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A Bibliometric Analysis on Tuberculosis Research of Korea from 1979 to 2017

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The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Yim JJ. Data curation: Lee HW. Formal analysis: Lee HW, Yim JJ. Investigation: Lee HW, Yim JJ. Methodology: Lee HW. Software: Lee HW. Supervision: Yim JJ. Writing - original draft: Lee HW. Writing - review & editing: Yim JJ.

ABSTRACT

Background: The prevalence, incidence, and mortality rates of tuberculosis (TB) have declined steadily in Korea since 1965. This study aimed to identify the characteristics and provide quantitative analysis of published medical literatures on TB written by researchers based in Korea.

Methods: We conducted a systematic literature search via the Web of Science database for articles in Science Citation Index (Expanded) journals, on TB, and published by researchers based in Korea, from inception to 2017. All articles were analyzed by publication year, publishing journal, article type, study design, research institutes, and research funds.

Results: During the study period, we identified 1,101 articles and included them for analysis. The first was published in 1979, while 105 were published in 2017. Between 1979 and 2017, the compound annual growth rate of TB articles by researchers based in Korea was 13.0%. Among 1,101 articles, 682 (61.9%) were clinical research and 383 (34.8%) were basic research. Studies with cross-sectional design were the most common type among the clinical research, while biochemistry was the most common field among the basic research. The number of articles dealing with diagnostics or treatment has increased significantly, although the number of articles on vaccines, and on operational and public health, has only a slight increase. The Ministry of Health and Welfare of Korea funded studies yielding 178 (20.1%) articles.

Conclusion: Articles on TB, especially those on clinical aspects, and published by researchers based in Korea have been increasing rapidly since 1979.

Keywords: Bibliometric Analysis; Tuberculosis; Research Design; Research Subjects; Journal Impact Factor; Publications

INTRODUCTION

Although tuberculosis (TB) is widely recognized as a disease of the past, annually published research on TB has increased steadily.¹ There are still unresolved obstacles in fully eradicating TB as an epidemic and public health problem.² No better vaccines have yet been developed,^{3,4} it is challenging to interrupt transmission,⁵ and TB is often detected late.⁶ Treatment of TB has become more complicated because of resistance to multiple anti-TB drugs⁷ and frequent co-infection with the human immunodeficiency virus.⁸

Since the first nationwide TB survey in 1965, the prevalence, incidence, and mortality rates of TB in Korea have declined steadily.^{9,10} Meanwhile, Korea has served as one of the leading contributors to the global scientific knowledge on TB. From 2007 to 2016, researchers in Korea published 885 articles, which comprised 2.6% of all articles on TB published worldwide.¹

Bibliometric analysis has increasingly been used to derive quantitative results for overall understanding of published articles.¹¹ By using computer-driven methods to extract and manipulate data from articles, content or citation analysis can be conducted to deal with the huge increase of scientific publications.¹² This study aimed to use bibliometric analysis to identify the characteristics and provide a quantitative analysis of published scientific literature on TB and performed by researchers based in Korea.

METHODS

Information sources and search strategies

We conducted a systematic literature search of the Web of Science database to obtain detailed bibliographic information of articles on TB and based at research institutes in Korea, from inception to December 31, 2017 (search date: July 19, 2018). Missing information was resolved through referring to other databases, including MEDLINE, Embase, Google Scholar, and individual journal websites. Information on category and 5-year impact factors (2017) of each journal was acquired from the citation database of the 2017 Journal Citation Reports. The search for the targeted references was conducted in the fields for titles, abstracts, keywords, and indexes, using the following terms: “tuberculosis,” “tuberculous NOT non-tuberculous,” “TB,” or “mycobacteri*.” We used the term “Korea” in the country fields to search for articles published by researchers based in Korea. The search was restricted to articles published in Science Citation Index (Expanded)—SCI(E)—journals registered in the Web of Science Core Collection.

Article selection

We selected articles on TB research by reading the title, index, and abstract. Full text review was conducted if there was any ambiguity. Articles with a corresponding author based at an institute in Korea were included in the analysis. Articles with more than one corresponding author were included if one of those authors was based at an institute in Korea. We excluded articles focusing on nontuberculous mycobacteria rather than TB. Studies in any language were acceptable and no limitations were applied on document types.

Collected items

We collected the following bibliographic information for each article: first and corresponding authors, publication year, publishing journal name, journal category, 5-year impact factor (2017) of publishing journal, article type, study design, research area, total citations, citations per year, research institute, and research funding. Articles published in journals for which the 5-year impact factor (2017) was not available were excluded from the analysis.

Article classification

Types of research were classified based on methods in previous reports.^{13,14} They were classified into three article types: basic, clinical, or secondary research. Study designs of articles included: basic research including animal study, biochemistry, cell study, genetic engineering or gene sequencing, genetic study, and material development; clinical research

including before and after study, case-control study, case report, case series, cross-sectional study, non-comparative study, prospective cohort study, randomized controlled trial, and retrospective cohort study; secondary research including review and systematic review with meta-analysis. Unclassifiable articles were grouped into “others.” Six classifications of research areas were used, in accordance with the International Roadmap for TB Research¹⁵; these were fundamental research, epidemiology, diagnostics, treatment, operational and public health research, and vaccines. Unclassifiable articles were grouped into “others.”

Analysis

The main analysis was to elucidate a trend in annually published articles on TB by research area. We then clarified the number of published articles and the total citations by article type or study design. The number of research institutes and amounts of funding were evaluated by research area. The publishing journals' 5-year impact factors (2017) were calculated and classified by article type and citations per year. We also evaluated the features of the 20 most-common academic journals that published the articles, their 5-year impact factor (2017), and their journal category. We listed the top three research institutes that contributed to published articles and were based in Korea by research area. Additionally, we described the 20 most-cited original articles.

Categorical variables were expressed as numbers and percentages. In continuous variables, the number of citations was described as median values with their range because of skewed distribution. A Cox-Stuart test was used for analysis examining whether an increasing or decreasing trend existed in a time series.¹⁶ All analyses were performed using R version 3.4.0 statistical computing software (R Core Team, Vienna, Austria).

Ethics statement

Ethical approval and consent to participate were not required because this study was designed as a bibliographic analysis of published articles.

RESULTS

Article selection

The search for relevant articles published in SCI(E) journals and using the pre-defined terms identified 181,924 records. Among these, 1,931 were published by researchers based in Korea. After reviewing the titles, indexes, and abstracts of the 1,931 articles, we excluded 830 that did not focus on TB, of which, 403 were related mainly with nontuberculous mycobacterial infection. Ultimately, 1,101 articles were included in the present analysis (Fig. 1).

Annual numbers of published articles

The first relevant TB article was published in 1979¹⁷ and the next in 1987.¹⁸ From 1990, the number of such articles by researchers based in Korea increased rapidly. The annual number peaked in 2015, at 119, and the compound annual growth rate (CAGR) of articles from 1979 to 2017 was 13.0%. Notably, the number of articles dealing with diagnostics or treatment of TB increased significantly and rapidly (CAGR = 15.3%; $P < 0.001$) while the number of articles on vaccines and on operational and public health, increased relatively slowly (CAGR = 2.8%; $P = 0.011$) (Fig. 2). **Supplementary Table 1** lists the 20 academic journals in which articles on TB were published most frequently.

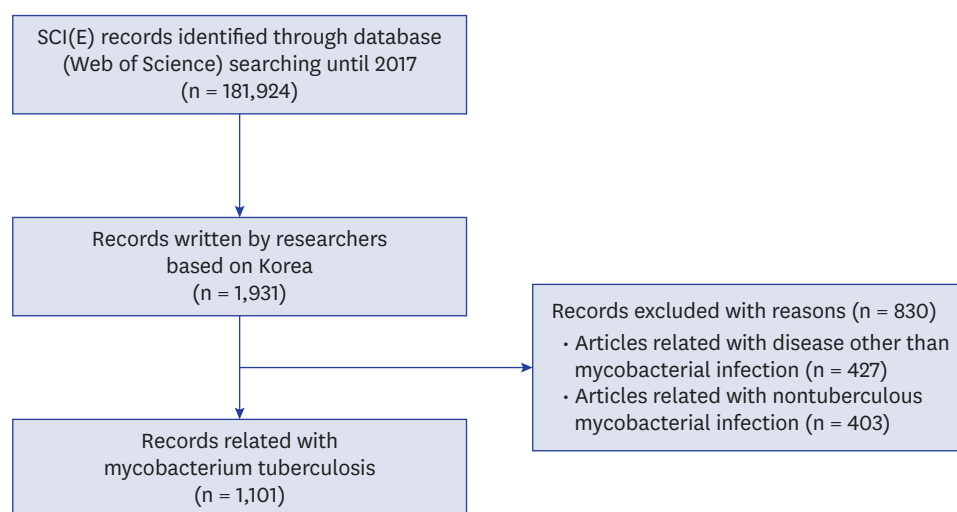


Fig. 1. Flowchart of study inclusion for the bibliometric analysis.

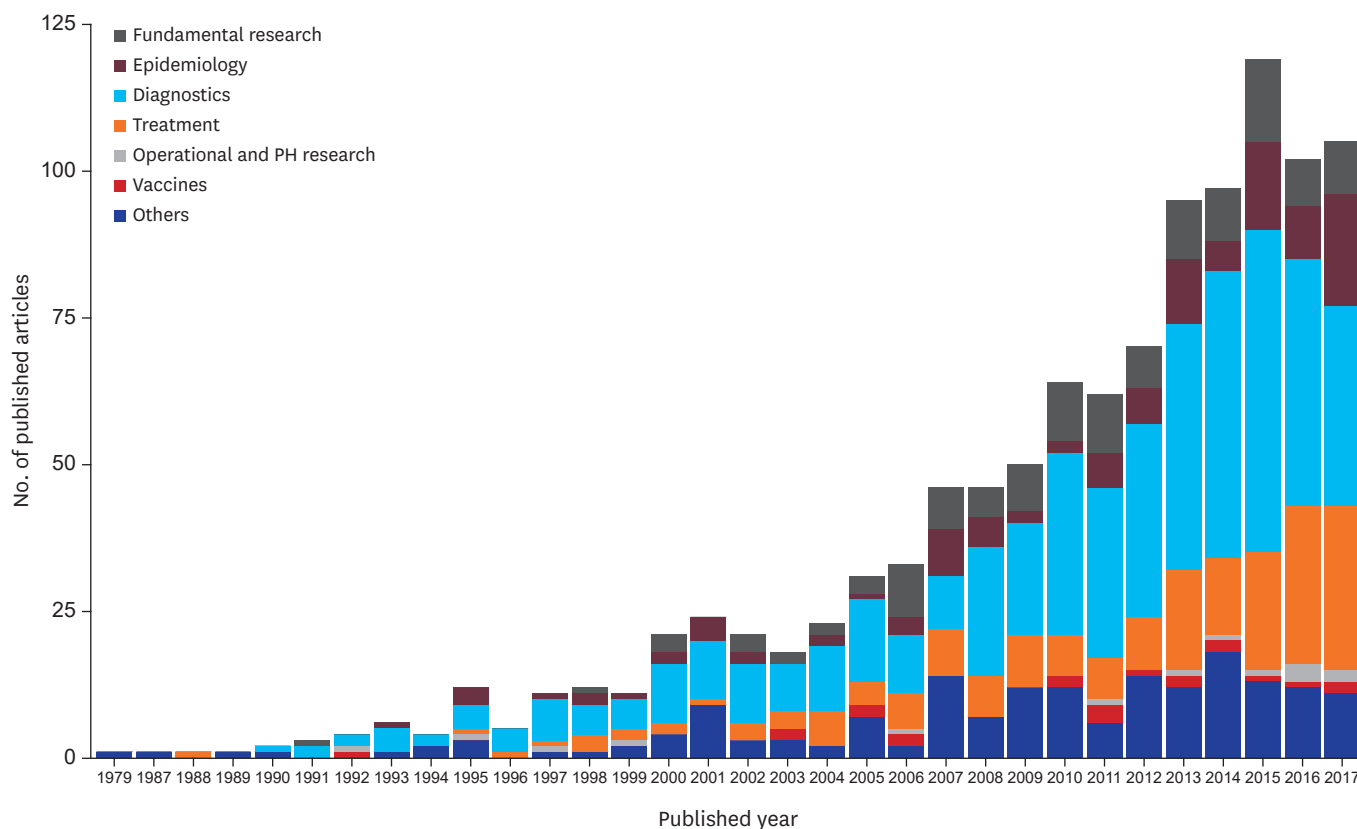


Fig. 2. Articles published annually on mycobacterium tuberculosis infection between 1979 and 2017 and based in Korea, by research area.

Types and areas of research

Among the 1,101 selected articles, 383 (34.8%) were basic research and 682 (61.9%) were clinical research. Among the former, biochemistry was the most common theme (146/383; 38.1%) (Table 1 and Fig. 3A). Biochemistry, genetic study, and cell study accounted for 75.6% (301/383) of all basic research, while genetic engineering/gene sequencing, animal study, and

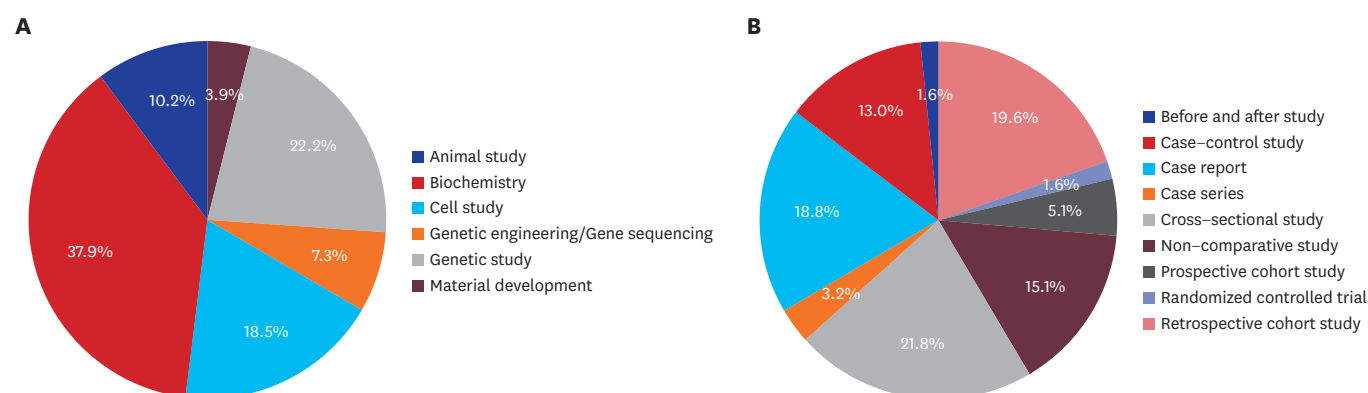


Fig. 3. Percentage of articles by study design in basic research and clinical research. The most common study design was biochemistry in basic research (**A**) and cross-sectional study in clinical research (**B**).

Table 1. Number of articles on mycobacterial tuberculosis infection by article type and study design and based in Korea, 1979–2017

Article type	Study design	Total number of articles (%)	Number of total citations, median (range)
Basic research	Biochemistry	145 (13.2)	7 (0–186)
	Genetic study	85 (7.7)	11 (0–94)
	Cell study	71 (6.4)	9 (0–380)
	Genetic engineering/Gene sequencing	28 (2.5)	6 (1–98)
	Animal study	39 (3.5)	5 (0–103)
	Material development	15 (1.4)	3 (0–73)
Clinical research	Cross-sectional study	149 (13.5)	8 (0–219)
	Retrospective cohort study	134 (12.2)	8 (0–155)
	Case report	128 (11.6)	2 (0–40)
	Non-comparative study	103 (9.4)	17 (0–244)
	Case-control study	89 (8.1)	6 (0–109)
	Prospective cohort study	35 (3.2)	12 (0–324)
	Case series	22 (2.0)	6.5 (0–41)
	Before and after study	11 (1.0)	3 (0–17)
	Randomized controlled trial	11 (1.0)	12 (0–274)
Secondary research	Review	17 (1.5)	14 (0–168)
	Systematic review with meta-analysis	1 (0.1)	4 (-)
Others	Editorial	9 (0.8)	1 (0–2)
	Letter	4 (0.4)	1 (0–3)
	Correction	4 (0.4)	0 (0–1)
	Reply	1 (0.1)	0 (-)

material development were less actively studied. Among clinical research, cross-sectional studies were most common (149/682; 21.8%) (**Fig. 3B**). Original investigations in clinical research were mainly conducted with retrospective study designs (475/682; 69.6%) including cross-sectional study, retrospective cohort study, non-comparative study, and case-control study. Prospective cohort study, before and after study, and randomized controlled trial were less-utilized methods. Additionally, case reports were actively published, and the sum of case reports and case series showed the largest portion in clinical research (150/682; 22.0%). Review articles were most common (17/18; 94.4%) among secondary research and editorial (9/18; 50.0%) was most common among “others.”

Institutes and funding sources

In total, 78 research institutes based in Korea contributed to TB research; **Table 2** lists the top 20 publishing institutes by research area. Seoul National University (184 studies; 16.7%), Yonsei University (136; 12.4%), and Ulsan University (98; 8.9%) were the top three

Table 2. Research institutes that most commonly published articles on mycobacterial tuberculosis infection and based in Korea, 1979–2017

Research institutions	Fundamental research	Epidemiology	Diagnostics	Treatment	Operational and public health research	Vaccines	Others	Total, No. (%)
Seoul National University	10	20	98	37	1	2	16	184 (16.7)
Yonsei University	18	12	63	10	0	11	22	136 (12.4)
University of Ulsan	1	12	52	24	0	0	9	98 (8.9)
Sungkyunkwan University	6	6	40	25	0	1	11	89 (8.1)
Chungnam National University	42	1	16	5	0	1	3	68 (6.2)
The Catholic University of Korea	2	7	15	5	1	0	23	53 (4.8)
Pusan National University	6	2	27	0	1	1	11	48 (4.4)
Korean Institute of Tuberculosis	0	16	17	6	6	1	0	46 (4.2)
Hanyang University	4	4	11	9	0	0	3	31 (2.8)
Kyungpook National University	6	3	11	6	0	0	4	30 (2.7)
Korea University	3	3	12	2	0	0	6	26 (2.4)
Chonnam National University	4	1	5	4	0	1	8	23 (2.1)
Kyung Hee University	1	2	7	4	0	0	7	21 (1.9)
Soonchunhyang University	1	0	6	11	0	0	1	19 (1.7)
Hallym University	2	0	14	0	0	0	2	18 (1.6)
Konkuk University	4	0	8	2	2	1	1	18 (1.6)
Gyeongsang National University	1	1	6	5	0	0	3	16 (1.5)
Inje University	0	1	8	1	0	0	5	15 (1.4)
Ajou University	0	1	7	0	0	0	3	11 (1.0)
Chung-Ang University	0	1	7	1	0	0	0	9 (0.8)
Total, No. (%)	121 (11.0)	110 (10.0)	474 (43.1)	186 (16.9)	14 (1.3)	21 (1.9)	175 (15.9)	1,101 (100)

in total number of publications. Apart from this result, research institutes contributed to specific fields (**Supplementary Table 2**). Seoul National University published more papers on epidemiology (20/110; 18.2%), diagnostics (98/474; 20.7%), and treatment areas (37/186; 19.9%). Chungnam National University published many articles in the fundamental research area (42/121; 34.7%). The Korean Institute of Tuberculosis was the leading research institute in operational and public health research (6/14; 42.9%). Over half of the vaccine research was conducted at Yonsei University (11/21; 52.4%).

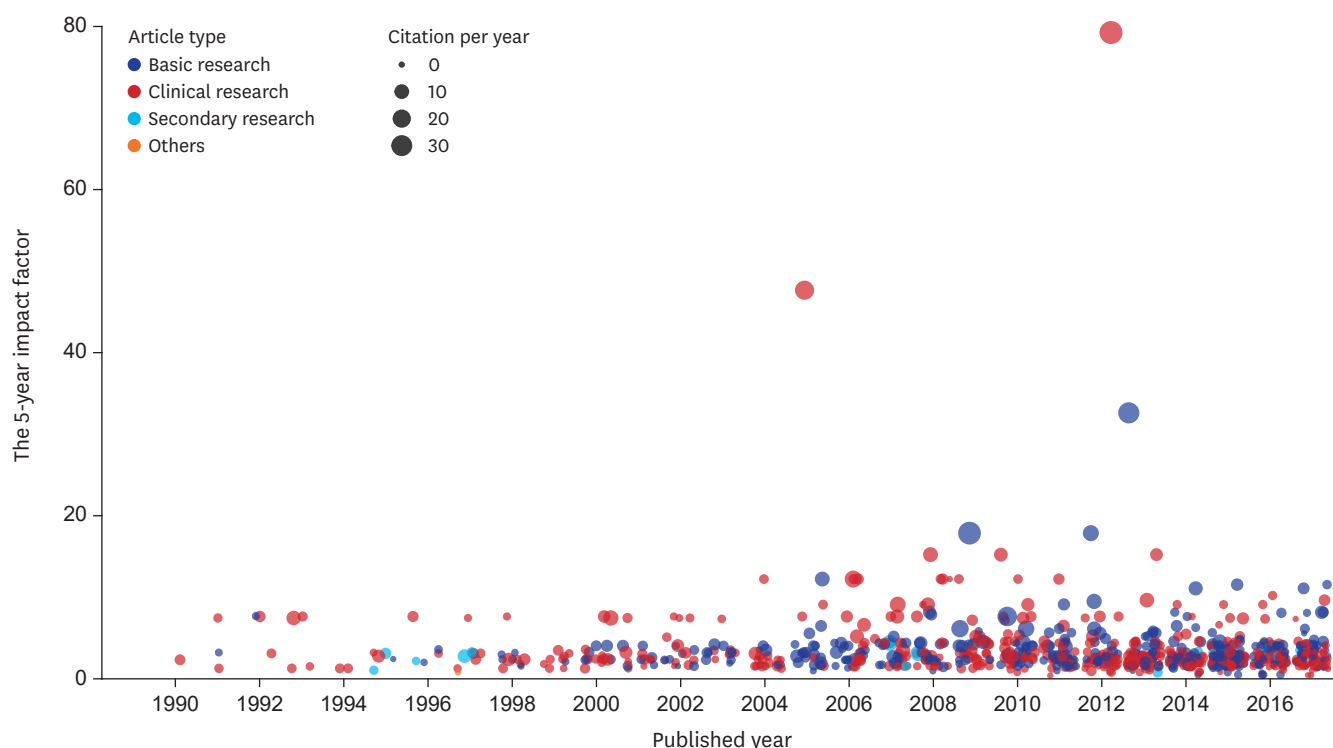
A total of 886 funding sources were acknowledged in 543 (49.3%) articles. Sources of domestic research funding, ranked from first to fourth, were the Ministry of Health and Welfare, National Research Foundation, Ministry of Education, Science, and Technology, and Ministry of Science, Information and Communication Technology, and Future Planning; these accounted for 55.0% of all reported funding. Most research funding focused on fundamental research, diagnostics, and treatment, making up 84.4% of the total (**Table 3**).

Impact of published articles

Median value of total citation number of the articles published in SCI(E) journals written by researchers based in Korea was 7. The two most-cited articles were: 1) a basic research with 380 citation times which revealed the fundamental mechanism on antimycobacterial defenses¹⁹ and 2) a clinical study with 324 citations on accuracy of interferon-gamma release assay for the diagnosis of latent TB infection.²⁰ As the number of total published articles increased, the number of those published in journals with high 5-year impact factors also increased (**Fig. 4**). From 2005, articles with more citations per year began to increase. The median value of total citations was highest in genetic studies (11; range, 0–94) among basic research, and in non-comparative studies (17; range, 0–244) among clinical research. Among seven research areas, the median value of total citations was highest in fundamental research (10; range, 0–380) and vaccine studies (10; range, 0–52). **Supplementary Table 3** lists top 20 published original articles in terms of highest number of citations.

Table 3. Research funds that most commonly contributed to published articles on mycobacterium tuberculosis infection and based in Korea, 1979–2017

Research funds	Fundamental research	Epidemiology	Diagnostics	Treatment	Operational and public health research	Vaccines	Others	Total, No. (%)
Ministry of Health and Welfare	33	10	89	36	1	7	2	178 (20.1)
National Research Foundation	49	11	46	25	2	9	4	146 (16.5)
Ministry of Education, Science, and Technology	33	3	30	16	6	4	1	93 (10.5)
Ministry of Science, Information and Communication Technology, and Future Planning	17	2	13	18	1	1	1	53 (6.0)
U.S. National Institutes of Health/National Institute of Allergy and Infectious Disease	8	1	10	2	1	2	0	24 (2.7)
Seoul National University Hospital	2	1	12	8	1	0	0	24 (2.7)
Yonsei University	1	3	9	2	0	4	1	20 (2.3)
Korea Health Industry Development Institute	1	1	7	6	0	1	0	16 (1.8)
Korea Science and Engineering Foundation	7	0	4	0	0	2	1	14 (1.6)
Korea Centers for Disease Control and Prevention	0	4	8	1	0	0	0	13 (1.5)
Bk21 Plus Project for Medicine, Dentistry, and Pharmacy	5	0	3	3	0	1	0	12 (1.4)
Pusan National University Hospital	3	1	4	0	0	0	3	11 (1.2)
Korean Academy of Tuberculosis and Respiratory Diseases	2	2	4	2	0	0	0	10 (1.1)
Asan Institute for Life Sciences	0	0	7	2	0	0	0	9 (1.0)
Chungnam National University	4	1	0	3	0	1	0	9 (1.0)
Korea Research Foundation	1	0	6	1	0	1	0	9 (1.0)
Korean Food and Drug Administration	1	1	1	2	0	0	4	9 (1.0)
Soonchunhyang University	0	0	3	6	0	0	0	9 (1.0)
Konkuk University	0	0	6	1	1	0	0	8 (0.9)
Samsung Medical Center	0	1	2	5	0	0	0	8 (0.9)
Total, No. (%)	195 (22.0)	57 (6.4)	365 (41.2)	188 (21.2)	18 (2.0)	38 (4.3)	25 (2.8)	886 (100)


Fig. 4. Five-year impact factor of journals in which articles on tuberculosis and by researchers based in Korea were published between 1979 and 2017.

DISCUSSION

Bibliometric analysis showed the number of publications on TB and by researchers based in Korea has been steadily increasing since the 1990s. Among a total of 1,101 articles, 682 (61.9%) were from clinical research and 383 (34.8%) from basic research. Marked growth was observed in the field of diagnostics and treatment. Additionally, articles cited more frequently and published in journals with higher impact factors occurred more commonly during the last 20 years.

The most noteworthy result of this study is that the output of TB research based in Korea has increased rapidly over the past two decades, and this increase rate was higher than that of international research on TB.¹ In fact, previous bibliometric analyses of publications up to 2016 showed Korea's publications on TB rose from 14th in 2006 to eighth between 2007 and 2016.^{1,21} The rapid growth in the field of diagnostics and treatment of TB in Korea seems to reflect increasing investment in TB research,^{22,23} as well as the considerable TB burden in Korea.⁹

This study showed that publication of research on diagnostics (43.1%) and treatment (16.9%) based in Korea has been increasing rapidly, while the numbers of articles on operational and public health research (1.3%), and vaccines (1.9%) have only a slight increase. In fact, the proportion of published articles on operational and public health research in Korea was 10 times lower than the global proportion.¹

The difference in the number of published articles by research area was closely related to the amount of research funds. In Korea, domestic funding for TB research was the largest source of funding. Most notably, governmental funds from the Ministry of Health and Welfare, National Research Foundation, Ministry of Education, Science and Technology, and Ministry of Science, Information and Communication Technology, and Future Planning accounted for more than half of all funds reported. However, such domestic funding for TB research in Korea is still limited. Although the total expenditure for research and development as a percentage of gross domestic product ranked first globally in 2015,²⁴ Korean governmental investment in TB research ranked 18th among all countries. Additionally, domestic research funding in Korea mainly supported articles in the diagnostics area, while investment in research in the operational and public health field fell short of international levels.^{23,24} Given that investment in research contributes to control of specific diseases,²⁵ the Korean government should more actively invest in TB research to reduce the burden of this disease.

To best interpret the results of our study correctly, several limitations should be taken into account. The ranking of research institutes does not reflect research quality because it is based solely on the number of publications, not on study quality or impact.²⁶ Additionally, we could only take frequency of funding into account, but could not elucidate the amount of funding. A different trend may be seen if information on the size of funding were available. Finally, although we used total citations and citations per year to evaluate study quality, there is criticism that citations may not reflect research quality.²⁷

In conclusion, articles in both fundamental and clinical aspects of TB, and published in SCI(E) journals by researchers based in Korea, have been increasing rapidly since 1979. These articles have been cited more frequently and have been more commonly published in journals with higher impact factors. Our comprehensive and systematic analysis of published literatures on TB by the researchers based in Korea highlighted the importance of the funding for TB research.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

Twenty most-common academic journals for published articles on mycobacterial tuberculosis infection and based in South Korea, 1979–2017

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Supplementary Table 2

Research institutes in Korea that most commonly published articles on mycobacterial tuberculosis infection, by research area

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Supplementary Table 3

The 20 most-cited original research articles on tuberculosis and by researchers based in Korea

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