: Global TB research publications: Institutional affiliations cluster

Table 2: Global TB research publications: Top 20 most productive authors and their impact (2011–2020)

Authors	Number of articles	Percentage as FA	Percentage as CA	AF	h-index	TC
Zhang	205	22	27	25.89	31	3409
Wang	161	16	12	18.48	25	1875
Wang	161	20	14	20.27	22	2541
Kumar	149	29	11	24.01	20	1458
Gupta	136	32	20	17.33	24	1886
Li	122	16	19	15.33	16	949
Dheda	120	5	58	13.92	37	5287
Kumar	119	15	6	16.75	19	1183
Abubakar	118	7	15	14.9	31	5054
Pang	117	21	44	14.68	21	1750
Singh	117	16	24	19.82	21	1433
Van Soolingen	114	1	12	15.24	31	2883
Liu	112	26	7	14.38	15	1712
Walzl	112	2	8	11.42	34	3544
Swaminathan	111	6	29	13.06	26	3237
Harries	110	7	15	14.01	23	1813
Kim	110	12	16	14.49	25	1892
Ottenhoff	110	2	10	11.31	34	3461
Barry	108	0	21	10.32	45	6421
Gagneux	108	0	13	9.77	35	4484

FA=First author, CA=Corresponding author, AF=Articles fractionalized, TC=Total citations

of Hygiene and Tropical Medicine with 1010 articles. Overall, 14 institutions had more than 500 articles each. Out of the top 20 affiliations, seven belonged to the USA, four to South Africa, and two to China.

The Sankey diagram for the top 20 countries, affiliations, and sources shows that the USA had the largest share in articles and had connections with most of the affiliations. South Africa showed a significant number of affiliation with the University of Cape Town. PLOS ONE was the largest source showing connections to articles from almost all countries [Figure 4].

Ten of the 20 highly cited articles were five articles each from The Lancet associated Journals and The New England Journal of Medicine with citations in 2011. Bochme CC, 2011 (Lancet) had the most Internal Citations (IC) at 403 and the most global citations (GC) cited 685 times. All the top 20 highly cited articles had an IC/GC ratio $\geq 50\%$, with Demay C, 2012; Infect Genet Evol had the highest IC/GC Ratio.

TB was the most frequently used keyword with over 9000 occurrences over the last decade, followed by *Mycobacterium tuberculosis*, with approximately 3500

Table 3: Global TB research publications: Top 20 countries with corresponding authors

Country	Total articles	CA	Percentage contribution	SCP	MCP	MCP ratio	TC
USA	21,675	4985	16.4	2728	2257	0.4528	105,628
China	14,960	4400	14.4	3662	738	0.1677	42,091
India	10,148	3632	11.9	3031	601	0.1655	31,108
United Kingdom	7513	1643	5.4	653	990	0.6026	34,027
South Africa	6964	1358	4.5	596	762	0.5611	25,174
Brazil	4691	1145	3.8	815	330	0.2882	8976
Korea	3297	892	2.9	816	76	0.0852	9057
France	3527	606	2.0	303	303	0.5	11,045
Japan	2141	576	1.9	446	130	0.2257	4370
Italy	2472	573	1.9	367	206	0.3595	9120
Iran	2212	563	1.8	479	84	0.1492	3196
Spain	3271	561	1.8	370	191	0.3405	8705
Canada	2473	519	1.7	297	222	0.4277	9035
Pakistan	1667	500	1.6	366	134	0.268	2260
Ethiopia	1616	472	1.5	276	196	0.4153	4675
Germany	2356	471	1.5	198	273	0.5796	11,991
Australia	2132	440	1.4	210	230	0.5227	5092
Netherlands	2132	423	1.4	147	276	0.6525	7542
Turkey	1311	399	1.3	371	28	0.0702	2263
Switzerland	2060	353	1.2	116	237	0.6714	11,503

CA=Corresponding author, SCP=Single or intra-country publication, MCP=Multiple or intercountry publications, TC=Total citations

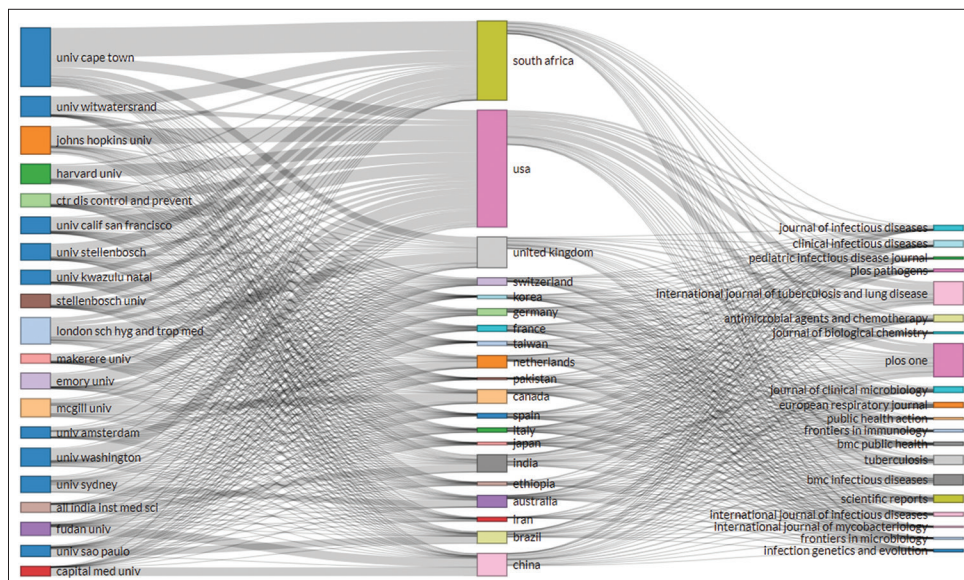


Figure 4: Global TB research publications: Sankey diagram for the top 20 affiliations, countries, and sources

total occurrences. The remaining keywords, such as HIV, pulmonary TB, and the diagnosis had <1000 total occurrences.

Some important keywords plus (ID) were “*M. tuberculosis*,” “infection,” and “pulmonary TB,” each of which occurred over 2000 times.

Yearly growth of the most abundant sources showed “PLOS ONE” in the lead with more than 2,200 articles in the last decade, followed closely by the “International Journal of TB and Lung Disease” with 1600 articles, and “BMC infectious disease” with 753. The yearly increase of PLOS ONE peaked in 2013 with over 300 annual occurrences, but then descended into a decreasing trend to <200 annual occurrences in 2020. The top two sources (PLOS ONE and the International Journal of TB and Lung Disease) have shown a decreasing trend in the last 5 years.

Discussion

This study evaluates the TB-related research performance and trends in the past decade to provide an outline for evidence-based future research. In 2015, The WHO sustainable development goals (SDGs) and End TB strategy set targets for 2030 and 2035, respectively, to fulfill a vision; “zero deaths, disease, and suffering due to TB.”^[32]

The general trend showed an increase in the last decade, with the most significant jump in the number of articles published from 2014 to 2015. The production which plateaued from 2015 to 2018, as shown by the almost horizontal blue line in Figure 2, is ironic because the SDGs set in 2015 warranted more TB research than a plateau. However, the pace of research resumed an upward trend after 2018. Another interesting finding is the decrease in the annual growth rate from 7.3% in 2007–2016 to 6.3% in 2011–2020.^[33] When global TB research production should have been increasing or at least been constant, it decreased, which is worrisome. Furthermore, the global COVID-19 pandemic had a highly negative short-term impact on the progress of SDG 3 (which pertains to TB), as stated by the SDG report.^[33] This further underscores the importance of this paper, as the world looks to bounce back and resume TB research with a road map.

Interestingly, the world’s Top 30 high-burden countries make up 86% of the total cases,^[3] and approximately 60% of the contribution to research articles. As attention shifted toward the COVID-19 pandemic, the number of people diagnosed with TB in India, the Philippines, Indonesia, and South Africa decreased,^[3] threatening to unravel previous work. Furthermore, these four

countries make up 44% of the global TB burden, but only two of them are in the top 20 countries with corresponding authors’ lists. This finding suggests that Indonesia and the Philippines need to step up or expand TB research.

The top three funding sources were from the USA, the fourth from China and the fifth from Europe. The UN had proposed increasing funding to 2 billion \$ annually from 2018 to 2022, of which not even half was met.^[3] This shows there is a need to increase funding globally to meet targets.

Most of the top-cited articles were published in high-impact factor (IF) journals, such as The Lancet and the New England Journal of Medicine; thus, these articles may have higher citations not necessarily because they were of high quality, but rather because they were published in high IF journals. Twelve of the 20 top-cited articles were on the prevention, diagnosis, and treatment of TB. This shows that articles targeting the management of TB are highly sought after.

Rather unusual is the fact that, none of the first authors of the top 20 most cited articles were in the top 20 productive authors list. Zhan Y and Wang J from the USA were two of the most prominent hotspots on the author collaboration network and had worked with each other significantly. The third-most prolific author Wang Y was from the UK, which may be why there was no significant collaboration with the top 2. Another interesting finding was that the top 20 authors had contributed almost 8% of the total TB research in the last decade.

The USA led TB research globally, as seen in the previous bibliometric analyses, but its share decreased from 24.1% in 1997–2006 to 18.4% in 2007–2016 to 16% in 2011–2020.^[21,34] The top five most productive countries make up almost half of the global production of TB articles [Table 3] and share almost 38.5% of the global TB burden. However, out of the top 20 countries with corresponding authors, only seven were from high-burden countries. The high-burden countries present in the top corresponding author list make up 48% of the global TB burden and 42% of the contribution to articles. India led with 26.4% burden, and 12% global contribution, China with 8.3% of global burden and 15% of contribution, Pakistan with 5.7% of burden and 2% of contribution, South Africa with 3.6% of the burden and 4% of contribution, Brazil with 0.96% of burden and 4% of contribution, Korea with 1.32% of burden and 3% of contribution, and Ethiopia with 1.57% of contribution and 2% production. This shows that Pakistan and India have a greater burden than their contribution to research and, therefore, need to put in more effort. Furthermore, much work is required

from other high-burden countries, especially Indonesia, Philippines, Bangladesh, and Nigeria, as these countries are in the top eight highly burdened countries, but are not in the top 20 corresponding authors list.

China and India showed more SCP, which was almost five times more than MCP. In comparison, the USA and the United Kingdom had SCP almost equal to MCP. Only five out of the top 20 countries had MCP more than SCP. This shows that there is still room for improvement in global collaboration to increase MCPs, especially from India and China.

The University of Cape Town was the most frequent affiliation worldwide, leading TB Research globally. It was also ranked number 13 in infectious diseases by the US News and World Report Best Global Universities Rankings for Subjects 2021.^[35] The third-most common affiliation, London School of Hygiene and Tropical Medicine, was fourth in infectious diseases.^[35] This shows that these institutions not only focus on TB but also other infectious diseases.

Furthermore, a study by Igwaran and Edoamodu, on research trends in Africa also showed the University of Cape Town as the most common affiliation, thus supporting our findings.^[19] Of the top eight high-burden countries, only South Africa, China, and India were present in the top 20 institutional affiliations. The remaining high-burden countries need to conduct more TB research in their institutions.

Only five of the top 30 high-burden countries, namely, South Africa, India, China, Brazil, and Uganda, had ten or more international collaborations. This further shows that more global collaboration is required, especially from the top eight high burdens that did not make the list, such as Pakistan, Bangladesh, Philippines, Indonesia, and Nigeria.^[3] The institutional collaboration cluster showed that two clusters were dominated by the USA institutions and one by South Africa [Figure 3] and only 6 out of the top 20 institutions belonged to the high-burden countries.

To the best of our knowledge, this is the only study that has tracked global TB research in the last decade. We made a comprehensive trends analysis, listed the top corresponding authors, country-wise contributions, frequent affiliations, and top-cited articles.

The limitations of our study were that we only included articles in English and used only WoS database. Newer, higher quality articles would not have been cited as much, so their analysis may not be representative of their quality. Using corresponding author affiliation as the source country of research production is also

not always accurate as the corresponding author may be from a country different from where the research is being conducted.

More such global and regional bibliometric studies on TB and other infectious diseases along with further in-depth exploration can be beneficial. Besides, as TB affects every continent, a collaborative research effort is very necessary.

More importantly, we recommend more research output and collaboration by high-burden countries with more corresponding authors from those countries.

Conclusion

This bibliometric analysis describes salient trends in global TB research from 2011 to 2020. There has been an increasing trend in article production over the last decade. High-income, low-burden countries, such as the USA and the UK have led the global output, but what is gratifying is that high-burden countries such as South Africa, China, and India were also in the top five involved in TB research. However, of the top 20 corresponding authors, only seven were from high-burden countries, suggesting that most of the high-burden countries still need to be supported to contribute more. Furthermore, only five high-burden countries were present in the top 30 collaborations.

The findings of this study are critical in progress toward the SDGs and the WHO End TB strategy.

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Conflicts of interest

There are no conflicts of interest.

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