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# Trends in Latent Tuberculosis Infection Among Healthcare Workers Over the Past Three Decades: A Comprehensive Bibliometric Analysis

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**KEYWORDS**

Latent Tuberculosis, Healthcare Workers, Bibliometric,Study Trends.

**ABSTRACT:**

**Introduction**: Latent Tuberculosis Infection (LTBI) is a health problem reported to affect approximately one-quarter of the global population, but the infection has not received adequate attention.

**Objectives**: This bibliometric analysis aims to explore the perspectives of LTBI in healthcare workers (HCWs) through a comprehensive bibliometric analysis of publications from 1995 to 2024, focusing on journal articles and reviews, influential countries, and authors.

**Methods**: A bibliometric analysis was conducted using the Scopus database, searching for publications related to LTBI in HCWs. The analysis included publication trends, citation patterns, co-authorship, institutional and country contributions, co-occurrence of keywords, and reference co-citation.

**Results**: A total of 281 publications were identified, comprising 254 articles and 27 reviews. Over time, the number of publications showed a fluctuating but generally increasing trend, with an annual growth rate of 3.86%. Additionally, the United States, South Korea, and Italy were the top contributing countries. The PLOS ONE journal had the highest number of publications (29) and citations (577). The most frequently used keywords were "human" and "healthcare personnel." Collaboration network analysis showed substantial international collaboration, signifying a strong global effort to address LTBI in HCWs.

**Conclusions**: This bibliometric analysis showed that research on LTBI in HCWs grew over the past three decades. Although publication numbers fluctuated, the general increasing trend suggested the significance of this issue in healthcare sector. The observed international collaborations further reflected the global effort made to combat LTBI in healthcare settings. Continued research and attention to LTBI among HCWs are essential to inform policy and practice.

## 1. Introduction

Tuberculosis (TB) is a persistent global health threat, as stated by World Health Organization (WHO) in 2023.[1,2] Despite significant efforts to control and reduce TB incidence, it remains a leading cause of morbidity and mortality worldwide.[3,4] To mitigate the future incidence of pulmonary TB, current strategies focus on identifying cases of latent tuberculosis infection (LTBI).[5–7] Moreover, LTBI cases are characterized by asymptomatic individuals with normal chest radiographs and positive results from Interferon-Gamma Release Assays (IGRA) or the Tuberculin Skin Test (TST).[8–11]

Healthcare workers (HCWs) are particularly at risk of LTBI due to the increased exposure to TB patients.[12–14] Understanding the prevalence and dynamics of LTBI among HCWs is crucial for developing effective prevention and control strategies.[15] Despite the significance of this issue, comprehensive reviews systematically analyzing the existing literature on LTBI in HCWs are lacking.[16–19]

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To achieve a more comprehensive understanding of global LTBI prevalence, new theories and methods are essential for LTBI research. This target can be fulfilled through bibliometrics, a scientific discipline that applies mathematical and statistical methods to examine quantitative relationships and development laws in knowledge areas, including documents and information systems.[20–22] Additionally, bibliometrics incorporates the exploration of the dynamic characteristics of science. As a relatively new literature review method, bibliometric analysis evaluates research activity trends using both qualitative and quantitative methods based on information provided by databases. This helps in understanding the development of specific fields and provides a basis for comparing contributions across different levels.[23,24]

Bibliometric methods can be used to examine the number of publications as well as identify influential publications, authors, journals, organizations, and countries.[25,26] Therefore, these methods were applied in conducting a statistical analysis of English literature related to LTBI among HCWs from 1995 to 2024.

The objectives of this analysis included (1) examining the global trends and developments in LTBI research, (2) assessing the contributions and collaborations among different countries, institutions, and journals, as well as identifying the most influential publications. (3) Evaluating the most productive and influential authors in LTBI research, (4) uncovering the primary research themes and focus areas through keyword analysis, and (5) identifying potential future directions and new trends in LTBI research.

## 2. Method

### *Data Sources and Search Strategy*

Relevant literature on LTBI in HCWs published between 1995 and 2024 was obtained from the Scopus database during this analysis. Furthermore, the search terms used included combinations of keywords such as "latent tuberculosis," OR "LTBI," AND "healthcare worker," OR "HCWs." The search process conducted was restricted to peer-reviewed journal articles and reviews written in English. Additionally, exclusion criteria were set to eliminate publications unrelated to LTBI in HCWs or those outside the specified time frame.

### *Data Collection*

The data collection process included a comprehensive search of the Scopus database using the defined keywords. Initial search results were screened based on titles and abstracts to identify relevant publications.[23] Subsequently, full-text articles were reviewed to ensure meeting the inclusion criteria. Extracted data comprised publication year, article type (journal article or review), author names, institutional affiliations, country of origin, journal name, and keywords.[27,28]

### *Bibliometric Analysis*

Bibliometric analysis was conducted using VOS viewer, Tableau, R Studio, and Bibliometrix. The analysis focused on various metrics such as publication trends, citation patterns, co-authorship networks, co-occurrence of keywords, and reference co-citation. Publication trends were analyzed to determine the annual growth rate of LTBI research in HCWs. Citation analysis identified the most frequently cited articles and influential journals. Co-authorship networks were mapped to show collaboration patterns among authors, institutions, and countries. Additionally, keyword co-occurrence analysis helped identify prominent research themes and topics in LTBI literature.

### *Statistical Analysis*

Statistical methods were used to analyze trends and patterns in bibliometric data. Furthermore, the annual growth rate of publications was calculated to assess the increase in research activity over time. The extent of international cooperation among research teams was examined through collaboration network analysis. Statistical tests were conducted to determine the significance of observed trends and patterns in the data.

**Figure 1** shows a schematic representation of bibliometric workflow, spanning from data sourcing and collection to analysis and interpretation. This workflow comprises various processing steps, including database search, screening and selection of relevant publications, data extraction, as well as bibliometric and statistical analysis.

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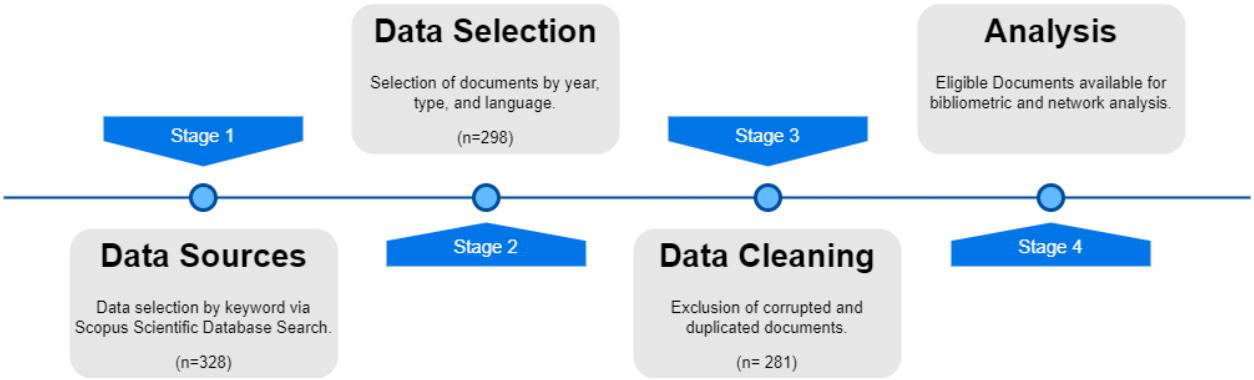


**Figure 1**. Workflow of Bibliometric Analysis Process

## 3. Results

**Table 1** presents an overview of key data regarding LTBI research from 1995 to 2024. Furthermore, bibliometric analysis covered 281 documents from 143 sources (journals), reflecting a substantial volume of research activity with an annual growth rate of 3.86%. The documents have an average age of 7.57 years and 17.48 citations each, signifying the level of impact and relevance possessed. The dataset comprised 8048 references, 1692 Keywords Plus (ID), and 1670 authors, with an average of 7.28 co-authors per document and 29.89% international co-authorship, representing significant global collaboration. Most documents were research articles (254), with a smaller portion of review papers (27), showing the strong focus of the field on original results.

### Publication Trends

**Figure 2** shows the trends in LTBI research publications and average citations per year among HCWs from 1995 to 2024. The number of publications significantly increased from 2007, reaching peak levels in 2010, 2012, and 2016. Meanwhile, average citations fluctuated per year, with significant peaks corresponding to the high publication years, reflecting intensified research activity and the impact on the field.

**Table 1.** Main information regarding LTBI research from 1995 to 2024

| Description | Results |
|---|---|
| **MAIN INFORMATION ABOUT DATA** | |
| Timespan | 1995:2024 |
| Sources (Journals, Books, etc.) | 143 |
| Documents | 281 |
| Annual Growth Rate % | 3.86 |
| Document Average Age | 7.57 |
| Average citations per doc | 17.48 |
| References | 8048 |
| **DOCUMENT CONTENTS** | |
| Keywords Plus (ID) | 1692 |
| Author's Keywords (DE) | 385 |
| **AUTHORS** | |
| Authors | 1670 |
| Authors of single-authored docs | 9 |

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| | |
|---|---|
| **AUTHORS COLLABORATION** | |
| Single-authored docs | 9 |
| Co-Authors per Doc | 7.28 |
| International co-authorships % | 29.89 |
| **DOCUMENT TYPES** | |
| article | 254 |
| review | 27 |

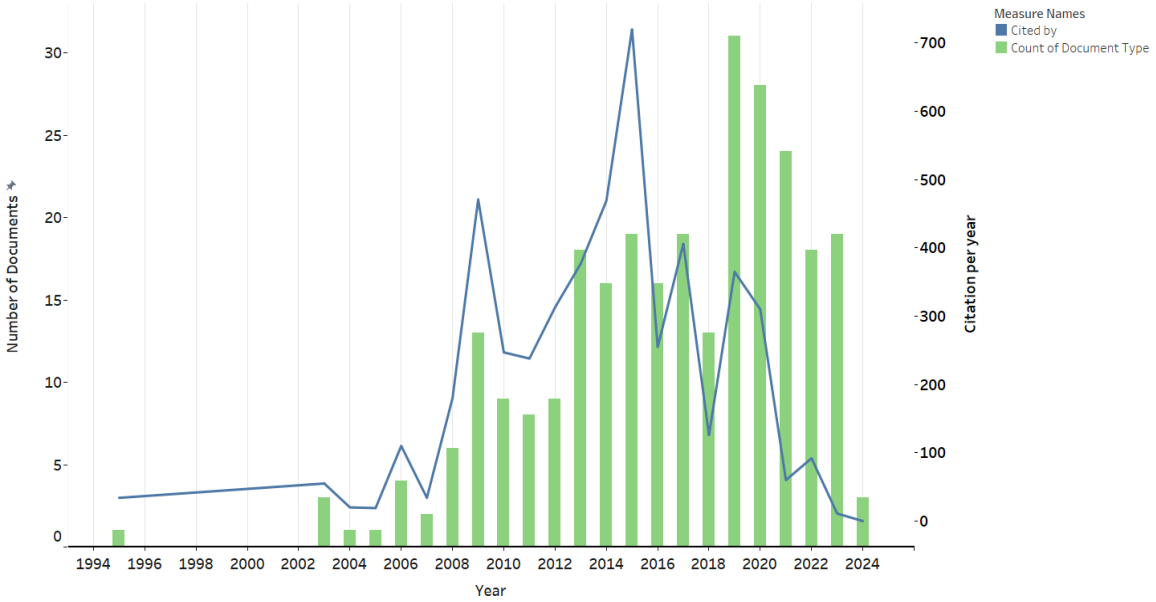


**Figure 2.** Documents and average citations on LTBI research in HCWs from 1995 to 2024

***Analysis of Contribution in Different Countries***

**Figure 3** shows the global scientific production on LTBI research from 1995 to 2024, presenting the contributions of the United States leading with 58 publications, followed by South Korea (32), the United Kingdom (24), Canada (23), Brazil (11), China, and Australia (14). Several other countries also provided significant contributions, and this distribution suggested LTBI research as a globally recognized issue.

The top five contributing countries based on citation include the United States, South Korea, Italy, China, and the United Kingdom, which present a significant trend over time. The United States shows a steep and continuous rise in citations, specifically after 2007, consistently maintaining the lead all through the period. This analysis shows the dynamic and increasing global collaboration and research efforts to tackle LTBI, with the leading countries driving significant advancements in the field.

***Analysis of Journal Contributions***

**Table 2** presents the top ten journals that published the highest number of articles on LTBI. PLOS ONE led with 29 documents and a total of 577 citations, averaging 19.90 citations per document. Infection Control and Hospital Epidemiology followed with 22 documents and 429 citations, averaging 19.50 citations per document. BMC Infectious Diseases published 10 articles with 223 total citations, achieving the highest average citations per document at 22.30. The Hospital Infection and European Respiratory Journal both provided substantial contributions, with the latter owning the highest total citations at 682 despite publishing fewer documents. Additionally, the Journal of Occupational Medicine and Toxicology, Scientific Reports, Clinical Infectious Diseases, International Journal of Environmental

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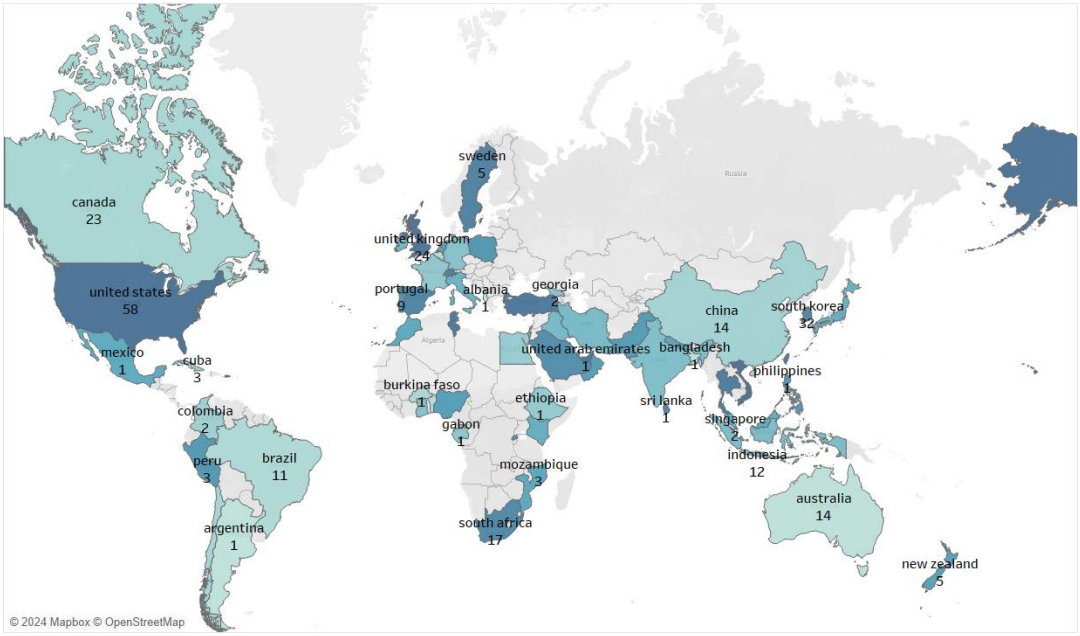
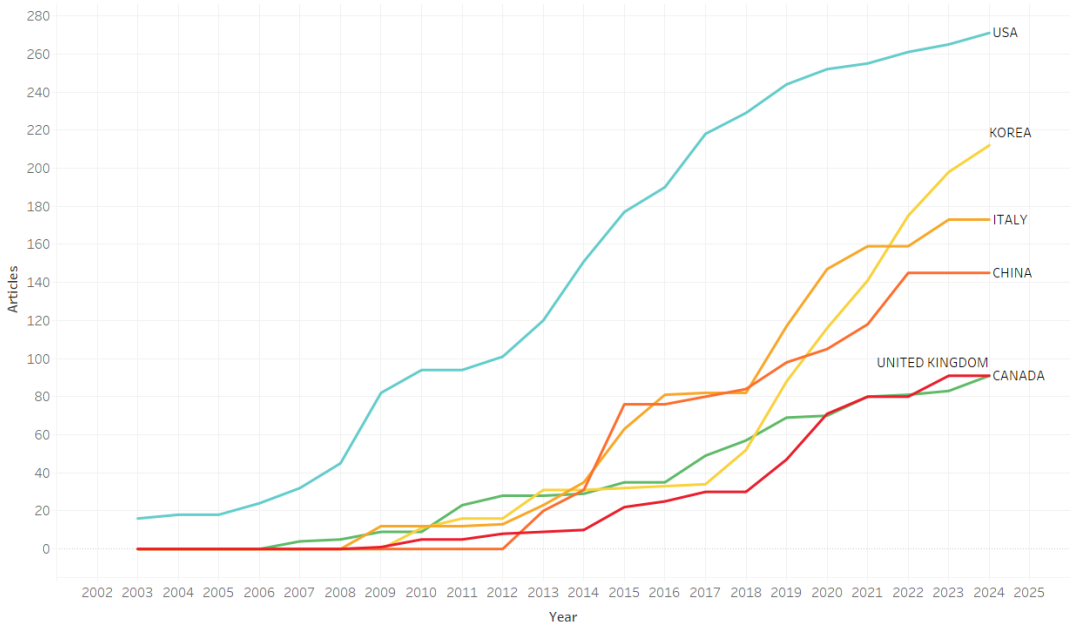
Research and Public Health, and BMJ Open contributed to the dissemination of results on LTBI, signifying the roles played in advancing knowledge and informing public health strategies.




(a)




(b)

**Figure 3.** Country scientific production on LTBI research from 1995 to 2024 (a) and the top five countries over time (b)

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**Table 2.** The top-ten journal that published the highest number of articles on LTBI

| Rank | **Journal** | **Documents** | **Total Citations** | **Avg. citations** | **Avg. publication year** | **Best Rank** | **H-index** |
|---|---|---|---|---|---|---|---|
| 1 | Plos One | 29 | 577 | 19.90 | 2017 | Q1 | 435 |
| 2 | Infection Control and Hospital Epidemiology | 22 | 429 | 19.50 | 2010 | Q1 | 152 |
| 3 | BMC Infectious Diseases | 10 | 223 | 22.30 | 2016 | Q1 | 129 |
| 4 | Journal of Hospital Infection | 10 | 158 | 15.80 | 2013 | Q1 | 138 |
| 5 | European Respiratory Journal | 8 | 682 | 85.25 | 2014 | Q1 | 282 |
| 6 | Journal of Occupational Medicine and Toxicology | 8 | 159 | 19.88 | 2014 | Q1 | 47 |
| 7 | Scientific Reports | 6 | 91 | 15.17 | 2019 | Q1 | 315 |
| 8 | Clinical Infectious Diseases | 6 | 72 | 12.00 | 2019 | Q1 | 387 |
| 9 | International Journal of Environmental Research and Public Health | 6 | 57 | 9.50 | 2020 | Q2 | 198 |
| 10 | BMJ Open | 6 | 31 | 5.17 | 2020 | Q1 | 160 |

**Table 3** presents the top ten authors actively publishing articles on LTBI, among which Albert Nienhaus leads with 18 documents and 599 citations, holding the highest H-index of 435. Anja Schablon and Madhukar Pai follow, with Schablon contributing 8 documents comprising 353 citations and Pai contributing 7 documents consisting of 580 citations. These authors represented a range of countries, including Spain, China, South Korea, the US, and Iran, reflecting the global research efforts in the field. Moreover, bibliometric analysis showed the significant contributions and influence of these leading scientists in advancing the understanding and knowledge of LTBI.

LTBI publications are featured in popular, high-impact journals indexed in Q1 and Q2 categories. These sets of research are often conducted by authors with high H-index scores from developed countries, with a trend showing significant academic and clinical interest in LTBI among HCWs. The involvement of leading scientists and reputable journals signifies the importance of this topic and ensures that the results reach a wide and influential audience in the scientific community.

**Table 3.** Top-ten authors actively publishing articles on LTBI

| **Rank** | **Authors** | **H-index** | **Documents** | **Citations** | **Avg. pub. Year** | **Country** | **Links** |
|---|---|---|---|---|---|---|---|
| 1 | Nienhaus, Albert | 435 | 18 | 599 | 2014 | Spain | 19 |
| 2 | Schablon, Anja | 25 | 8 | 353 | 2014 | Spain | 19 |
| 3 | Pai, Madhukar | 96 | 7 | 580 | 2013 | China | 19 |
| 4 | Menzies, Dick | 89 | 7 | 306 | 2019 | Spain | 19 |
| 5 | Trajman, Anete | 28 | 6 | 50 | 2020 | South Korea | 16 |
| 6 | Diel, Roland | 48 | 6 | 257 | 2014 | US | 19 |
| 7 | Zwerling, Alice | 25 | 5 | 315 | 2014 | Spain | 19 |
| 8 | Kang, Young ae | 35 | 5 | 29 | 2019 | China | 19 |
| 9 | Srisungngam, Sopa | 7 | 4 | 17 | 2020 | US | 19 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10 | Sotgiu, Giovanni | 72 | 4 | 75 | 2016 | Iran | 19 |

***Analysis of Articles in accordance with the Authors***

**Table** 4 presents the top ten articles cited in LTBI research, showing the significant impact made on the field.[29,30] The most cited article was written by Getahun H, titled "Management of latent Mycobacterium tuberculosis infection: WHO guidelines for low tuberculosis burden countries," published in the European Respiratory Journal in 2015, with 451 citations and an average of 45.10 citations per year. The article by Zwerling A article on interferon-gamma release assays for TB screening in HCWs, published in BMJ Thorax in 2012, followed by 204 citations. Dorman SE and Dheda K also contributed highly cited works focused on TB diagnostics and immunodiagnosis. Nienhaus A appeared twice in the top ten, suggesting the significant contributions provided to cost-effectiveness analysis and evaluation of TB screening strategies. These articles, published in various high-impact journals, presented key advancements and methodologies in TB research, offering crucial insights for ongoing and future investigations.[29–37]

**Table 4.** Top-ten articles cited in LTBI research

| Rank | Authors | Title | Journal | Year | Citations | TC per Year |
|---|---|---|---|---|---|---|
| 1 | Getahun H | Management of Latent Mycobacterium Tuberculosis Infection: WHO Guidelines for Low Tuberculosis Burden Countries | European Respiratory Journal | 2015 | 451 | 45.10 |
| 2 | Zwerling A | Interferon-Gamma Release Assays for Tuberculosis Screening of Healthcare Workers: A Systematic Review | BMJ Thorax | 2012 | 204 | 15.69 |
| 3 | Dorman Se | Interferon-γ Release Assays and Tuberculin Skin Testing for Diagnosis of Latent Tuberculosis Infection in Healthcare Workers in the United States | American Journal of Respiratory and Critical Care Medicine | 2014 | 191 | 17.36 |
| 4 | Dheda K | T-Cell Interferon-Gamma Release Assays for the Rapid Immunodiagnosis of Tuberculosis: Clinical Utility in High-Burden vs. Low-Burden Settings | Current Opinion in Pulmonary Medicine | 2009 | 163 | 10.19 |
| 5 | Nienhaus A | A Systematic Review of Cost and Cost-Effectiveness of Different TB-Screening Strategies | BMC Health Services Research | 2011 | 107 | 7.64 |
| 6 | Uden L | Risk of Tuberculosis Infection and Disease for Health Care Workers: An Updated Meta-Analysis | Open Forum Infectious Diseases | 2017 | 101 | 12.63 |
| 7 | Farao J | A User-Centered Design Framework for mHealth | Plos One | 2020 | 79 | 15.80 |
| 8 | Slater Ml | Challenges with QuantiFERON-TB Gold Assay for Large-Scale, Routine Screening of U.S. Healthcare Workers | American Journal of Respiratory and Critical Care Medicine | 2013 | 79 | 6.58 |

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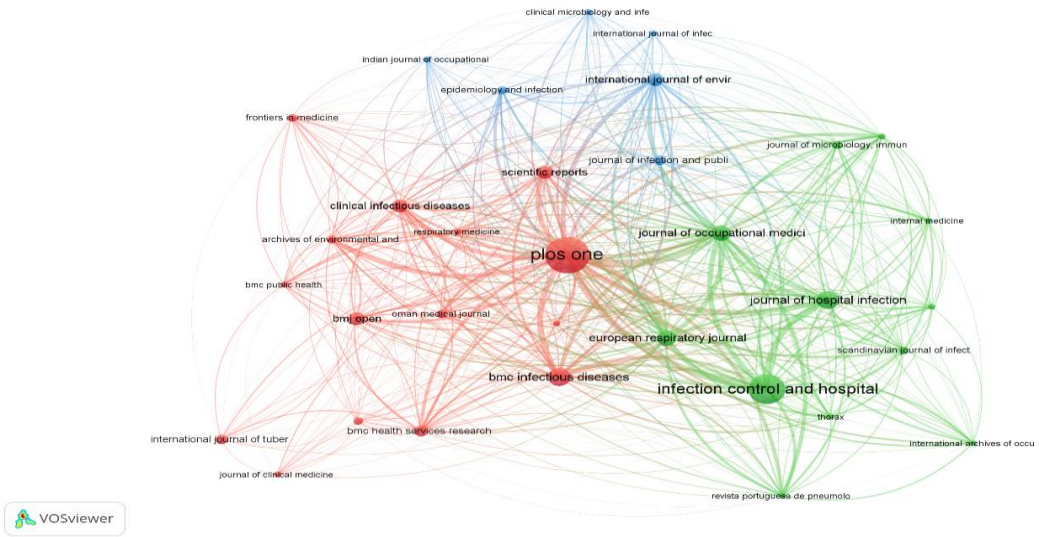
| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | Nienhaus A | Evaluation of the Interferon-Gamma Release Assay in Healthcare Workers | International Archives of Occupational and Environmental Health | 2008 | 68 | 4.00 |
| 10 | Sandgren A | Initiation and Completion Rates for Latent Tuberculosis Infection Treatment: A Systematic Review | BMC Infectious Diseases | 2016 | 59 | 6.56 |

***Bibliographic Coupling Analysis***

**Figure 4** shows the interconnectedness of journals, authors, and institutions included in LTBI research. Panel (a) represents the coupling of journals, with PLOS ONE at the center of the network, signifying the crucial role played in disseminating LTBI research. Other prominent journals comprise Infection Control and Hospital Epidemiology, Journal of Hospital Infection, and BMC Infectious Diseases, presenting the relationship and interconnectedness owned in the research community.

Panel (b) shows the coupling of authors, with Albert Nienhaus, Anja Schablon, and Madhukar Pai as central figures, reflecting the significant influence and collaborative efforts made in the field. The dense network of interconnected authors signifies robust collaboration and a highly integrated research community focusing on LTBI.

Panel (c) depicts the coupling of institutions, with major contributors such as the Centers for Disease Control and Prevention, Asan Medical Center, and McGill University at the core of the network. Additionally, it shows the institutions are central to advancing research on LTBI, fostering extensive collaborations that drive the field forward. The interconnected web of institutions signifies the global and collaborative nature of LTBI research, with substantial contributions from various regions around the world.




(a)

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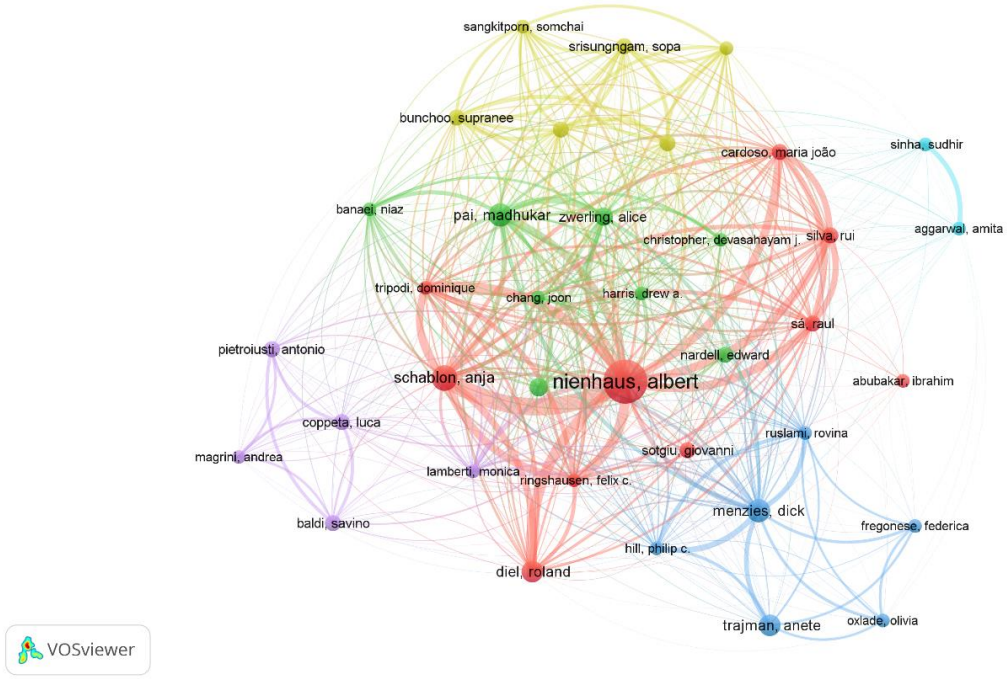


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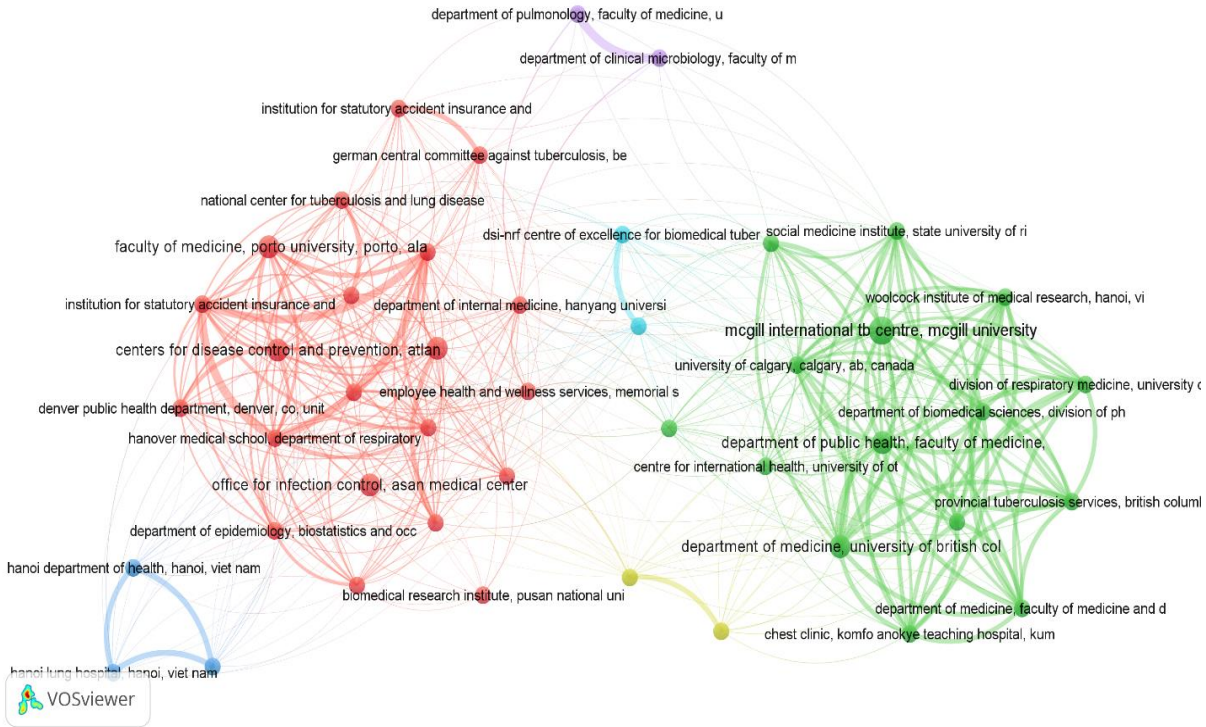


(c)

**Figure 4.** Bibliographic coupling analysis of (a) journal, (b) authors, and (c) institutions.

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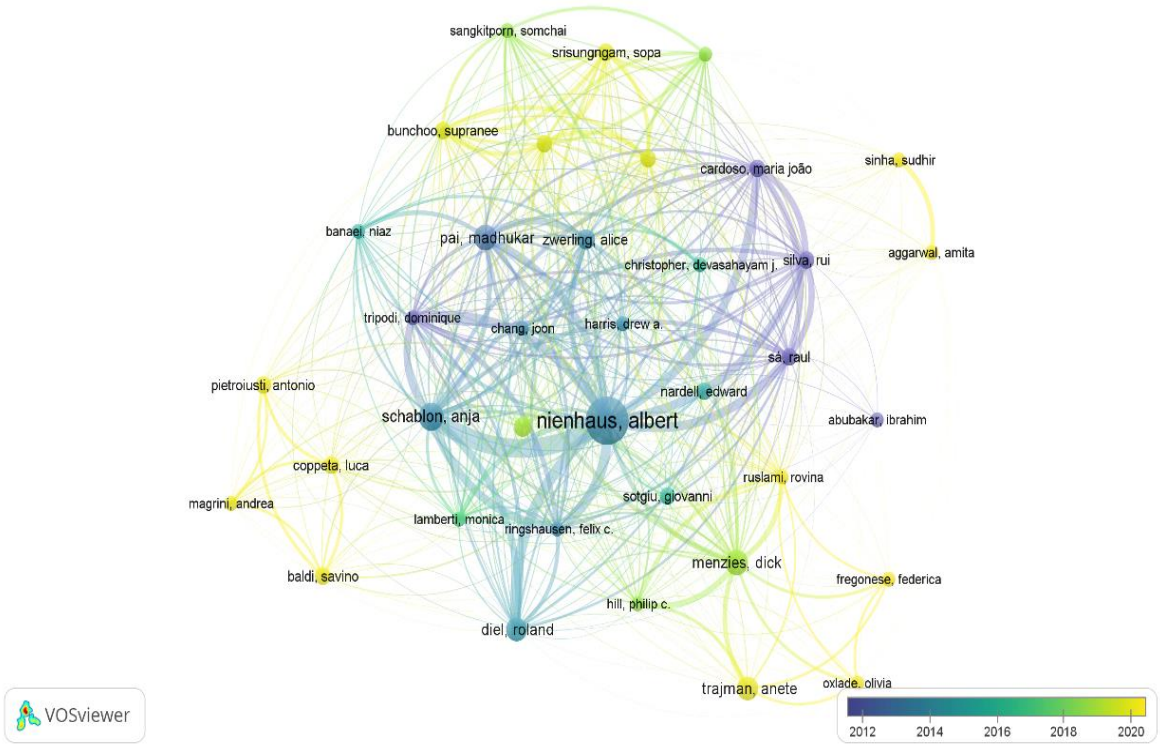
**Figure 5** presents the collaborative network analysis, showing the interactions and collaborations among authors and countries that participated in LTBI research. Panel (a) shows the collaborative network among authors, where Albert Nienhaus is prominently positioned at the center, indicating the extensive collaboration made with numerous scientists. Other central figures include Anja Schablon, Madhukar Pai, and Alice Zwerling, reflecting the significant contributions and widespread collaborative efforts provided. The dense interconnections of the network show the collaborative nature of LTBI research, with multiple authors working together to advance the field.

Panel (b) depicts the collaborative network among countries, with the United States occupying the central position, which signifies the major role played in global TB research collaboration. Additionally, South Korea, Italy, China, and the United Kingdom have extensive collaborative ties with numerous other countries. The network presents strong international cooperation, with countries from diverse regions contributing to and benefiting from shared research efforts. This interconnectedness shows the global commitment to addressing LTBI through scientific collaborations.

***Co-Occurrence Analysis***

**Table 5** and **Figure 6** present a bibliographic analysis of keywords related to LTBI research. Furthermore, panel (a) shows a network of interconnected keywords, with "latent tuberculosis" at the center, surrounded by terms including "healthcare personnel," "interferon-gamma release assay," and "tuberculin test." The clusters contain significant themes such as demographics ("male," "female"), risk factors, screening methods, and preventive measures including BCG vaccination. Panel (b) depicts the development of key terms over time, from 1995 to 2024, signifying trends and shifts in research focus. Keywords comprising "public health," "risk factors," and "healthcare workers" have been consistently prominent, while newer terms such as "quantiferon" and "IGRA" reflect advancements in diagnostic methods, which show the evolving priorities in LTBI research.

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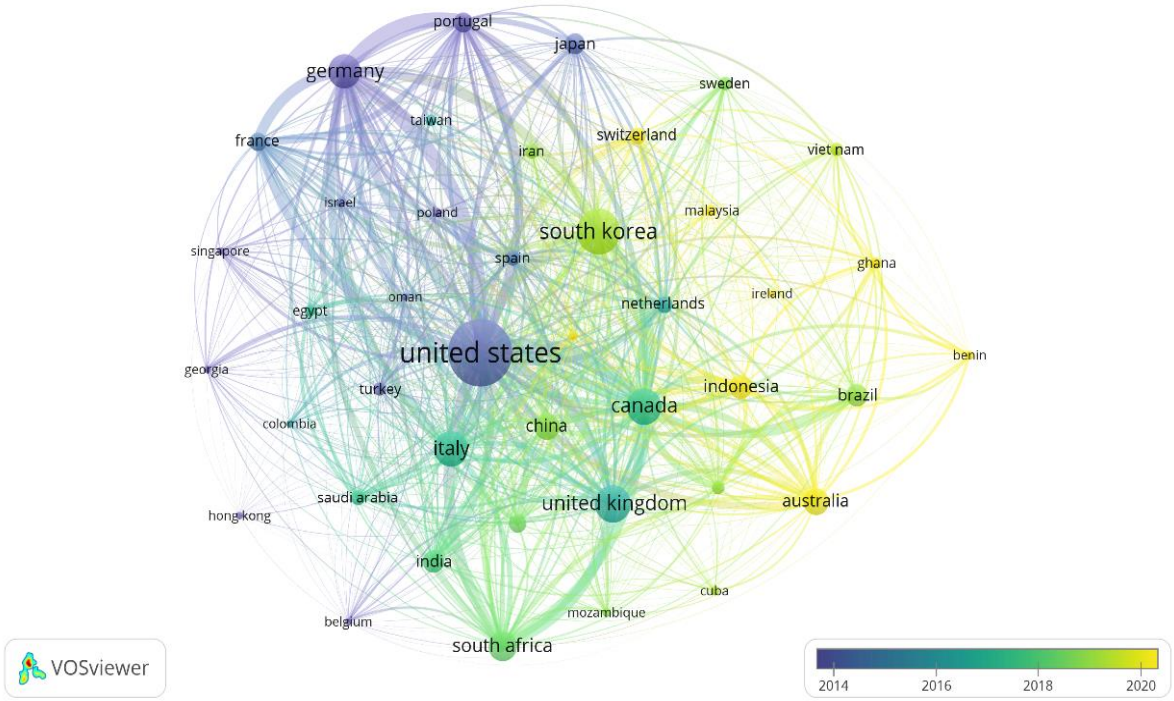
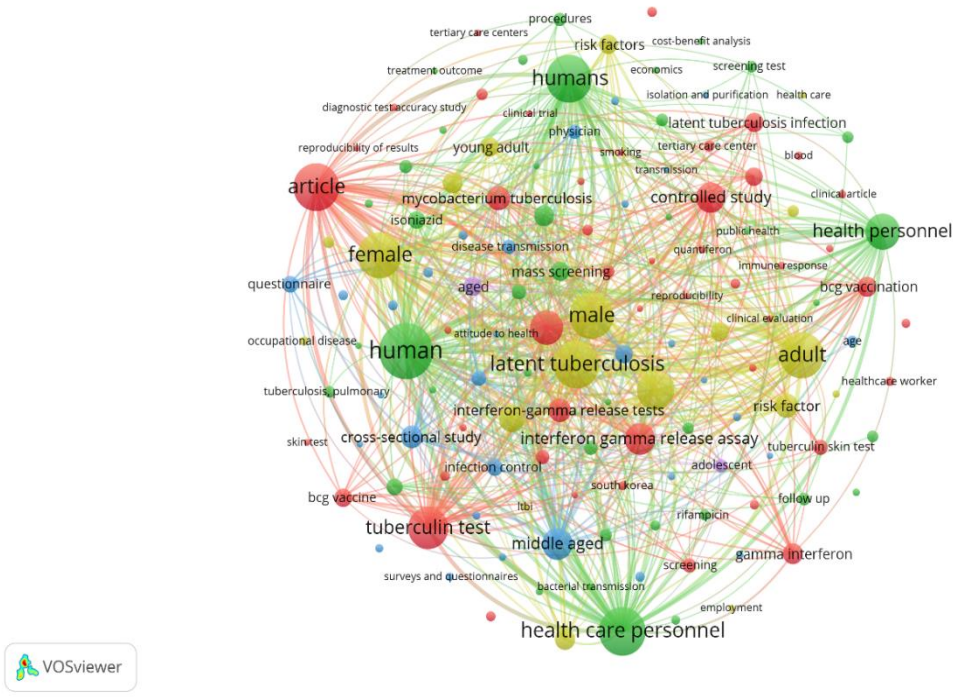



(b)

**Figure 5.** Collaborative network analysis of (a) authors and (b) countries.




(a)

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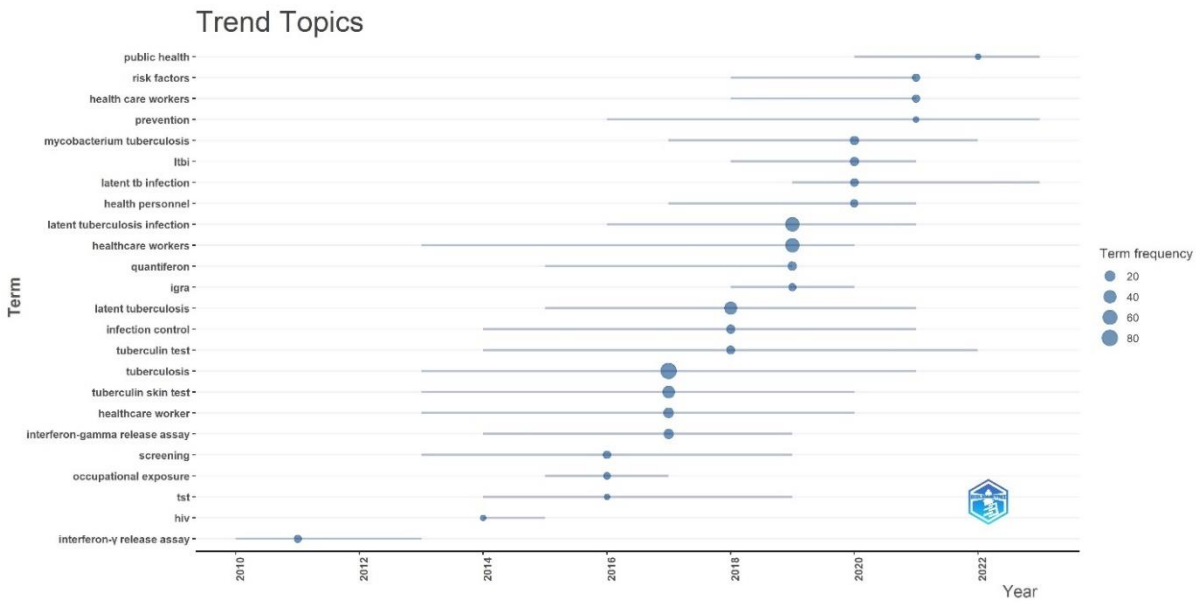


(b)

**Figure 6.** Bibliographic analysis of (a) keywords, (b) development of keywords between 1995-2024

**Table 5.** Most used keywords

| Rank | Label | Occurrences | Total link strength |
|---|---|---|---|
| 1 | Human | 264 | 5358 |
| 2 | Healthcare personnel | 215 | 4516 |
| 3 | Article | 209 | 4493 |
| 4 | Latent tuberculosis | 209 | 4298 |
| 5 | Humans | 206 | 4358 |
| 6 | Adult | 196 | 4346 |
| 7 | Male | 196 | 4313 |
| 8 | Female | 195 | 4300 |
| 9 | Tuberculin test | 170 | 3661 |
| 10 | Tuberculosis | 155 | 2998 |
| 11 | Health personnel | 133 | 2929 |
| 12 | Major clinical research | 127 | 2931 |
| 13 | Middle-aged | 113 | 2679 |
| 14 | Interferon-gamma release assay | 110 | 2415 |
| 15 | Controlled research | 104 | 2351 |

***Prevalence of LTBI in HCWs***

**Table 6** shows five recent research conducted on LTBI prevalence HCWs using IGRA test. Prevalence rates vary significantly, with the highest reported by Chen et al. (2019) in China at 33.9%, and the lowest by Bukhary et al. (2018) in Saudi Arabia at 10.8%. Other reports include prevalence rates of 27.0% in the UK (Henderson et al., 2017), 16.4% in Italy (Napoli et al., 2017), and 19.1% in China (He et al., 2015). These variations

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present geographical differences in LTBI prevalence among HCWs.[38–43]

**Table 6.** Five recent published research of LTBI among HCWs through IGRA test

| No | Author | Publication year | Country | Participants | Prevalence (%) | Reference |
|---|---|---|---|---|---|---|
| 1 | Chen et al. | 2019 | China | 487 | 33.9 | [6] |
| 2 | Bukhary et al. | 2018 | Saudi Arabia | 520 | 10.8 | [7] |
| 3 | Henderson et al. | 2017 | UK | 587 | 27,0 | [8] |
| 4 | Napoli et al. | 2017 | Italy | 2290 | 16.4 | [9] |
| 5 | He et al. | 2015 | China | 880 | 19.1 | [10] |

***Future Perspective and Limitation***

The comprehensive bibliometric analysis of LTBI research in HCWs shows several key insights that can shape future research and policy directions. The increasing trend in publications and international collaborations signifies the global recognition of LTBI as a significant public health issue. Future research should continue to focus on improving diagnostic methods, such as interferon-gamma release assays (IGRAs) and tuberculin skin tests, to enhance early detection and management.

Addressing the specific needs and risks of HCWs through targeted prevention and intervention strategies remains crucial. Furthermore, themes identified through keyword analysis, such as public health, occupational exposure, and risk factors, show the need for multidisciplinary methods that integrate epidemiology, clinical practice, and health policy. Further exploration of these areas can lead to more effective control measures and finally reduce the tuberculosis burden. As the research landscape evolves, fostering strong international collaborations and leveraging advancements in technology and data analytics will be essential to drive innovation and improve outcomes in the fight against LTBI.

Interpreting the results of bibliometric analysis on LTBI in HCWs requires acknowledging certain methodological limitations. These limitations are inherent due to the lack of a perfect search strategy and the restriction to literature indexed in the Scopus database, excluding non-Scopus-indexed journals. Despite trusting Scopus, future investigations should incorporate additional databases such as the Web of Science (WoS) to enhance generalizability. The results obtained still provide a valid basis for discussing the scientific literature on LTBI among HCWs and are capable of guiding future research and policy development in this area.

## 4. Conclusion

In conclusion, this comprehensive bibliometric analysis of LTBI among HCWs showed significant trends and insights corresponding to the research objectives. The global trends in LTBI research signified a steady increase in publications, showing growing awareness and importance of this issue in healthcare sector. The analysis of contributions and collaborations showed that the United States, South Korea, Italy, and China were key players, with extensive international cooperation representing the global effort made to address LTBI.

The most productive authors, including Albert Nienhaus and Anja Schablon, made substantial contributions to the field, while journals such as PLOS ONE and Infection Control and Hospital Epidemiology were major platforms for disseminating research results. Additionally, keyword analysis showed that major research themes included diagnostic methods, public health implications, and occupational exposure, reflecting the multidisciplinary nature of LTBI research.

Future research should focus on improving diagnostic methods, enhancing prevention strategies, and fostering international collaborations to comprehensively understand and mitigate LTBI risks among HCWs. Despite methodological limitations, such as reliance on the Scopus database, this analysis provided a valid and comprehensive overview of the current research landscape and offered valuable insights for subsequent investigations and policy developments.

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**Authors' Contribution Statement**

All authors provided significant contributions during the development and writing process.

**Data Availability Statement**

Data will be made available on request.

**Declaration of Competing Interest**

The authors affirm that no financial interests or personal relationships influenced this analysis.

**Acknowledgment**

Not Available.

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