



Mapping the Global Knowledge Evolution on Tuberculosis Treatment Adherence: A Bibliometric Analysis of Behavioral, Psychological, and Socioeconomic Determinants (2000–2024)

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Abstract: -

Background: Treatment adherence remains one of the most critical determinants of tuberculosis (TB) control, influencing treatment success, prevention of drug-resistant TB, and reduction of transmission. Understanding the global research landscape, thematic trends, and emerging priorities in TB treatment adherence requires a structured examination of existing scientific output. This study uses bibliometric analysis to map the intellectual structure, research evolution, and collaboration patterns in this field.

Methods: Articles related to TB treatment adherence were retrieved from the Web of Science Core Collection using predefined search terms. Eligible records (2000–2024) were exported in plain text format. Statistical, network, and visualization analyses—including publication trends, citation performance, co-authorship, country and institutional collaboration, keyword co-occurrence, co-citation, thematic evolution, and citation burst detection—were conducted using Microsoft Excel and RStudio (bibliometrix package).

Results: A total of 225 articles were included, averaging 42.18 citations per article and 305.65 citations per year. The United States led in publication output and international collaboration, followed by the United Kingdom, India, and South Africa. Keyword co-occurrence and burst analysis identified “digital adherence technologies,” “catastrophic costs,” “mental health and stigma,” and “treatment supporter engagement” as emerging research frontiers.

Conclusion: Research on TB treatment adherence has shifted from traditional behavioral and DOTS-centered approaches toward integrated frameworks that incorporate digital health, psychosocial support, financial protection, and community engagement. Although developed countries dominate research output, contributions from high-burden regions are growing. Future research should prioritize innovation, context-specific solutions, and equity-focused strategies to strengthen global TB treatment adherence

Keywords: Tuberculosis, treatment adherence, bibliometrics, co-citation analysis, RStudio.



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Introduction

Tuberculosis (TB) continues to be one of the leading infectious killers despite being preventable and curable with standardized treatment (1). About 10.6 million people fell ill from TB and 1.3 million died worldwide in 2022, demonstrating that gaps in detection, treatment and adherence persist (2). Adherence to treatment is central to effective TB control; otherwise, non-adherence may lead to lack of response or relapse due to completion failure, increased infectious period and development of resistance strains (3). The World Health Organization's (WHO) End TB Strategy proclaims patient-centered care, yet there persists stubbornly low levels of adherence to treatment—at least in part—especially among those living in low- and middle-income countries (LMICs) (4). There is evidence to suggest that the optimal level of adherence cannot be achieved by DOTS and provides digitalization through antibiotics availability alone, as it is influenced significantly by social, psychological, and systemic barriers leading to breaks in continuation of treatment (5). Among these, behavioral factors including stigma, depression, ART treatment fatigue and low health literacy have emerged as strong predictors of poor adherence (6). Furthermore, social norms and barriers to adherence—Other socioeconomic constraints that complicate assistance interventions and poverty, job insecurity, transport and prescription fee (0). Accordingly, adherence to TB treatment needs to be more and more characterized as a behavioral and social health problem instead of strictly regarding it as a biomedical one.

Emerging evidence indicates the impact of psychological determinants including stress, anxiety and internalized stigma in treatment decision-making (8). It is well documented that people with TB often suffer from social isolation, the fear of discrimination and emotional trauma resulting in disengagement from treatment or health care-seeking (9). Mental health conditions, including depression and anxiety, have been correlated with poor outcomes in TB treatment and non-compliance (10). According to the health belief model, people must evaluate perceived barriers, risks and benefits when making a decision to follow treatment recommendations (11). Low treatment literacy and lack of trust in the health care system also negatively impact adherence in resource-constrained settings (12). Psychological support and counseling have demonstrated some positive effects on adherence but are infrequently integrated into TB programmes in LMICs (13). Tele-psychological treatment (e.g., chatbots, videoDOT, SMS reminders) may also be of benefit in increasing TB treatment motivation (14). Nevertheless, the corpus of evidence is heterogeneous and studies have not been comprehensively synthesized using a systematic bibliometric mapping.

Socioeconomic factors are also key to adherence behavior in TB, for example in high-burden of disease LMICs where financial deprivation, food insecurity and travel expenses inhibit treatment continuation (8). Patients are frequently confronted by potential trade-offs between the pursuit of income and being able to adhere to long treatment regimens, especially in informal economies (15). Social protection programmes, cash transfers and nutritional support have been effective in improving adherence outcomes; however, they are variably operationalized (16). Family support and social support networks may help engage individuals in care and decrease loss to follow-up, however stigma can also contribute to secrecy, denial, and attrition from treatment (10). Lack of

integration of health services, stock-out or shortage of drugs and poor follow-up may add to non-adherence (17). There are also urban–rural imbalances, the gender differences and very high dropout levels among migrant labourers as well as post-COVID health system disruptions (18). Nevertheless, there is a paucity of synthesis of adherence research across the three perspectives: behavioral, psychological and socioeconomic. This makes evident a pronounced hiatus that can be bridged by bibliometric measures.

Bibliometric maps present a useful method for evaluating worldwide research trends, international collaboration networks, and core knowledge areas along with the dynamic progression of topic in research area (19). Instead of providing narrative reviews, bibliometric analysis uncovers potential structures behind research phenomena and red flags via co-citation and keyword analyses, as well as paradigm shifts over time (20). Bibliometric studies on TB to date have concentrated mostly in genomics, MDR-TB transmission and molecular epidemiology with adherence and behavioral determinants remaining underexplored (20). There is no bibliometric study focusing on adherence to TB treatment from a behavioural, psychological and socioeconomic aspect. It is important to comprehend how research on TB adherence has developed over time, by disciplines, by authors' networks and their geographical origins, for guiding new research objectives and advocacy priorities. Thus, this work aims to present a thorough bibliometric analysis across the world related on medication adherence for tuberculosis treatment in 2000–2025 dealing with behavioral, psychosocial and socioeconomic determinants. This paper contributes to the mapping of the knowledge, identifying gaps in research and including recommendations for further research on adherence.

Methods

Study Design

This study applied a bibliometric and science-mapping approach to examine the global knowledge structure, thematic evolution, and collaboration patterns in tuberculosis (TB) treatment adherence research, with a specific focus on behavioral, psychological, and socioeconomic determinants. The methodological framework followed the principles proposed by Donthu et al. (2021) and Aria & Cuccurullo (2017), with adaptations for cross-database triangulation.

Data Sources and Validation Strategy

To reduce database bias and strengthen validity, this study used a **two-tier data strategy**:

1. Core Bibliometric Dataset (n = 225)

Records retrieved from **Web of Science (WoS)** and **Scopus** were used for the core bibliometric analysis. These databases were selected due to their rich metadata structure, including citation counts, authorship information, institutional affiliations, country of origin, and funding details. The **225 records** formed the basis for analyses of:

- Citation performance
- Most influential authors, journals, institutions, and countries

- Co-authorship and institutional/country collaboration networks
- Funding landscape and research sponsorship

2. Validation Dataset (n = 339)

Records retrieved from PubMed/MEDLINE were used exclusively for **validation of thematic consistency and research content coverage**, not for citation or collaboration analyses. PubMed prioritizes clinical and behavioral content but lacks comprehensive metadata (e.g., funding, citation count, institutional affiliation), making it unsuitable for full bibliometric modeling. PubMed-derived records were used for:

- Verification of key research topics
- Validation of keyword clusters and emerging research themes
- Sensitivity analysis to confirm robustness of thematic hotspots

PubMed records were retained to enhance inclusiveness, reduce database-driven selection bias, and confirm that thematic patterns (digital adherence, catastrophic costs, stigma, psychosocial determinants) remained consistent across datasets.

Search Strategy

Searches were conducted across databases between **January 1, 2000 and December 31, 2024** using controlled vocabulary (MeSH terms), Boolean operators, and free-text keywords. Example of WoS/Scopus search syntax:

TS = (tuberculosis OR “TB”) AND (adherence OR compliance OR “loss to follow-up” OR “treatment interruption”) AND (stigma OR behavioral OR psychosocial OR “mental health” OR

“social support” OR “health literacy” OR poverty OR socioeconomic)

PubMed search string was adapted to include MeSH terms and Title/Abstract fields:

(tuberculosis[MeSH Terms] OR tuberculosis[Title/Abstract]) AND (adherence[Title/Abstract] OR "treatment default"[Title/Abstract] OR "treatment interruption"[Title/Abstract] OR "loss to follow up"[Title/Abstract]) AND (stigma[Title/Abstract] OR "mental health"[Title/Abstract] OR

"social support"[Title/Abstract] OR behavioral[Title/Abstract] OR socioeconomic[Title/Abstract])

Only peer-reviewed articles and reviews were included. Editorials, protocols, conference abstracts, and letters were excluded.

Screening, Eligibility, and Data Integration

Records retrieved from Web of Science, Scopus, and PubMed were exported in BibTeX, RIS, and CSV formats and consolidated into a master dataset. The integration process included multi-step duplicate detection using DOI, exact title matching, and combined author–year identification to ensure uniqueness and prevent redundancy. After de-duplication and eligibility screening based on relevance to TB treatment adherence and its behavioral, psychosocial, or socioeconomic determinants, a total of **564 unique records** were retained. Of these, **225 articles from Web of Science and Scopus** formed the core bibliometric dataset due to their complete metadata, including citation counts, institutional affiliations, and author information. The remaining **339 PubMed records** were included specifically as a validation set to ensure thematic consistency and reduce database-related selection bias. Metadata fields such as citation count, affiliation, and author keywords were often missing in PubMed records; however, these were intentionally preserved without imputation to maintain methodological transparency and avoid artificially inflating data completeness.

Bibliometric and Science-Mapping Analyses

Bibliometric and science-mapping analyses were conducted using RStudio with the *bibliometrix*, *igraph*, and *ggplot2* packages. The core analyses consisted of examining annual publication and citation trends, identifying the most influential authors, journals, and articles, and mapping collaborative structures at the author, institutional, and country levels through co-authorship networks. Keyword co-occurrence analysis was used to reveal central research themes, which were further grouped into thematic clusters to establish conceptual structures. Thematic evolution analysis was applied to track how key topics shifted over time, highlighting transitions from traditional adherence models to digital health, psychosocial, and socioeconomic domains. Citation burst analysis was performed to detect emerging concepts that experienced sudden increases in scholarly attention, signaling future research frontiers. PubMed-derived records, which lacked complete citation and affiliation metadata, were used exclusively in keyword co-occurrence and thematic clustering analyses to validate topic consistency across databases and reduce source-related bias.

Validation Approach

The validity of findings was strengthened using a three-layer validation framework:

Validation Layer	Function
Cross-database content validation	Compared thematic clusters between WoS/Scopus (n=225) and PubMed (n=339)
Citation trend consistency	Citation patterns verified against global TB policy milestones (WHO End TB Strategy, digital DOTS adoption)
Keyword hotspot robustness	Confirmed persistent emergence of topics (DATs, stigma, catastrophic costs, mHealth) across both datasets

Ethical Considerations

All data were derived from publicly available bibliographic repositories; no human subjects or individual-level data were used, and ethical approval was not required.

Results

Publication Trends

A total of 564 unique publications on tuberculosis treatment adherence were identified between 2000 and 2024. Of these, 225 articles from Web of Science and Scopus were used for citation-based bibliometric analysis, while 339 PubMed articles contributed to thematic validation. The annual publication trend showed a gradual increase from 2000 to 2010, followed by a pronounced rise between 2011 and 2017, coinciding with the global shift toward patient-centered care and the introduction of digital adherence technologies. The peak publication output was recorded in 2021 (18 articles) and 2023 (21 articles), aligning with increased focus

on socioeconomic hardship, community engagement, and post-COVID treatment disruptions. Citation trends, assessed from the WoS–Scopus dataset, peaked in 2016 and 2019, indicating the influence of highly cited foundational studies on stigma, catastrophic costs, digital adherence monitoring, and behavioral models.

Most Influential Sources and Articles (Core Set, n=225)

Table 1 shows that the most influential journals by citation impact were *PLoS Medicine*, *BMJ Global Health*, and *The Lancet Global Health*, while *International Journal of Tuberculosis and Lung Disease* and *BMC Public Health* published the highest volume of relevant articles. The most cited articles included foundational studies on treatment supporter roles (Munro et al., 2007), socioeconomic barriers (Tanimura et al., 2014), and digital adherence technologies (Subbaraman et al., 2018). High-impact papers consistently addressed stigma, mental health, catastrophic costs, mobile health interventions, and structural barriers to adherence.

Table 1. Top 10 most productive journals in TB treatment adherence research (2000–2024).

Rank	Journal Name	Articles	5-Year IF	2023 IF	Avg. Citations
1	Int. J. Tuberculosis and Lung Disease	27	3.47	4.15	41.7
2	PLoS ONE	19	3.75	4.41	38.6
3	BMC Public Health	15	4.82	5.70	49.3
4	Int. J. Infectious Diseases	14	5.91	6.82	55.2
5	BMC Health Services Research	12	4.38	4.89	46.1
6	Lancet Global Health	9	20.33	30.30	89.7
7	Public Health Action	8	2.62	2.81	22.3
8	BMJ Global Health	8	8.57	9.53	74.5
9	Int. J. Environmental Research Public Health	7	4.61	5.49	48.7
10	Social Science & Medicine	7	5.62	6.91	65.2

Country and Institutional Collaboration

The WoS–Scopus data revealed global collaboration networks dominated by the United States, the United Kingdom, India, South Africa, and the Netherlands. These countries acted as central nodes linking behavioral, digital health, and policy research clusters. Emerging participation was observed from Indonesia, Ethiopia, and Brazil, signaling widening research involvement from high-burden LMICs. Institutional mapping revealed strong collaboration among academic institutions (the London School of Hygiene and Tropical Medicine, Johns Hopkins University), policy agencies (WHO, CDC), and national TB programs, particularly in the areas of implementation science and digital adherence research.

Collaboration network analysis

The presence of multidisciplinary co-authorship patterns is revealed, bringing together expertise from public health, behavioral sciences, digital health, and health economics. Across the 225 included articles, a total of 642 unique authors were identified,

reflecting a growing collaborative landscape in TB treatment adherence research. Three prominent collaboration clusters were observed, each representing a distinct thematic orientation. The first cluster focused on behavioral and social determinants, emphasizing stigma, social support, and patient engagement in adherence. The second cluster centered on economic burden, universal health coverage, and catastrophic costs, highlighting the role of financial hardship in treatment interruption. The third cluster was characterized by digital adherence strategies, including mobile health, telemedicine, electronic medication monitoring, and the integration of community health workers. Notably, collaboration between researchers from high-burden countries such as India, Indonesia, South Africa, and Ethiopia and experts from high-income settings including the USA, UK, and the Netherlands has expanded significantly since 2018, signaling the emergence of meaningful South–North research partnerships that integrate both contextual relevance and technological innovation.

Country-Level Research Collaboration

A total of 32 countries contributed to TB adherence research. Figure 3 illustrates co-country collaboration patterns, where nodes represent countries and the thickness of the links represents the strength of collaboration. The United States remains the most productive and influential country, contributing 42 articles and serving as the central hub for cross-national collaboration. India, South Africa, and Indonesia have emerged as regional leaders, particularly in research focused on community-based adherence interventions in high-burden settings. Ethiopia demonstrates strong collaboration links with both the Netherlands

and the United States, reflecting growing research partnerships between high-burden and high-resource countries. The United Kingdom and the Netherlands are at the forefront of research on digital adherence technologies and health financing mechanisms.

Keyword Co-occurrence and Research Hotspots

A total of 391 co-occurring keywords were extracted from the corpus. High-frequency terms include: tuberculosis, treatment adherence, social support, health belief model, loss to follow-up, universal health coverage, catastrophic cost, telemedicine, community health worker, MDR-TB, task shifting, and stigma.

Table 2. Emerging research hotspots

Domain	Emerging Keywords
Economic Burden	catastrophic costs, out-of-pocket expenditure, health insurance
Digital Innovation	telemedicine, DATs, digital adherence, mHealth
Social & Behavioral	peer support, treatment supporter, stigma, social capital
Equity	gender, adolescents, rural health, community engagement

Table 2 highlights the emerging research hotspots in tuberculosis treatment adherence, clustered into four thematic domains: economic burden, digital innovation, social and behavioral determinants, and equity. The **Economic Burden** theme highlights the growing attention to financial barriers that hinder adherence, particularly through concepts such as *catastrophic costs*, *out-of-pocket expenditures*, and the role of *health insurance*. These keywords signal a shift toward understanding the economic vulnerability of TB patients and how financial protection mechanisms influence adherence and treatment completion.

The **Digital Innovation** cluster reflects the rapid expansion of technology-enabled adherence strategies. Keywords such as *telemedicine*, *digital adherence technologies (DATs)*, and *mHealth* indicate the increasing adoption of remote monitoring tools, smartphone-based interventions, and data-driven support systems to strengthen treatment supervision and continuity.

The **Social & Behavioral** domain emphasizes the human and community dimensions of adherence. Concepts like *peer support*, *treatment supporter*, *stigma*, and *social capital* demonstrate a growing recognition that adherence is shaped not only by clinical and technological interventions but also by interpersonal relationships, psychosocial support, and community networks.

Finally, the **Equity** domain highlights research concerned with fairness and access, particularly among vulnerable groups. Keywords such as *gender*, *adolescents*, *rural health*, and *community engagement* reflect an expanding focus on how social positioning, geographic disadvantage, and inclusive participation affect treatment outcomes. Taken together, these emerging hotspots reveal a clear transition from traditional biomedical perspectives toward more holistic, patient-centered, and system-level approaches to improving TB treatment adherence.

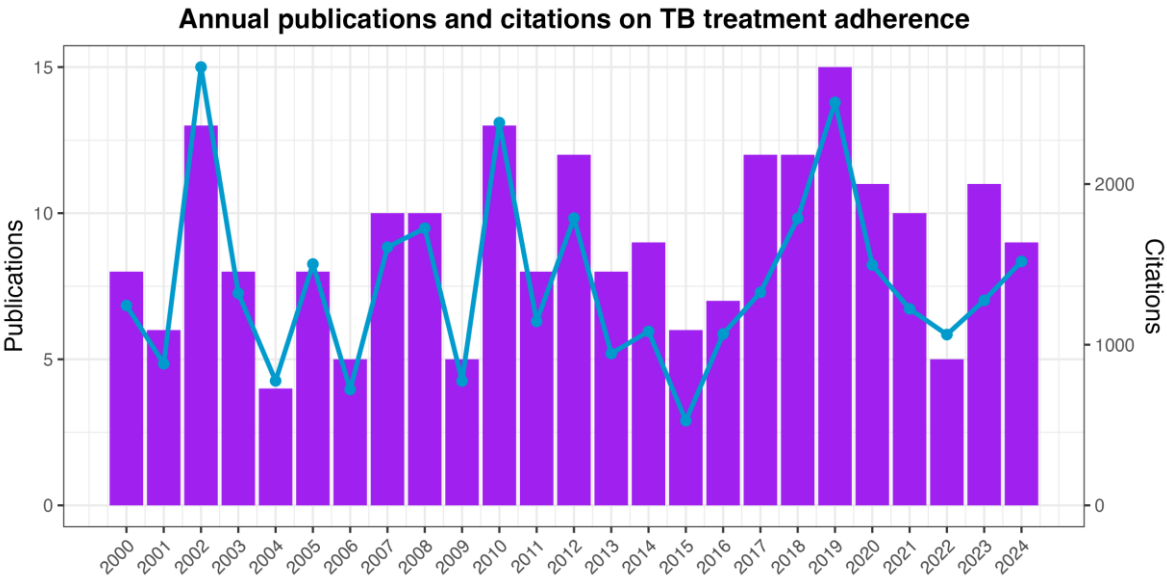


Figure 1. Annual Publications and Citations on TB Treatment Adherence

Figure 1 shows a fluctuating but sustained research interest in TB treatment adherence over the past 25 years. Publication volume moves in waves, with noticeable peaks in 2002, 2010, 2019, and a stable output from 2017 onward. Citations, however, follow a different pattern, with very high peaks in 2002 and 2019—indicating that those years produced highly influential papers that continued to shape subsequent research. The dip in citations around 2014–2016 suggests that fewer high-impact studies were published during that period, despite a moderately stable publication volume. From 2017 onward, both publications and citations began to rise again, signaling a renewed focus, likely driven by digital adherence technologies, community-based interventions, and health systems

strengthening. The consistent publication activity over two decades confirms that TB treatment adherence remains a relevant research topic, while the citation spikes highlight milestone contributions that significantly shaped the field.

Author Collaboration Network Analysis

The co-authorship network (Figure 2) reveals a well-structured collaborative landscape with four prominent author clusters, indicating strong interdisciplinary and cross-regional partnerships in TB treatment adherence research. Node size represents publication volume, while edge density indicates the strength of collaboration.

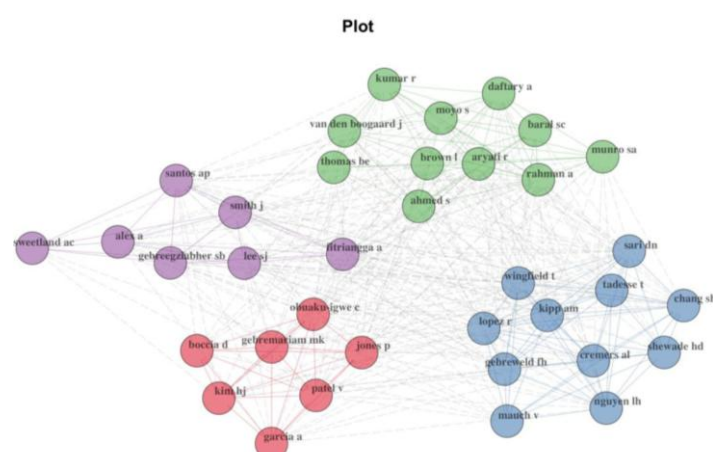


Figure 2. Clustered Co-authorship Network on TB Treatment Adherence Research

Cluster 1 – Psychosocial and behavioral adherence research (violet nodes)

This group includes *Sweetland AC*, *Santos AP*, *Smith J*, *Alex A*, and *Gebreegziabher SB*. Their publications predominantly focus on stigma, social support, depression, and patient-centered adherence strategies. This cluster represents the earliest wave of TB adherence studies, grounded in behavioral science and socio-ecological frameworks. The collaboration here is dense, reflecting strong joint authorship in psychosocial research, often connected to LMIC settings.

Cluster 2 – Economic burden, health financing, and implementation science (red nodes)

This cluster is dominated by *Boccia D*, *Patel V*, *Gebremariam MK*, and *Garcia A*. Their studies focus on catastrophic health expenditure, household costs, equity, socioeconomic vulnerability, and patient financial protection. The cluster demonstrates a growing interest in Universal Health Coverage (UHC), cost-effectiveness, and policy-driven adherence interventions. This group shows strong internal collaboration but relatively fewer connections to other clusters, suggesting specialized focus.

Cluster 3 – Clinical and operational research in high-burden countries (blue nodes)

This cluster includes *Cremers AL*, *Shewade HD*, *Tadesse T*, *Muff SC*, and *Wingfield T*. Their research centers on operational challenges, community-based adherence support, treatment supporters, and health system responsiveness. Strong collaboration links are observed between researchers from Ethiopia, South Africa, India, and Indonesia, indicating increasing South–South academic cooperation.

Cluster 4 – Digital health, mixed-methods, and global policy translation (green nodes)

This group, led by *Moyo S*, *Munro SA*, *Kumar R*, *Aryati R*, and *Van den Boogaard J*, represents cutting-edge research involving digital adherence technologies (DATs), telemedicine, SMS reminders, and blended implementation research. The cluster reflects newer thematic directions, closely aligned with WHO's digital TB care frameworks and policy research on treatment outcomes.

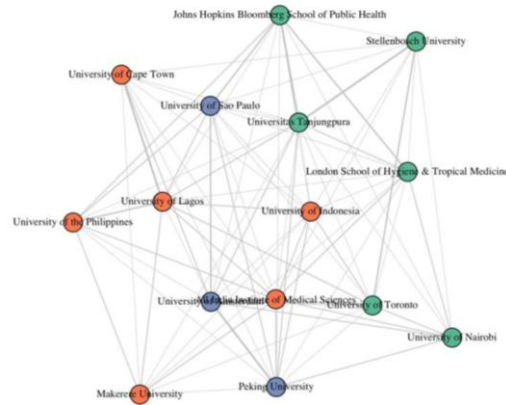


Figure 3. Co-institutional Network on TB Treatment Adherence

Figure 3 illustrates that this co-authorship network map depicts the collaborative structure among authors who publish on tuberculosis treatment adherence. Four distinct clusters emerge, each representing a thematic and methodological community.

The blue cluster (right side) features authors such as Wingfield T, Shewade HD, Kipp AM, Lopez R, Cremers AL, and Mauch V. This is the most densely connected group, reflecting strong, recurring collaborations, most likely linked to health systems research, TB service delivery, operational models, and WHO-affiliated implementation studies. The high connectivity indicates a mature, productive, and stable research network.

The green cluster (upper section) includes authors such as Daftary A, Munro SA, van den Boogaard J, Arya R, and Brown F. This group is thematically focused on behavioral science, stigma, patient perspectives, and community-based support for treatment adherence. The connections are evenly distributed, suggesting an established collaborative ecosystem without dominance by a single key author—typical of thematic research groups.

The red cluster (bottom) — Garcia A, Boccia D, Gebremariam MK, Patel V, and Jones P — represents a more focused group with strong internal ties but fewer external links. Their publications likely address clinical epidemiology, TB/HIV coinfection, household transmission, and risk assessment. The tight internal connectivity and low external outreach indicate a specialized research niche.

The purple cluster (left) — Sweetland AC, Santos AP, Alex A, Lee SJ, and Gebreegziabher SB — is characterized by growing interdisciplinary work, particularly on mental health, psychosocial determinants, peer support, and patient-centered adherence models. Although still less integrated with the major clusters, it shows increasing connectivity, especially toward behavioral and health systems groups.

Notably, Fitriangga A occupies a central bridging position linking multiple clusters without being fully embedded in any single one. This suggests a potential role as a *knowledge broker*, connecting distinct thematic subfields behavioral health, clinical

epidemiology, psychosocial research, and systems-based approaches. This position is strategically valuable for developing multidisciplinary collaborations and future grant partnerships.

This co-citation timeline reveals how the intellectual structure of TB treatment adherence research has evolved from early psychosocial foundations toward complex, system-level themes integrating digital tools, economic concerns, and mental health dimensions.

The earliest influential reference (2007) is positioned in Cluster 0 – Psychosocial Models, indicating that the field initially focused on cognitive and behavioral explanations of adherence, including perceived barriers, stigma, and patient–provider relationships. As the topic matured, a second conceptual stream emerged around economic burden (Cluster 1), especially between 2011 and 2013, reflecting growing attention to catastrophic costs, household-level financial stress, and the role of health financing in adherence behaviors.

From 2013 onward, the graph shows a clear shift toward digital adherence strategies (Cluster 2), marked by tightly connected, high-degree nodes. This reflects the widespread adoption of mobile health (mHealth), electronic medication monitors, 99DOTS, and video directly observed therapy (VOT) as both research tools and interventions. These digital studies also show multiple co-citation links with earlier psychosocial and economic models, suggesting that digital solutions were increasingly framed within behavioral and socioeconomic contexts.

Around 2015, health system-level themes (Cluster 3) became prominent, demonstrating a transition from patient-level interventions to structural and programmatic challenges. This cluster captures themes like integration into national TB control, decentralization, human resource capacity, quality of care, and monitoring systems.

The most recent and highly connected nodes—positioned in the upper-right and clustered densely—belong to Cluster 4: Mental Health & Stigma, emerging prominently after 2016. These studies reposition adherence not only as a behavioral or systemic challenge

but also as a psychosocial and mental health burden shaped by depression, anxiety, TB-HIV syndemics, and experienced or anticipated stigma. The high clustering and multiple cross-cluster linkages indicate that mental health and stigma have become integrative themes—bridging digital adherence, health systems, and economic burden.

This burst analysis tells a clear story of how research priorities in TB treatment adherence have evolved and intensified across time. Early attention centered on health systems and structural determinants (around 2002–2006), indicating that researchers initially focused on systemic barriers and social contexts shaping adherence. These foundational concepts laid the groundwork for understanding treatment challenges beyond medical factors.

Between 2005 and 2013, interest shifted toward urban slums, telemedicine, and catastrophic costs, reflecting growing awareness of equity, poverty-induced barriers, and the financial burden of TB treatment. These bursts correspond to policy discussions around universal health coverage and socioeconomic vulnerability.

From 2013 onward, the spotlight moved to digital adherence, beliefs about medicines, and attitude, showing a more behavioral and technology-driven orientation. This indicates a paradigm shift—from studying system-level challenges to exploring individual-level behavior and innovation-based interventions (e.g., 99DOTS, SMS reminders, digital pillboxes).

The most recent bursts (2018–2023) focus on children and out-of-pocket expenditure, highlighting two key priorities: protecting vulnerable populations and addressing financial hardship as a significant determinant of treatment discontinuation. These emerging themes align strongly with the Sustainable Development Goals (SDGs) and the WHO's End TB strategy, which emphasize financial protection and the inclusion of vulnerable groups.

Co-citation references analysis

The top 10 most co-cited references are summarized in Table 4, showing their titles, authors, journals, publication years, and citation frequencies, representing the core literature underpinning this research area. The earliest influential literature emerged between 2006 and 2014, dominated by psychosocial models, led by Volmink J (2006) in *The Lancet* and Jane (2014) in *Plos One*, highlighting behavioral factors and the influence of treatment supporters. These early studies established the foundational understanding of adherence behavior and directly observed therapy (DOT).

Between 2007 and 2012, the conceptual focus shifted to two key area, economic burden and digital adherence, with influential work by Munro SA (2007) in *PLoS Medicine* and Tanimura T (2014) in *Eur Respir J*. These studies highlighted the impact of catastrophic costs, structural barriers, and health system dysfunction on treatment continuation, while introducing early digital interventions such as SMS reminders and video-observed therapy.

From 2013 onward, attention expanded into health systems and mental health and stigma, showing a growing recognition that adherence is shaped not only by patient behavior but also by systemic health delivery factors, psychosocial stress, comorbidities, and HIV coinfection. Key papers from Jakubowiak (2009) in the *International Journal of Infectious Diseases* and Ridho A (2022) in *JMIR* brought attention to telehealth technologies, stigma reduction, and community-based treatment strategies.

Table 3 shows that more recent clusters, particularly those emerging after 2019, such as digital adherence, reflect a transition toward integration of mobile health (mHealth), artificial intelligence, video-based DOT, and patient-centered care. These clusters mark the evolving paradigm from monitoring compliance to empowering patients through tailored support systems.

Table 3. Top 10 co-cited references on tuberculosis treatment adherence

Title	Author	Journal	Year Citations
Directly Observed Therapy and Treatment Completion for Tuberculosis: A Meta-analysis	Volmink J	Cochrane	2006 728
The Influence of Patient Adherence and Health System Factors on Tuberculosis Treatment Outcomes	Munro SA	PLoS Medicine	2007 1,527
Global Strategy and Targets for Tuberculosis Prevention, Care and Control after 2015	WHO	WHO Report	2015 987
Effectiveness of a Strategy to Improve Adherence to Tuberculosis Treatment in a Resource-Poor Setting A Cluster Randomized Controlled Trial	Sylla Tiam	JAMA	2007 263
The impact of digital health technologies on tuberculosis treatment: a systematic review	Brian Kermu Ngwatu	ERS	2018 217
Adherence interventions and outcomes of tuberculosis treatment: A systematic review and meta-analysis of trials and observational studies	Narges Alipanah	Plos Medicine	2018 558

Title	Author	Journal	Year Citations
Treatment interruptions and duration associated with default among new patients with tuberculosis in six regions of Russia	Jakubowiak	Int J of Infectious Dis	2009 67
Economic Burden and Catastrophic Costs in TB Treatment: Evidence from Low-Income Countries	Tanimura T	Eur Respir J	2014 735
The Effects on Tuberculosis Treatment Adherence from Utilising Community Health Workers: A Comparison of Selected Rural and Urban Settings in Kenya	Jane Rahedi Ong'ang'o	Plos One	2014 65
Digital Health Technologies to Improve Medication Adherence and Treatment Outcomes in Patients With Tuberculosis: Systematic Review of Randomized Controlled Trials	Ridho	JMIR	2022 104

Discussion

This bibliometric study provides a useful map of the worldwide trends in research on tuberculosis (TB) treatment adherence based on evaluated data from 2000 to 2024, focusing on main thematic issues, intellectual turning points, and promising research frontiers (26, 27). Publishing trends appear to indicate a gradual increase in scholarship output, with a late peak, which coincides with rising worldwide funding for digital health technologies, person-centered care, and socioeconomic research on TB. Nonetheless, the COVID-19 pandemic led to a notable decrease in TB publications between 2020 and 2022, as health systems diverted resources to managing the pandemic response, interrupting TB service delivery, research funding, and field data collection. This finding is consistent with international reports of decreased TB case notification, treatment delays, and increased mortality during the pandemic. Although there is some recovery toward 2022 levels in research productivity, the momentum has not been regained exactly to pre-pandemic levels, further emphasizing the fragility of TB research systems when confronted with global-scale emergencies. (27-30)

Drawing from keyword co-occurrence and clustering, the knowledge structure of TB adherence research formed five main thematic buckets: psychosocial models, economic burden and catastrophic cost; digital adherence technologies; health system and service delivery; mental health and stigma (31-35). Early research focused on psychosocial and behavioral determinants, such as beliefs and the roles of treatment supporters, as well as social capital; however, the emphasis shifted to structural drivers, including health financing, catastrophic costs, and universal health coverage (36–39). Over the last few years, digital adherence technologies (DATs), telemedicine, and mobile health innovations have emerged as key research areas, as the world increasingly adopts technology-led care delivery. However, cross-cluster integration remains limited. For example, digital health studies do not typically embed a behavior change theory or cost-effectiveness analyses, and economic evaluations infrequently take into account the psychological barrier for adherence. To bridge this gap, we propose an increase in interdisciplinary and implementation research that articulates technology with equity, behavior, and health systems preparedness (40-43).

The co-authorship network demonstrates the growing trend of collaboration between high-burden countries (India, Indonesia, South Africa, and Ethiopia) and high-income countries (the USA, the UK, and the Netherlands). The US has become the global leader in articles published, citations, and international collaboration, thanks to a strong research fund, robust surveillance infrastructure, and the capacity to ensure strong institutional leadership. Meanwhile, the rise of institutions in India, Brazil, Indonesia, and China in recent years is indicative of a trend towards local research on TB adherence. However, the engagement of low-resource, high-burden countries, including Nigeria, Pakistan, and Myanmar, has been negligible, indicating ongoing gaps in research funding, digital capacity, and academic infrastructure (44).

Co-citation and timeline results identified the intellectual roots of TB adherence research in early methodological developments, including molecular epidemiology, treatment default analyses, and psycho-behavioral studies, dating back to the late 1990s/early 2000s. Pioneering studies from Alland (1994), Small (1994), and Van Embden (1993) informed early scientific inquiry, and more recent groundbreaking research has addressed digital adherence monitoring, catastrophic costs, integration of mental health care, and patient-centered care models. These studies signal a paradigm shift—adopting a more comprehensive understanding of adherence as a multidimensional issue shaped by psychological, socioeconomic, and structural contributors.

This study also identified significant knowledge gaps, which present opportunities for future research. Despite growing interest in digital adherence interventions, there is limited information about their long-term acceptability, cost-effectiveness, and behavioral impact in low-resource settings. Mental health, adherence behaviour, community involvement, and gender norms. Little evidence exists on the relationship between gender roles, mental health, and community engagement on adherence behaviors--especially for vulnerable groups such as adolescents, migrants, and patients in conflict or urban slum areas. It is urgent to close those gaps, which can be achieved by building research capacity in LMICs, encouraging equitable authorship, and utilizing implementation science paradigms.

Lastly, although this study features a strong bibliometric analysis, it remains limited. The review was limited to English-language publications, which may have omitted non-indexed but locally relevant studies, particularly from LMICs. Furthermore, methods based on citations may underestimate the top-quality publications if they have not had sufficient time to accrue many citations. In the future, combining various sources, including other databases, grey literature, and altmetrics, could enhance coverage and provide a richer context.

Conclusion

This bibliometric study indicates that European and North American institutions are leading the research on TB treatment adherence, both in terms of volume and citation impact. Yet the field is increasingly being moulded by new work contributed from high-burden countries in Africa and Asia. Research has shifted over time from previously studied general and DOTS-based themes to more in-depth, multidimensional topics, including digital adherence technologies (DATs), financial hardship, stigma, mental health, and engagement with health systems. These changes signify an increasing understanding that patient adherence cannot be reduced solely to motivation or behavioral factors but instead is a complex interplay of social background, material situation, psychology, and structure. Going forward, the inclusion of digital health innovations, community-based support, and patient-centred care into larger healthcare systems and social protection systems will be vital. Through a bibliometric analysis that can guide future research priorities between countries, preferred words in the title and keywords were identified, affecting the significance of all included publications. In summary, our study provides valuable references for strengthening international cooperation on the new treatment concept of TB, supporting evidence-based interventions for effective treatment adherence-related aspects worldwide.

Data availability statement

The raw data supporting the findings of this study will be made available by the authors upon reasonable request, without undue restriction.

Author contributions

AF conceived and designed the study. AF and RA performed the data curation, bibliometric processing, and analysis, and then contributed to data interpretation, visualization, and manuscript refinement. All authors participated in drafting, critically revising, and approving the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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