The Global Impact of COVID-19 on Tuberculosis: A Thematic Scoping Review, 2020-2023

(Running Title: Global Impact of COVID-19 on TB)

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Abstract

Background: This thematic scoping review of publications sought to understand the global impact of COVID-19 on tuberculosis (TB), interpret the scope of resonating themes, and offer policy recommendations to stimulate TB recovery and future pandemic preparedness.

Data Sources: Publications were captured from three search engines, PubMed, EBSCO, and Google Scholar, and applicable websites written in English from January 1, 2020, to April 30, 2023.

Study Selection: Our scoping review was limited to publications detailing the impact of COVID-19 on TB. Original research, reviews, letters, and editorials describing the deleterious and harmful—yet sometimes positive— impact of COVID-19 (sole exposure) on TB (sole outcome) were included. The objective was to methodically categorize the impacts into themes through a comprehensive review of selected studies to provide significant health policy guidance.

Data Extraction: Two authors independently screened citations and full texts, while the third arbitrated when consensus was not met. All three performed data extraction.

Data Synthesis/Results: Of 1,755 screened publications, 176 (10%) covering 39 countries over 41 months met the inclusion criteria. Ten principal themes were established, which encompassed TB's care cascade, patient-centered care, psychosocial issues, and health services: 1) case-finding and notification (n=45; 26%); 2) diagnosis and laboratory systems (n=19; 10.7%) 3) prevention, treatment, and care (n=22; 12.2%); 4) telemedicine/telehealth (n=12; 6.8%); 5) social determinants of health (n=14; 8%); 6) airborne infection prevention and control (n=8; 4.6%); 7) health system strengthening (n=22; 13%); 8) mental health (n=13; 7.4%); 9) stigma (n=11; 6.3%); and 10) health education (n=10; 5.7%).

Limitations: Heterogeneity of publications within themes.

Conclusions: We identified ten globally generalizable themes of COVID-19's impact on TB. These thematic areas will guide evidence-informed policies to strengthen comprehensive global responses, recovery for TB, and future airborne pandemic preparedness.

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BACKGROUND

Before the first COVID-19 cases were reported in Wuhan, China, in late 2019 [1-2] and the World Health Organization's (WHO) declaration of COVID-19 as a global pandemic on March 11, 2020 [3], tuberculosis (TB) was the world's leading cause of death from a single infectious disease, causing 1.4 million deaths in 2019 [4]. Global TB deaths declined by 35% between 2009 and 2019, due in part to Member State commitments to WHO's 2015 "End TB Strategy" [5] and the 2018 United Nations High-Level Meeting declaration to end the TB epidemic [6].

The global spread of COVID-19 likely derailed the promise of and trajectory for ending TB in this decade. COVID-19 wiped out over 12 years of hard-fought gains, such as increased TB detections and decreased TB-related mortality [7]. The initial marked drop in the reported number of newly diagnosed TB cases dropped from a peak of 7.1 million in 2019 to 5.8 million in 2020—a decline of 18% [8]. It is estimated that there will be 4,702,800 TB cases and an additional 1,044,800 TB deaths worldwide between 2020 and 2025 due to the disruptions in TB

detection and treatment during lockdowns, and the prioritization of COVID-19 services [9]. By 2022, the WHO [10] stated, "…the COVID-19 pandemic continues to have a damaging impact on access to TB diagnosis and treatment and the burden of TB disease."

We conducted a scoping review to explore the impact, effect, and aftermath of COVID-19 on all aspects of TB, from the clinical cascade to patient-centered care, provision, and psychosocial issues. Based on our analysis, we identified ten principal themes and expanded the traditional model of a scoping review by offering policy recommendations aligned with these principal themes. This review and discussion target policymakers. As COVID-19 continues to cause morbidity and mortality, and the threat of future airborne infection pandemics remains a real possibility, it seemed prudent to offer TB policy recommendations to global and national leaders to build and maintain a robust TB infrastructure with surge capacity for response, recovery, and resilience.

METHODS

The analysis of publications and grey literature was conducted to identify and define resonating themes of COVID-19's global impact on TB and inform policy recommendations to assist in TB resilience, recovery, and future pandemic preparedness. This scoping review was conducted in accordance with PRISMA Extension for Scoping Reviews guidelines and Joanna Briggs Institute (JBI)methodology [11-12] (Appendix 1, JBI Protocol, and published at DOI: https://doi.org/10.6084/m9.figshare.24566842.v1; Appendix 2, "Checklist")

Data Sources and Searches

We included qualitative and quantitative original research, case series, letters to the editor, editorials, and review articles that met the inclusion criteria. On May 1, 2023, publications written in English were captured from three search engines: PubMed, EBSCO, Google Scholar, and global health multilateral websites from January 1, 2020, to April 30, 2023. The PubMed search terms, which originated from the consensus in review team meetings, were: *((Mycobacterium tuberculosis or tuberculosis or TB [MeSH Terms])) AND ((COVID-19 or COVID or pandemic COVID-19 or coronavirus or sars-cov-2 [MeSH Terms])) AND ((primary healthcare or health services or healthcare system [MeSH Terms]))).* (See Appendix 1a: "Search Strategy" for the search terms employed for EBSCO and Google Scholar.)

This search strategy was designed to be wide-ranging and purposeful to include as many studies as possible from low- and middle-income counties (LMIC). Identified citations were uploaded to EndNote™ 20 (Clarivate™) and transferred to COVIDENCE systematic review software for screening.

Study Selection

The Population, Concept, and Context (PCC) framework [11] was applied to assist the review team in setting eligibility criteria. The inclusion criteria stipulated that the literature must discuss COVID-19 (the sole exposure) as the impact, effect, or consequence of any aspect of TB (the sole outcome). Letters to the editor and editorials were required to contain original data or substantive recommendations. We excluded 1) published abstracts; 2) magazines; 3) online

pre-publications that were never published; and 4) literature focusing on the clinical sequelae of COVID-19 and TB co-infection, or co-infection dynamics between TB and COVID-19 with other illnesses (e.g., HIV, diabetes).

MHM and KGC conducted independent screening of titles and abstracts; when disagreement occurred, SA adjudicated. MHM and KGC conducted independent full-text reviews with SA, confirming ineligible publications.

Data Extraction and Quality Assessment

Data were extracted independently by the three authors using a data extraction tool developed by the review team (Appendix 1b; Table 1). Descriptive variables extracted included author(s), geography, publication year, publication type, and perceived themes.

Data Synthesis and Analysis

Determining the resonating themes of publications and how many were decided by consensus. Analysis of a publication's sub-themes was essential for proper categorization. While a publication's title/topic pointed to a specific theme (e.g., case-finding and notification), there were instances when it was added to a different theme because of substantial, pertinent discussions on additional underlying causes or solutions. Themes and their respective publications were presented in tabular form (Appendix 3) with a narrative summary describing how each related to COVID-19's global impact on TB.

Role of the Funding Source

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RESULTS

Figure 1 describes the selection process for publication. Three search engines identified 1,755 publications: PubMed (n=701), EBSCO (n=105), and Google Scholar (n=701). Through citation searching, 35 additional publications were captured; 4 were grey literature. There were 114 duplicate titles, leaving 1,674 publications for title and abstract screening. There was agreement from MHM and KGC that 1,426 were irrelevant—i.e., not meeting inclusion criteria––with a discrepancy of 33. SA adjudicated, characterizing all 33 irrelevant, leaving 1,459 discarded and 217 publications moving to full-text review. Of the full texts reviewed by MHM and KGC, 41 were ineligible, with confirmation by SA. Thus, 176 publications went forward for data capturing and analysis.

Figure 1. Scoping Review Schema **Courtesy of COVIDENCE**

In our analyses of 176 publications from 39 countries covering 41 months, ten principal themes (as depicted in Figure 2) were identified characterizing the breadth of the global impact of COVID-19 on TB: 1) case-finding and notification (n=45; 26%); 2) diagnosis and laboratory systems (n=19; 10.7%); 3) prevention, treatment, and care (n=22; 12.2%); 4) telemedicine/telehealth (n=12; 6.8%); 5) social determinants of health (n=14; 8%); 6) airborne

infection prevention and control (n=8; 4.6%); 7) health system strengthening (n=22; 13%); 8) mental health (n=13; 7.4%); 9) stigma (n=11; 6.3%); and 10) health education (n=10; 5.7%).

Figure 2. Ten Themes Characterizing the Global Impact of COVID-19 on TB

Case-Finding and Notifications

A quarter of the publications (n=45) from over 20 counties [7, 9, 13-55] addressed the deleterious impact of COVID-19 on active TB case-finding, notification, and contact tracing during multiple lockdowns and restrictions. Globally, TB case-finding and notification decreased by an estimated 18% between 2019 and 2020 [8], yet resilient TB programs initiated measures to address this drop-off when community health workers (CHWs) were overwhelmed by COVID-19 testing and response activities. A retrospective data analysis of the impact of COVID-19 on TB case notification and other indicators from Migliori et al. [39] covered five continents and drew data from 43 TB centers in 19 countries. TB case notification decreased from 32,898 in 2019 to 16,396 in 2020; the most precipitous decline occurred in March 2020. Only two counties, Australia, and Singapore, and one state (Virginia, in the U.S.) did not report decreases.

To help blunt the precipitous global decline in TB case notification, finding, and detection, Sahu, et al. [7] stressed the urgency of resilience and recovery from COVID-19 by fast-tracking the 2018 United Nations General Assembly High-Level Meeting TB targets [6] and aligning vaccination services with active early case finding and other community-based TB services.

Publications from several countries described the diversion of resources from TB to COVID-19 and how multiple lockdowns during the pandemic negatively impacted active case-finding and contact investigations, markedly decreasing the detection of people with TB disease or TB infection [7, 15, 17, 26, 30, 43, 52-55]. A few publications [7, 17, 53-55] acknowledged that digital tools developed and deployed for COVID-19 contact tracing could help facilitate future TB contact investigations. Pai, et al. [54] described the need for targeted active case-finding initiatives employing portable digital X-ray systems with artificial intelligence (AI) software. Ruhwald, et al. [53] asserted that the novel use of COVID-19 molecular technologies and bi-directional testing will benefit TB diagnosis and reduce reliance on suboptimal tools, such as smear microscopy. Sahu, et al. [7] asserted that these advanced diagnostics must be readily implemented in the community to meet people where they live. Finally, Chan, et al. [17] highlighted the benefits and risks of using molecular technology in the community.

Diagnosis and Laboratory Systems

Nineteen publications [56-74] focused on COVID-19's detrimental impacts on TB diagnosis, laboratory capacity and systems, and the supply chain.

Mauer, et al. (73) detailed a WHO survey of 31 national TB reference laboratories in the European Union and the United Kingdom, reporting that COVID-19-related disruptions to TB laboratory services peaked from March to June 2020. The core laboratory setbacks were: 1) sample turnaround time; 2) access to external quality assessment; and 3) availability of diagnostic services.

Tovar, et al. [72] conducted a modelling analysis to determine the impact of COVID-19 setbacks in TB diagnostic and laboratory services on patient mortality in India, Indonesia, Kenya, and Pakistan in 2022. They calculated that stark, pandemic-related reductions in new TB diagnoses could result in 378,000 excess deaths across the four countries.

Integrating COVID-19 and TB testing was proposed by MacLean, et al. [63] as a solution to identify and diagnose more people with TB disease. They contended that during the pandemic, too many people refrained from accessing healthcare, including essential TB testing. They provided integrated testing recommendations for 1) urban settings with the highest TB prevalence and those vulnerable to COVID-19; 2) rural settings in high-burden countries to improve the quality of patient care; and 3) countries with high HIV prevalence.

In 2020, Aswathi and Singh [74] provided solutions for India's TB diagnostic and laboratory obstacles. They called for the Indian government to increase testing by arranging additional machines and increasing the number of shifts for laboratory testing. Furthermore, they called for the Government's TB Program to offer upfront TB testing with GeneXpert® or Truenat® instead of smear microscopy.

Prevention, Treatment, and Care

Twenty-two publications [75-96] centered on the pandemic's negative impact on TB prevention, treatment, and care in diverse patient populations; some proposed measures to optimize TB treatment.

In a 2023 rapid review from South Korea, Jeong et al. [83] reported that global detection and treatment of TB infection were among the most negatively impacted steps in the TB cascade across low-, middle-, and high-income countries (LMHC). Two retrospective data analyses comparing TB preventive treatment initiation before and during the pandemic reported a 44.7% decline in Addis, Ethiopia [76] and 30% and 66% in Montreal and Toronto, Canada [77], respectively.

The pandemic resulted in global stockouts of BCG vaccine for infants [89, 94]. Namkoong, et al. [89] hypothesized that the vaccine shortage was partly caused by WHO's supplier withdrawal due to production issues, which left UNICEF [97] with a 30% decrease in supply. Another explanation was the renewed interest in basic science research [98] that supported BCG's enhancement of immune responses. This led to off-label use, even after the publication of results from a failed efficacy trial of BCG for COVID-19 prevention [99].

Arega et al. [76] conducted a retrospective data analysis of TB treatment outcomes in Ethiopia, finding that the TB treatment success rate decreased by 17% between March 2019 and March 2020 and that rifampicin resistance (RR) increased by 27.7%.

The increase of RR/multidrug-resistant (MDR) TB was observed in different settings during the pandemic. From the proceedings of the National Academies of Sciences workshop, "Innovations for Tackling Tuberculosis in the Time of COVID-19," Salmaan Keshavjee [90] underscored the

263 necessity of continuing TB treatment during the pandemic by administering the most tolerable
264 and shortest DS-TB, and all-oral DR TB regimens, and promoting treatment adherence.
265
266 ***Telemedicine/Telehealth***
267 Twelve publications [100-111] discussed how LMIC swiftly implemented telehealth
268 interventions to offset COVID-19 disruptions in TB services. Various digital tools enabled virtual
269 case identification, TB care, treatment, and adherence [4].
270
271 A rapid assessment of telemedicine's potential to optimize TB care and treatment was
272 conducted by Klinton et al. [102] during March – December 2020 in seven high-burden
273 countries. The interventions included telemedicine/telehealth platforms (e.g., text messages,
274 phone, and video) enabling consultations, video-observed therapy (VOT) for adherence, refill
275 reminders, and novel diagnostic platforms such as AI-based and portable digital chest X-rays.
276 Researchers noted that digital tools could strengthen the diagnostic capacity of TB programs,
277 enhance patient-centered care, decentralize TB services, and contribute towards progress in
278 achieving the EndTB goals.
279
280 Calnan, et al. [107] described a phone-based TB case-finding and case-management
281 intervention launched in two regions of the Philippines between October 2020 and September
282 2021. Fourteen TB contact centers conducted TB screening and contact investigation and
283 provided information about testing, delivery of test results, and adherence support. Call centers
284 identified 9.2% of people with TB in the region, of which 43.5% (827/1,901) initiated treatment.

A cost-benefit analysis compared the new telehealth service versus standard-of-care (SOC) case-finding interventions found that the 1-year cost for implementing call centers totaled USD 557 per patient, only USD 7.00 more than SOC.

A 197-person study by Visca, et al. (108) compared the effectiveness and cost of VOT versus clinic-based directly observed therapy (DOT) in Moldova. They found that VOT significantly improved adherence (1.29 missed days versus 5.24 missed days) over two weeks spent on clinic transport among VOT patients by 58 hours.

Social Determinants of Health

Fourteen publications [112-125] addressed social determinants of health (SDH) and COVID-19's outsized effect on vulnerable populations and offered solutions to mitigate them. Singh et al. [112] summarized the contribution of SDH to an additional 700,000 undiagnosed and missing active TB cases in Southeast Asia between 2019 and 2020, noting that the pandemic adversely impacted the nutritional status and BMI of the affected populations, which, in turn, was likely to have contributed to secondary immunodeficiency and an influx of undiagnosed TB cases.

In a 2020 editorial, Saunders et al. [115] proposed social protection interventions–"safety nets"—for vulnerable populations, noting that impoverished, at-risk TB populations could not work and access funds to provide social protection during lockdowns. They recommended special provisions, including cash transfers or food parcels for TB-affected households. Notably,

306 they called for psychosocial support for affected households and access to digital technology to
307 improve equity and access to virtual care during lockdowns.
308
309 In Brazil, Souza, et al. [123] surveyed healthcare workers about the surge in MDR TB during the
310 first two waves of COVID-19, documenting an association between MDR TB cases and SDH (e.g.,
311 poverty, vulnerability, and social risk). Weakened adherence was associated with cuts in social
312 protection and benefits.
313

314 *Airborne Infection Prevention and Control*

315 Eight publications [126-133] addressed airborne infection prevention and control and personal
316 protective equipment (PPE) for healthcare workers and people with TB.
317
318 Mannan et al. [126] from Joint Effort for Elimination of TB (JEET) in India, a nationwide Global
319 Fund project across 406 districts in 23 states, surveyed 21,750 physicians between February
320 and March 2021. Many survey questions examined infection prevention and control measures
321 (IPC) implemented in their clinics due to COVID-19. Approximately 82% of surveyed providers
322 employed social distancing and increased the interval between patients' appointments. While
323 70% reported knowledge that IPC measures could decrease TB transmission, 62% initiated PPE
324 use, and only 13% physically implemented physical changes (e.g., air filters and isolation of
325 patient areas).
326

To prevent airborne infections in TB diagnostic and treatment centers, Awan, et al. [127] proposed several measures at clinics: building and maintaining sizeable outdoor patient waiting areas, installing ventilation and air circulation exhaust systems in clinics, ultraviolet germicidal irradiation lights, and designated sputum expectoration areas.

The shortage of PPE during COVID-19 was echoed in multiple publications from various countries [129-131]. Jain and colleagues [130] reviewed literature published in India in May 2020, which underscored complaints about the paucity of PPE, noting that this made it impossible for HCWs to provide safe, regular healthcare services for people with TB. Moreover, healthcare workers were fearful and reluctant to take samples from people with TB due to a lack of appropriate PPE.

Health System Strengthening

National TB Programs (NTP) in many LMICs were hobbled and underperformed well before the advent of COVID-19. The pandemic imposed an unprecedented burden, leaving programs and services faltering. Twenty publications examined the need for health system strengthening (HSS) [134-155].

Khan, et al. [139] cited NTP data on widespread disruptions across the care cascade in Pakistan during 2020 due to limited and dwindling resources. Between March 1 and June 30, 2020, GeneXpert® machines and hospital isolation wards were re-directed from TB to COVID-19, delayed TB diagnoses. Meanwhile, outpatient TB visits dropped by 59.55%, and hospitalizations

348 declined by 50.7%, increasing the risk of household transmission. Due to staffing shortages, TB
349 treatment was often interrupted, and follow-up visits were delayed or canceled.
350
351 Some publications addressed TB differentiated service delivery (DSD) as an essential facet of
352 strengthening health systems [148, 150, 153-154]. DSD models (such as multi-month
353 dispensing, pickup points for or home delivery of medications, and VOT) quickly emerged,
354 allowing TB services to continue outside the clinic during lockdowns. While piecemeal DSD
355 models for TB were rolled out in the past, these were developed and deployed in an expansive,
356 global, warp-speed offensive during the pandemic [101, 104, 146].
357
358 Klinton et al. [142] observed a silver lining for TB HSS, noting global resilience, recovery, and
359 innovative improvements despite the erosion of TB services during the pandemic. The private
360 sector enabled the rapid deployment of innovations that improved TB services and health
361 systems, demonstrating resilience by adapting guidelines, policies, and digital tools to improve
362 accessibility, acceptability, and quality of TB prevention, care, and treatment. The pandemic
363 experience highlighted the importance of strengthening and adapting TB health system
364 services, and the essential role of public-private partnerships in maintaining them. These
365 observed benefits strengthened overall health systems well beyond TB services.
366
367 ***Mental Health***
368 Depression is more prevalent among people with TB than in the general population. A 2020
369 systematic review and meta-analysis by Ruiz-Grosso, et al. [156] documented a strong

association between TB and depression that caused adverse TB treatment outcomes, including poor adherence, loss-to-follow-up, and death. Thirteen publications [157-169] discussed mental health concerns, emphasizing the escalation of fear and anxiety among people with TB during the pandemic.

Loveday, et al. [157] noted that lockdowns and other COVID-19 restrictions in South Africa posed harsh financial consequences for people who were already economically vulnerable, contributing to anxiety, stress, and depression among people with TB.

Pronounced fear and anxiety were evident in an 842-person global survey [162] coordinated by nine TB non-governmental organizations (NGOs). Qualitative and quantitative data were collected from people with TB and survivors, healthcare workers, NTP staff, civil society, and advocates between May 26, 2020, and July 2, 2020. Over half of the people with TB reported feeling increased vulnerability to and fear of contracting COVID-19, which prevented some of them from seeking treatment. This study and others [154-157] mentioned that healthcare workers feared seeing patients because of anxiety about acquiring COVID-19 and transmitting it to their families.

During the pandemic, a novel telehealth approach to assess mental health among people with TB and healthcare providers was implemented in Pakistan [159]. Through regular phone calls, mental health providers checked emotional well-being and screened people for depression and anxiety. Additional support was provided for those who acquired COVID-19.

Stigma

Eleven publications [170-180] addressed TB-related stigma, the populations most affected, and its adverse effects—especially during COVID-19—and solutions to combat it.

Dheda et al. [180] shared their frank views of TB-related stigma in a 2022 commentary. They asserted that "social stigma kills," noting that it is repugnant for people who battle airborne infectious diseases in isolation to fight social stigma simultaneously.

Mahnoor Islam [173] wrote that TB-related stigma during the height pandemic led to poor treatment outcomes. He asserted that the stigma of respiratory symptoms faced by people with TB, which COVID-19 often compounded, led to a reluctance to visit healthcare facilities, thus enabling drug resistance because of incomplete therapy.

Anti-stigma interventions must be specifically tailored to patient groups (e.g., women and girls) in different countries. In a commentary on COVID-19 and TB in Pakistan, Fatima et al. [172] asserted that the best way to alleviate the stigma of TB for women and girls is to develop and employ TB interventions in rural communities with the aid and expertise of lady health workers.

Health Education

Ten publications [181-190] addressed the need for TB patient education programs and community information campaigns to assuage fear, anxiety, and stigmatization, which leads those with TB—and undiagnosed people— to avoid clinics for fear of COVID-19. Likewise,

412 educating TB healthcare workers about COVID-19 and how to reduce their risk is essential for
413 them to feel safe and continue working.
414
415 An Iranian qualitative study by Shahnavazi, et al. [190] discussed the reduction in time HCWs
416 had for patient education and follow-up instructions during the pandemic. HCW disclosed that
417 they only had enough time to dispense TB medication before abruptly leaving to attend to
418 COVID-19 duties.
419
420 In 2021, Nkereuwem, et al. [181] surveyed European and West African healthcare workers in
421 2021. Many of the respondents underscored the importance of intensified health education.
422 One respondent said TB education campaigns can help remind the world “not to forget TB” and
423 make people aware that a chronic cough may not be from COVID-19. Another respondent
424 decreed that there must be more public education on TB because COVID-19 overshadowed
425 messaging about other diseases. Some urged NTPs to offer timely statements and guidance on
426 routine TB screening, diagnosis, and treatment during COVID-19 and future pandemics.
427
428 Chapman et al. [182] noted that digital health interventions exist to transform TB care by
429 disseminating essential health information that supports treatment adherence and encourages
430 health-seeking behaviors among people with TB. They addressed the need for public health
431 communication campaigns to combat the “infodemic,” which they defined as “the rapid spread
432 of false information on TB and COVID-19.”
433

DISCUSSION

This comprehensive scoping review assessed the global impact of COVID-19 on TB. It covers the most prolonged publication period (41 months [January 1, 2000 – April 30, 2023]) and the most significant number of publications analyzed (n=176) from 39 countries. The timespan includes publications with data and perspectives from multiple pandemic waves—the COVID-19 Wuhan-Hu-1, Delta, and Omicron variants.

This scoping review sought to be inclusive of publications from LMIC in an effort to add to prior publications from high-income countries. By casting a wide net, we were able to detail the diversity of complex TB issues and conditions faced globally by many countries, cultures, and patient populations during the pandemic. The analysis of 176 publications yielded ten key themes, categorized into areas such as the tuberculosis care cascade, patient-centered care, and psychosocial issues. Many publications, mainly reviews and editorials, had overlapping themes.

Several publications, across all themes, offered recommendations for combatting a wide range of TB issues [7, 54, 74, 83, 90, 108, 117, 127, 137, 139, 142, 153, 157, 172, 174, 180-181]. Some recommendations took a “glass half-full” approach by addressing the potential for positive, post-pandemic impacts on TB—leveraging and retrofitting aspects of the pandemic response, such as new developments in case-finding, diagnostics, and health education.

There are limitations in our scoping review. Some letters to the editors, which were included due to an a priori requirement that original data be discussed, risked the inclusion of data not validated for accuracy. We also detected heterogeneity of publications within themes.

This all-inclusive scoping review established that, despite geographic and income-level heterogeneity, there are several generalizable themes between countries on the impact of COVID-19 on TB. The intensity and magnitude of illness and death from COVID-19 in 2020 rapidly overwhelmed TB programs. Consequently, the TB infrastructure and workforce were repurposed for the COVID-19 response. It will take time for TB programmatic aspects to fully recover and regain a sense of normalcy and productivity.

The most recent 2023 United Nations General Assembly High-Level Meeting on TB included commitments to universal health coverage, pandemic prevention, preparedness, and response, and the fight against TB, underscoring the crucial need to simultaneously strengthen and address urgent realities and serious threats [191, 192]. The ten themes identified through this scoping review provide a framework for comprehensive progress by TB programs to simultaneously achieve the End TB goal and address future airborne disease pandemics.

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REFERENCES

1. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020;395(10223):497-506. doi: 10.1016/s0140-6736(20)30183-5.
2. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A Novel Coronavirus from Patients with Pneumonia in China, 2019. N Engl J Med. 2020;382(8):727-33. doi: 10.1056/NEJMoa2001017.
3. World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. Available from: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020
4. World Health Organization. Global Tuberculosis Report 2020. Available from: https://www.who.int/publications/i/item/9789240013131
5. World Health Organization. The End TB Strategy. Available from: https://iris.who.int/bitstream/handle/10665/331326/WHO-HTM-TB-2015.19-eng.pdf?sequence=166.
6. United Nations General Assembly Resolution A/RES/73/3**.** Political declaration of the high-level meeting of the General Assembly on the fight against tuberculosis. Recovering from the Impact of the Covid-19 Pandemic and Accelerating to Achieving the United Nations General Assembly Tuberculosis Targets, October 2018. Washington, DC. Available from: https://www.undocs.org/en/A/RES/73/3
7. Sahu S, Ditiu L, Sachdeva KS, Zumla A**.** Recovering from the Impact of the Covid-19 Pandemic and Accelerating to Achieving the United Nations General Assembly Tuberculosis Targets. Int J Infect Dis. 2021;113 Suppl 1:S100-3. doi: 10.1016/j.ijid.2021.02.078.
8. World Health Organization. Global Tuberculosis Report 2021. Available from: https://www.who.int/publications/i/item/9789240037021

9. Cilloni L, Fu H, Vesga JF, Dowdy D, Pretorius C, Ahmedov S, et al. The potential impact of the COVID-19 pandemic on the tuberculosis epidemic a modelling analysis. EClinicalMedicine. 2020;28:100603. doi: 10.1016/j.eclinm.2020.100603.

10. World Health Organization. Global Tuberculosis Report 2022. Available from: https://www.who.int/teams/global-tuberculosis-programme/tb-reports/global-tuberculosis-report-2022

11. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467-73. doi: 10.7326/m18-0850.

12. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. JBI Evid Implementation. 2021;19(1):3-10. doi: 10.1097/xeb.0000000000000277.

13. Alene KA, Wangdi K, Clements ACA**.** Impact of the COVID-19 pandemic on tuberculosis control: An Overview. Trop Med Infect Dis. 2020;5(3):123. doi: 10.3390/tropicalmed5030123.

14. Arentz M, Ma J, Zheng P, Vos T, Murray CJL, Kyu HH**.** The impact of the COVID-19 pandemic and associated suppression measures on the burden of tuberculosis in India. BMC Infect Dis. 2022;22(1):92. doi: 10.1186/s12879-022-07078-y.

15. Aznar ML, Espinosa-Pereiro J, Saborit N, Jové N, Sánchez Martinez F, Pérez-Recio S, et al. Impact of the COVID-19 pandemic on tuberculosis management in Spain. Int J Infect Dis. 2021;108:300-5. doi: 10.1016/j.ijid.2021.04.075.

16. Bhargava A, Bhargava M, Meher A**.** Universal health coverage and tuberculosis care in India in the times of Covid-19: Aligning Ayushman Bharat (National Health Assurance Scheme) to improve case detection, reduce deaths and catastrophic health expenditure. Natl Med J India. 2020;33(5):298-301. doi: 10.4103/0970-258x.303111.

17. Chan G, Triasih R, Nababan B, du Cros P, Wilks N, Main S, et al. Adapting active case-finding for TB during the COVID-19 pandemic in Yogyakarta, Indonesia. Public Health Action. 2021;11(2):41-9. doi: 10.5588/pha.20.0071.

18. Choi H, Ko Y, Lee CY, Chung SJ, Kim HI, Kim JH, et al. Impact of COVID-19 on TB epidemiology in South Korea. Int J Tuberc Lung Dis. 2021;25(10):854-60. doi: 10.5588/ijtld.21.0255.

19. Crowder R, Geocaniga-Gaviola DM, Fabella RA, Lim A, Lopez E, Kadota JL, et al. Impact of shelter-in-place orders on TB case notifications and mortality in the Philippines during the COVID-19 pandemic. J Clin Tuberc Other Mycobact Dis. 2021;25:100282. doi: 10.1016/j.jctube.2021.100282.

20. Datta B, Jaiswal A, Goyal P, Prakash A, Tripathy JP, Trehan N**.** The untimely demise of the TB Free block model in the wake of coronavirus disease 2019 in India. Trans R Soc Trop Med Hyg. 2020;114(11):789-91. doi: 10.1093/trstmh/traa067.

21. de Souza CDF, Coutinho HS, Costa MM, Magalhaes M, Carmo RF**.** Impact of COVID-19 on TB diagnosis in Northeastern Brazil. Int J Tuberc Lung Dis. 2020;24(11):1220-2. doi: 10.5588/ijtld.20.0661.

22. Ding W, Li Y, Bai Y, Li Y, Wang L, Wang Y**.** Estimating the effects of the COVID-19 outbreak on the reductions in tuberculosis cases and the epidemiological trends in China: a causal impact analysis. Infect Drug Resist. 2021;14:4641-55. doi: 10.2147/IDR.S337473.

23. Fei H, Yinyin X, Hui C, Ni W, Xin D, Wei C, et al. The impact of the COVID-19 epidemic on tuberculosis control in China. Lancet Reg Health West Pac. 2020;3:100032. doi: 10.1016/j.lanwpc.2020.100032.

24. Maia CMF, Martelli DRB, Silveira D, Oliveira EA, Martelli Junior H**.** Tuberculosis in Brazil: the impact of the COVID-19 pandemic. J Bras Pneumol. 2022;48(2):e20220082. doi: 10.36416/1806-3756/e20220082.

25. Gigante AR, Sousa M, Aguiar A, Pinto M, Gaio R, Duarte R**.** The impact of COVID-19 on the TB response: data from the field. Int J Tuberc Lung Dis. 2021;25(9):769-71. doi: 10.5588/ijtld.21.0149.

26. Godoy P, Parrón I, Barrabeig I, Caylà JA, Clotet L, Follia N, et al. Impact of the COVID-19 pandemic on contact tracing of patients with pulmonary tuberculosis. European Journal of Public Health. 2022;32(4):643-7. doi: 10.1093/eurpub/ckac031.

27. Golandaj JA**.** Pediatric TB detection in the era of COVID-19. Indian J Tuberc. 2022;69(1):104-8. doi: 10.1016/j.ijtb.2021.04.015.

28. Hasan T, Nguyen VN, Nguyen HB, Nguyen TA, Le HTT, Pham CD, et al. Retrospective Cohort Study of Effects of the COVID-19 Pandemic on Tuberculosis Notifications, Vietnam, 2020. Emerg Infect Dis. 2022;28(3):684-92. doi: 10.3201/eid2803.211919.

29. Iyengar KP, Jain VK**.** Tuberculosis and COVID-19 in India- double trouble! Indian J Tuberc. 2020;67(4s):S175-6. doi: 10.1016/j.ijtb.2020.07.014.

30. Kadota JL, Reza TF, Nalugwa T, Kityamuwesi A, Nanyunja G, Kiwanuka N, et al. Impact of shelter-in-place on TB case notifications and mortality during the COVID-19 pandemic. Int J Tuberc Lung Dis. 2020;24(11):1212-14. doi: 10.5588/ijtld.20.0626.

31. Komiya K, Yamasue M, Takahashi O. The COVID-19 pandemic and the true incidence of Tuberculosis in Japan. J Infect. 2020;81(3):e24-e25. doi: 10.1016/j.jinf.2020.07.004.

32. Kwak N, Hwang S-S, Yim J-J**.** Effect of COVID-19 on tuberculosis notification, South Korea. Emerg Infect Dis. 2020;26(10):2506-8. doi: 10.3201/eid2610.202782.

33. Lebina L, Dube M, Hlongwane K, Brahmbatt H, Lala SG, Reubenson G, et al. Trends in paediatric tuberculosis diagnoses in two South African hospitals early in the COVID-19 pandemic. S. Afr. Med. J.. 2020;110(12):1149-51. doi: 10.7196/SAMJ.2020.v110i12.15386.

34. Lewer D, Mulchandani R, Roche A, Cosgrove C, Anderson C**.** Why has the incidence of tuberculosis not reduced in London during the COVID-19 pandemic? Lancet Respir Med. 2022;10(3):231-3. doi: 10.1016/s2213-2600(22)00012-1.

35. Liu Q, Lu P, Shen Y, Li C, Wang J, Zhu L**.** Collateral impact of the coronavirus disease 2019 (COVID-19) pandemic on tuberculosis control in Jiangsu Province, China. Clin Infecti Dis. 2021;73(3):542-4. doi: 10.1093/cid/ciaa1289.

36. Martin-Hughes R, Vu L, Cheikh N, Kelly SL, Fraser-Hurt N, Shubber Z, et al. Impacts of COVID-19-related service disruptions on TB incidence and deaths in Indonesia, Kyrgyzstan, Malawi, Mozambique, and Peru: implications for national TB responses. PLOS Glob Public Health. 2022;2(3):e0000219. doi: 10.1371/journal.pgph.0000219.

37. McQuaid CF, Henrion MYR, Burke RM, MacPherson P, Nzawa-Soko R, Horton KC**.** Inequalities in the impact of COVID-19-associated disruptions on tuberculosis diagnosis by age and sex in 45 high TB burden countries. BMC Med. 2022;20(1):432. doi: 10.1186/s12916-022-02624-6.

38. McQuaid CF, McCreesh N, Read JM, Sumner T, Houben R, White RG, et al. The potential impact of COVID-19-related disruption on tuberculosis burden. Eur Respir J. 2020;56(2):2001718. doi: 10.1183/13993003.01718-2020.

589 39. Migliori GB, Thong PM, Alffenaar JW**.** Country-specific lockdown measures in response to the COVID-19
590 pandemic and its impact on tuberculosis control: a global study. J Bras Pneumol. 2022;48(2):e20220087.
591 doi: 10.36416/1806-3756/e20220087.
592 40. Migliori GB, Thong PM, Alffenaar JW, Denholm J, Tadolini M, Alyaquobi F, et al. Gauging the impact of the
593 COVID-19 pandemic on tuberculosis services: a global study. Eur Respir J. 2021;58(5) doi:
594 10.1183/13993003.01786-2021.
595 41. Odume B, Falokun V, Chukwuogo O, Ogbudebe C, Useni S, Nwokoye N, et al. Impact of COVID-19 on TB
596 active case finding in Nigeria. Public Health Action. 2020;10(4):157-62. doi: 10.5588/pha.20.0037.
597 42. Ortiz-Martínez Y, Rodríguez-Morales AJ, Henao-Martínez AF**.** Decreased notification of TB cases during the
598 COVID-19 pandemic. Int J Tuberc Lung Dis. 2022;26(2):177-8. doi: 10.5588/ijtld.21.0651.
599 43. Ozdemir S, Oztomurcuk D, Oruc MA**.** Impact of the COVID-19 pandemic on tuberculosis patients and
600 tuberculosis control programs in Turkey, review and analysis. Arch Public Health. 2022;80(1):252. doi:
601 10.1186/s13690-022-01007-w.
602 44. Ranasinghe L, Achar J, Gröschel MI, Whittaker E, Dodd PJ, Seddon JA**.** Global impact of COVID-19 on
603 childhood tuberculosis: an analysis of notification data. Lancet Glob Health. 2022;10(12):e1774-81. doi:
604 10.1016/s2214-109x(22)00414-4.
605 45. Tok PSK, Kamarudin NA, Jamaludin M, Ab Razak MF, Ahmad MAS, Abu Bakar FA, et al. Effect of COVID-19
606 on tuberculosis notification in Johor Bahru, Malaysia. Infect Dis. 2022;54(3):235-7. doi:
607 10.1080/23744235.2021.2000636.
608 46. Wang X, He W, Lei J, Liu G, Huang F, Zhao Y**.** Impact of COVID-19 pandemic on pre-treatment delays,
609 detection, and clinical characteristics of tuberculosis patients in Ningxia Hui Autonomous Region, China.
610 Front Public Health. 2021;9:644536. doi: 10.3389/fpubh.2021.644536.
611 47. World Health Organization. Impact of the COVID-19 pandemic on TB detection and mortality in 2020.
612 Accessed from: https://www.who.int/publications/m/item/impact-of-the-covid-19-pandemic-on-tb-
613 detection-and-mortality-in-2020 on May 9, 2023
614 48. Wu Z, Chen J, Xia Z, Pan Q, Yuan Z, Zhang W, et al. Impact of the COVID-19 pandemic on the detection of
615 TB in Shanghai, China. Int J Tuberc Lung Dis. 2020;24(10):1122-4. doi: 10.5588/ijtld.20.0539.

49. Xu C, Li T, Hu D, Zhang H, Zhao Y, Liu J**.** Predicted Impact of the COVID-19 responses on deaths of tuberculosis - China, 2020. China CDC Wkly. 2021;3(2):21-4. doi: 10.46234/ccdcw2021.004.

50. Xu J, Wang Y, Liu F, Yang H**.** Changes of tuberculosis infection in mainland China before and after the COVID-19 pandemic. J Infect. 2023;86(2):154-225. doi: 10.1016/j.jinf.2022.12.008.

51. Zamani S, Honarvar MR, Behnampour N, Sheikhy M, Sedaghat M, Ghaemi S, et al. Decline in TB incidence during the COVID-19 pandemic. Int J Tuberc Lung Dis. 2021;25(12):1043-4. doi: 10.5588/ijtld.21.0548.

52. Burzynski J, Macaraig M, Nilsen D, Schluger NW**.** Transforming essential services for tuberculosis during the COVID-19 pandemic: lessons from New York City. Int J Tuberc Lung Dis. 2020;24(7):735-6. doi: 10.5588/ijtld.20.0283.

53. Ruhwald M, Carmona S, Pai M**.** Learning from COVID-19 to reimagine tuberculosis diagnosis. The Lancet Microbe. 2021;2(5):e169-70. doi: 10.1016/s2666-5247(21)00057-4.

54. Pai M, Kasaeva T, Swaminathan S**.** Covid-19's devastating effect on tuberculosis care—a path to recovery. N Engl J Med. 2022;386(16):1490-3. doi: 10.1056/NEJMp2118145.

55. Tobing KL, Letelay AM, Senewe FP, Lolong DB, Pracoyo NE, Susanti L, et al. TB Active case-finding before and during the Covid-19 pandemic. Proceedings of the 1st International Conference for Health Research – BRIN (ICHR 2022); 2023:469-81.;2023:469-81.

56. Bardhan M, Hasan MM, Ray I, Sarkar A, Chahal P, Rackimuthu S, et al. Tuberculosis amidst COVID-19 pandemic in India: unspoken challenges and the way forward. Trop Med Health. 2021;49(1):84. doi: 10.1186/s41182-021-00377-1.

57. Di Gennaro F, Gualano G, Timelli L, Vittozzi P, Di Bari V, Libertone R, et al. Increase in tuberculosis diagnostic delay during first wave of the COVID-19 pandemic: data from an Italian infectious disease referral hospital. Antibiotics (Basel). 2021;10(3):272. doi: 10.3390/antibiotics10030272.

58. Diallo A, Combary A, Veronese V, Dahourou DL, Ouédraogo S, Traoré IT, et al. Delays in TB diagnosis and treatment initiation in Burkina Faso during the COVID-19 pandemic. Trop Med Infect Dis. 2022;7(9):232. doi: 10.3390/tropicalmed7090237.

59. Hazra D, Chawla K, Shenoy VP, Pandey AK, S N. The aftermath of COVID-19 pandemic on the diagnosis of TB at a tertiary care hospital in India. J Infect Public Health. 2021;14(8):1095-8. doi: 10.1016/j.jiph.2021.07.001.

60. Lakoh S, Jiba DF, Baldeh M, Adekanmbi O, Barrie U, Seisay AL, et al. Impact of COVID-19 on tuberculosis case detection and treatment outcomes in Sierra Leone. Trop Med Infect Dis. 2021;6(3):154. doi: 10.3390/tropicalmed6030154.

61. Lestari T, Kamaludin, Lowbridge C, Kenangalem E, Poespoprodjo JR, Graham SM, et al. Impacts of tuberculosis services strengthening and the COVID-19 pandemic on case detection and treatment outcomes in Mimika District, Papua, Indonesia: 2014-2021. PLOS Glob Public Health. 2022;2(9):e0001114. doi: 10.1371/journal.pgph.0001114.

62. Loh FK, Thong PM, Ong CWM. The crucial need for tuberculosis translational research in the time of COVID-19. Lancet Respir Med. 2022;10(6):531-3. doi: 10.1016/s2213-2600(22)00099-6.

63. MacLean EL, Villa-Castillo L, Ruhwald M, Ugarte-Gil C, Pai M. Integrated testing for TB and COVID-19. Med (N Y). 2022;3(3):162-6. doi: 10.1016/j.medj.2022.02.002.

64. Malik AA, Safdar N, Chandir S, Khan U. Tuberculosis control and care in the era of COVID-19. Health Policy Plan. 2020;35(8):1130-32. doi: 10.1093/heapol/czaa109.

65. Mohammed H, Oljira L, Roba KT, Yimer G, Fekadu A, Manyazewal T. Containment of COVID-19 in Ethiopia and implications for tuberculosis care and research. Infect Dis Poverty. 2020;9(1):131. doi: 10.1186/s40249-020-00753-9.

66. Muñiz-Salazar R, Le T, Cuevas-Mota J, González-Fagoaga JE, Zapata-Garibay R, Ruiz-Tamayo PS, et al. Impact of COVID-19 on tuberculosis detection and treatment in Baja California, México. Front Public Health. 2022;10:921596. doi: 10.3389/fpubh.2022.921596.

67. Nalunjogi J, Mucching-Toscano S, Sibomana JP, Centis R, D'Ambrosio L, Alffenaar JW, et al. Impact of COVID-19 on diagnosis of tuberculosis, multidrug-resistant tuberculosis, and on mortality in 11 countries in Europe, Northern America, and Australia. A Global Tuberculosis Network study. Int J Infect Dis. Int J Infect Dis. 2023;130(Suppl 1):S25-9. doi: 10.1016/j.ijid.2023.02.025.

68. Narita M, Hatt G, Toren KG**.** Narita M, Hatt G, Toren KG**.** Delayed tuberculosis diagnoses during the coronavirus disease 2019 (COVID-19) pandemic in 2020—King County, Washington. Clin Infect Dis. 2021;73(Suppl 1):S74-6. doi: 10.1093/cid/ciab387.

69. Nikolayevskyy V, Holicka Y, van Soolingen D, van der Werf MJ, Ködmön C, Surkova E, et al. Impact of COVID-19 on tuberculosis case detection and treatment outcomes in Sierra Leone.Eur Respir J. 2021;57(1):154. doi: 10.1183/13993003.03890-2020.

70. Santos VS, Allgayer MF, Kontogianni K, Rocha JE, Pimentel BJ, Amorim MTP, et al. Pooling of sputum samples to increase tuberculosis diagnostic capacity in Brazil during the COVID-19 pandemic. Int J Infect Dis. 2023;129:10-4. doi: 10.1016/j.ijid.2023.01.009.

71. Schiza V, Kruse M, Xiao Y, Kar S, Lovejoy K, Wrighton-Smith P, et al. Impact of the COVID-19 pandemic on TB infection testing. Int J Tuberc Lung Dis. 2022;26(2):174-6. doi: 10.5588/ijtld.21.0628.

72. Tovar M, Aleta A, Sanz J, Moreno Y**.** Modelling the impact of COVID-19 on future tuberculosis burden. Commun Med (Lond). 2022;2:77. doi: 10.1038/s43856-022-00145-0.

73. Maurer FP, Shubladze N, Kalmambetova G, Felker I, Kuchukhidze G, Drobniewski F, et al. Impact of the COVID-19 pandemic on tuberculosis national reference laboratory services in the WHO European Region, March to November 2020. Euro Surveill. 2021;26(24):2100426. doi: 10.2807/1560-7917.Es.2021.26.24.2100426.

74. Awasthi AK, Singh PK**.** Tuberculosis management in India during COVID-19 crisis. J Public Health Policy. 2021;42(1):185-9. doi: 10.1057/s41271-020-00265-8.

75. Apolisi I, Mema N, Tyeku N, Beko B, Memani B, Daniels J, et al. Supporting families with tuberculosis during COVID-19 in Khayelithsa, South Africa. Lancet Respir Med. 2022;10(6):542-3. doi: 10.1016/s2213-2600(22)00121-7.

76. Arega B, Negesso A, Taye B, Weldeyohhans G, Bewket B, Negussie T, et al. Impact of COVID-19 pandemic on TB prevention and care in Addis Ababa, Ethiopia: a retrospective database study. BMJ Open. 2022;12(2):e053290. doi: 10.1136/bmjopen-2021-053290.

77. Benade M, Long L, Meyer-Rath G, Miot J, Evans D, Tucker JM, et al. Reduction in initiations of drug-sensitive tuberculosis treatment in South Africa during the COVID-19 pandemic: analysis of retrospective, facility-level data. PLOS Glob Public Health. 2022;2(10):e0000559. doi: 10.1371/journal.pgph.0000559.

78. Caren GJ, Iskandar D, Pitaloka DAE, Abdulah R, Suwantika AA**.** COVID-19 pandemic disruption on the management of tuberculosis treatment in Indonesia. J Multidiscip Healthc. 2022;15:175-83. doi: 10.2147/jmdh.S341130.

79. Chilot D, Woldeamanuel Y, Manyazewal T**.** Real-time impact of COVID-19 on clinical care and treatment of patients with tuberculosis: a multicenter cross-sectional study in Addis Ababa, Ethiopia. Ann Glob Health. 2021;87(1):109. doi: 10.5334/aogh.3481.

80. Coutinho I, Alves LC, Werneck GL, Trajman A**.** The impact of the COVID-19 pandemic in tuberculosis preventive treatment in Brazil: a retrospective cohort study using secondary data. Lancet Reg Health Am. 2023;19:100444. doi: 10.1016/j.lana.2023.100444.

81. Gandhi AP, Kathirvel S, Rehman T**.** Effect of COVID-19 lockdown on the pathway of care and treatment outcome among patients with tuberculosis in a rural part of northern India: a community-based study. J Rural Med. 2022;17(2):59-66. doi: 10.2185/jrm.2021-039.

82. Geric C, Saroufim M, Landsman D, Richard J, Benedetti A, Batt J, et al. Impact of COVID-19 on tuberculosis prevention and treatment in Canada: a multicenter analysis of 10,833 patients. 2022;225(8):1317-20. doi: 10.1093/infdis/jiab608.

83. Jeong Y, Min J. Impact of COVID-19 pandemic on tuberculosis preventive services and their post-pandemic recovery strategies: a rapid review of literature. J Korean Med Sci. 2023;38(5):e43. doi: 10.3346/jkms.2023.38.e43.

84. Louie JK, Agraz-Lara R, Romo L, Crespin F, Chen L, Graves S**.** Tuberculosis-associated hospitalizations and deaths after COVID-19 shelter-in-place, San Francisco, California, USA. Emerg Infect Dis. 2021;27(8):2227-9. doi: 10.3201/eid2708.210670.

85. Magro P, Formenti B, Marchese V. Impact of the SARS-CoV-2 epidemic on tuberculosis treatment outcome in Northern Italy. Eur Respir J. 2020;56(4):2002665. doi: 10.1183/13993003.02665-2020.

86. Meneguim AC, Rebello L, Das M, Ravi S, Mathur T, Mankar S, et al. Adapting TB services during the COVID-19 pandemic in Mumbai, India. Int J Tuberc Lung Dis. 2020;24(10):1119-21. doi: 10.5588/ijtld.20.0537.

87. Min J, Ko Y, Kim HW, Koo HK, Oh JY, Jeong YJ, et al. Increased healthcare delays in tuberculosis patients during the first wave of COVID-19 pandemic in Korea: a nationwide cross-sectional study. J Korean Med Sci. 2022;37(3):e20. doi: 10.3346/jkms.2022.37.e20.

88. Mohr-Holland E, Douglas-Jones B, Apolisi I**.** Tuberculosis preventive therapy for children and adolescents: an emergency response to the COVID-19 pandemic. Lancet Child Adolesc Health. 2021;5(3):159-61. doi: 10.1016/S2352-4642(21)00003-1.

89. Namkoong H, Horita N, Ebina-Shibuya R**.** Concern over a COVID-19-related BCG shortage. The International Journal of Tuberculosis and Lung Disease. 2020;24(6):642-3. doi: 10.5588/ijtld.20.0240.

90. Keshavjee S**.** Progress toward global tuberculosis elimination goals and opportunities for moving forward. In: Biffl C, Liao J, Nicholson A, eds. Innovations for tackling tuberculosis in the time of COVID-19: proceedings of a workshop, 2022. National Academies of Sciences, Engineering, and Medicine. The National Academies Press, Washington, DC. Available from: https://nap.nationalacademies.org/catalog/26530/innovations-for-tackling-tuberculosis-in-the-time-of-covid-19.

91. Padmapriyadarsini C, Banurekha V, Arora VK**.** Challenges in TB control and the anticipated COVID-19 third wave: Way forward. Indian J Tuberc. 2021;68(4):425-7. doi: 10.1016/j.ijtb.2021.07.014.

92. Rai DK, Kumar R, Pandey SK**.** Problems faced by tuberculosis patients during COVID-19 pandemic: urgent need to intervene. Indian J Tuberc. 2020;67(4s):S173-4. doi: 10.1016/j.ijtb.2020.07.013.

93. Sahu S, Wandwalo E, Arinaminpathy N. Exploring the impact of the COVID-19 pandemic on tuberculosis care and prevention. J Pediatric Infect Dis Soc. 2022;11(Suppl 3):S67-71. doi: 10.1093/jpids/piac102.

94. Shaikh N, Pelzer PT, Thysen SM, Roy P, Harris RC, White RG**.** Impact of COVID-19 disruptions on global BCG coverage and paediatric tb mortality: a modelling study. Vaccines. 2021;9(11):1228. doi: 10.3390/vaccines9111228.

95. Tiberi S, Vjecha MJ, Zumla A, Galvin J, Migliori GB, Zumla A. Accelerating development of new shorter TB treatment regimens in anticipation of a resurgence of multi-drug resistant TB due to the COVID-19 pandemic. Int J Infect Dis. 2021;113(Suppl 1):S96-9. doi: 10.1016/j.ijid.2021.02.067.

96. Abikoye TM. Collateral damage: the impact of the COVID-19 pandemic on the care of a patient with tuberculous neuroretinitis in Lagos, Nigeria. Pan Afr Med J. 2020;35(Suppl 2):S135. doi: 10.11604/pamj.supp.2020.35.135.24691.

97. United Nations International Children's Emergency Fund. Bacillus Calmette-Guérin (BCG) vaccine supply and demand update, UNICEF, Copenhagen, August 2019. Available from: https://www.unicef.org/supply/reports/bacillus-calmette-guérin-bcg-supply-and-demand-update

98. Ritz N, Hanekom WA, Robins-Browne R, Britton WJ, Curtis N. Influence of BCG vaccine strain on the immune response and protection against tuberculosis. FEMS Microbiol Rev. 2008;32(5):821-41. doi: 10.1111/j.1574-6976.2008.00118.x.

99. Pittet LF, Messina NL, Orsini F, Moore CL, Abruzzo V, Barry S, et al. Randomized Trial of BCG Vaccine to Protect against Covid-19 in Health Care Workers. N Engl J Med. 2023;388(17):1582-96. doi: 10.1056/NEJMoa2212616.

100. Cardenas-Escalante J, Fernandez-Saucedo J, Cubas WS. Impact of the COVID-19 pandemic on tuberculosis in Peru: Are we forgetting anyone? Enferm Infecc Microbiol Clin (Engl Ed). 2022;40(1):46-7. doi: 10.1016/j.eimce.2021.07.008.

101. Fekadu G, Jiang X, Yao J, You JHS. Cost-effectiveness of video-observed therapy for ambulatory management of active tuberculosis during the COVID-19 pandemic in a high-income country. Int J Infect Dis. 2021;113:271-8. doi: 10.1016/j.ijid.2021.10.029.

102. Klinton JS, Heitkamp P, Rashid A, Faleye BO, Win Htat H, Hussain H, et al. One year of COVID-19 and its impact on private provider engagement for TB: A rapid assessment of intermediary NGOs in seven high TB burden countries. J Clin Tuberc Other Mycobact Dis. 2021;25:100277. doi: 10.1016/j.jctube.2021.100277.

103. Koura KG, Harries AD, Fujiwara PI, Dlodlo RA, Sansan EK, Kampoer B, et al. COVID-19 in Africa: community and digital technologies for tuberculosis management. Int J Tuberc Lung Dis. 2020;24(8):863-5. doi: 10.5588/ijtld.20.0412.

104. Kumwichar P, Chongsuvivatwong V, Prappre T**.** Video-observed therapy with a notification system for improving the monitoring of tuberculosis treatment in Thailand: usability study. JMIR Form Res. 2022;6(5):e35994. doi: 10.2196/35994.

105. Lippincott CK, Perry A, Munk E, Maltas G, Shah M**.** Tuberculosis treatment adherence in the era of COVID-19. BMC Infect Dis. 2022;22(1):800. doi: 10.1186/s12879-022-07787-4.

106. Watts K, McKeown A, Denholm J, Baker AM**.** Responding to COVID-19: adjusting TB services in a low-burden setting. Int J Tuberc Lung Dis. 2020;24(8):866-9. doi: 10.5588/ijtld.20.0337.

107. Calnan M, Moran A, Jassim AlMossawi H**.** Maintaining essential tuberculosis services during the COVID-19 pandemic, Philippines. Bull World Health Organ. 2022;100(2):127-34. doi: 10.2471/blt.21.286807.

108. Visca D, Tiberi S, Pontali E, Spanevello A, Migliori, GB. Tuberculosis in the time of COVID-19: quality of life and digital innovation. Eur Respir J. 2020;56(2):2001998. doi: 10.1183/13993003.01998-2020.

109. Bachina P, Lippincott CK, Perry A, Munk E, Maltas G, Bohr R, et al. Programmatic adoption and implementation of video-observed therapy in Minnesota: prospective observational cohort study. JMIR Form Res. 2022;6(8):e38247. doi: 10.2196/38247.

110. Migliori GB, Thong PM, Akkerman O, Alffenaar JW, Álvarez-Navascués F, Assao-Neino MM, et al. Worldwide effects of coronavirus disease pandemic on tuberculosis services, January-April 2020. Emerg Infect Dis. 2020;26(11):2709-12. doi: 10.3201/eid2611.203163.

111. Bhatia V, Mandal PP, Satyanarayana S, Aditama TY, Sharma M**.** Mitigating the impact of the COVID-19 pandemic on progress towards ending tuberculosis in the WHO South-East Asia Region. WHO South East Asia J Public Health. 2020;9(2):95-9. doi: 10.4103/2224-3151.294300.

112. Singh PK**.** Strengthening social protection for TB patients: Lessons from COVID-19. PLOS Global Public Health. 2022;2(8):e0000950. doi: 10.1371/journal.pgph.0000950.

113. Chatterjee S, Das P, Vassall A**.** Impact of COVID-19 restrictive measures on income and health service utilization of tuberculosis patients in India. BMC Infect Dis. 2022;22(1):711. doi: 10.1186/s12879-022-07681-z.

114. Bhargava A, Shewade HD**.** The potential impact of the COVID-19 response related lockdown on TB incidence and mortality in India. Indian J Tuberc. 2020;67(4s):S139-46. doi: 10.1016/j.ijtb.2020.07.004.

115. Saunders MJ, Evans CA. COVID-19, tuberculosis and poverty: preventing a perfect storm. Eur Respir J. 2020;56(1):2001348. doi: 10.1183/13993003.01348-2020.

116. George S, Paranjpe A, Nagesh P, Saalim M. Barriers to treatment adherence for female tuberculosis (TB) patients during the COVID-19 pandemic: qualitative evidence from front-line TB interventions in Bengaluru City, India. Indian J Public Health. 2022;66(1):38-44. doi: 10.4103/ijph.ijph_1146_21.

117. Khan FMA, Kazmi Z, Hasan MM. Resurgence of tuberculosis amid COVID-19 in Peru: associated risk factors and recommendations. 2021;36(6):2441-2445. doi: 10.1002/hpm.3291.

118. Knipper M, Sedas AC, Keshavjee S, Abbara A, Almhawish N, Alashawi H, et al. The need for protecting and enhancing TB health policies and services for forcibly displaced and migrant populations during the ongoing COVID-19 pandemic. Int J Infect Dis. 2021;113 Suppl 1:S22-7. doi: 10.1016/j.ijid.2021.03.047.

119. Louie JK, Reid M, Stella J, Agraz-Lara R, Graves S, Chen L, et al. A decrease in tuberculosis evaluations and diagnoses during the COVID-19 pandemic. Int J Tuberc Lung Dis. 2020;24(8):860-2. doi: 10.5588/ijtld.20.0364.

120. McQuaid CF, Vassall A, Cohen T, Fiekert K, White RG. The impact of COVID-19 on TB: a review of the data. Int J Tuberc Lung Dis. 2021;25(6):436-46. doi: 10.5588/ijtld.21.0148.

121. Ryckman T, Robsky K, Cilloni L. Ending tuberculosis in a post-COVID-19 world: a person-centred, equity-oriented approach. Lancet Infect Dis. 2023;23(2):e59-66. doi: 10.1016/S1473-3099(22)00500-X.

122. Shrinivasan R, Rane S, Pai M. India's syndemic of tuberculosis and COVID-19. BMJ Glob Health. 2020;5(11) doi: 10.1136/bmjgh-2020-003979.

123. Souza LLL, Santos FLd, Crispim JdA, Fiorati RC, Dias S, Bruce ATI, et al. Causes of multidrug-resistant tuberculosis from the perspectives of health providers: challenges and strategies for adherence to treatment during the COVID-19 pandemic in Brazil. BMC Health Serv Res. 2021;21(1):1-10. doi: 10.1186/s12913-021-07057-0.

124. Vanleeuw L, Zembe-Mkabile W, Atkins S. Falling through the cracks: Increased vulnerability and limited social assistance for TB patients and their households during COVID-19 in Cape Town, South Africa. PLOS Glob Public Health. 2022;2(7):e0000708. doi: 10.1371/journal.pgph.0000708.

125. Zumla A, Chakaya J, Khan M, Fatima R, Wejse C, Al-Abri S, et al. 'The Clock is Ticking'—and the world is running out of time to deliver the United Nations General Assembly commitments to End TB due to the COVID-19 pandemic. Int J Infect Dis. 2021;113(Suppl 1):S1-6. doi: 10.1016/j.ijid.2021.03.046.

126. Mannan S, Oga-Omenka C, Soman ThekkePurakkal A, Huria L, Kalra A, Gandhi R, et al. Adaptations to the first wave of the COVID-19 pandemic by private sector tuberculosis care providers in India. J Clin Tuberc Other Mycobact Dis. 2022;28:100327. doi: 10.1016/j.jctube.2022.100327.

127. Awan HA, Sahito AM, Sukaina M, Khatri G, Waheed S, Sohail F, et al. Tuberculosis amidst COVID-19 in Pakistan: a massive threat of overlapping crises for the fragile healthcare systems. Epidemiol Infect. 2022;150:e41. doi: 10.1017/s0950268822000358.

128. Cox V, Wilkinson L, Grimsrud A, Hughes J, Reuter A, Conradie F, et al. Critical changes to services for TB patients during the COVID-19 pandemic. Int J Tuberc Lung Dis. 2020;24(5):542-4. doi: 10.5588/ijtld.20.0205.

129. Driessche KV, Mahlobo PZ, Venter R**.** Face masks in the post-COVID-19 era: a silver lining for the damaged tuberculosis public health response? Lancet Respir Med. 2021;9(4):340-342. doi: 10.1016/S2213-2600(21)00020-5.

130. Jain VK, Iyengar KP, Samy DA, Vaishya R**.** Tuberculosis in the era of COVID-19 in India. Diabetes Metab Syndr. 2020;14(5):1439-43. doi: 10.1016/j.dsx.2020.07.034.

131. Jamal WZ, Habib S, Khowaja S, Safdar N, Zaidi SMA**.** COVID-19: ensuring continuity of TB services in the private sector. Int J Tuberc Lung Dis. 2020;24(8):870-2. doi: 10.5588/ijtld.20.0400.

132. Marti M, Zürcher K, Enane LA, Diero L, Marcy O, Tiendrebeogo T, et al. Impact of the COVID-19 pandemic on TB services at ART programmes in low- and middle-income countries: a multi-cohort survey. J Int AIDS Soc. 2022;25(10):e26018. doi: 10.1002/jia2.26018.

133. Masina HV, Lin IF, Chien LY**.** The Impact of the COVID-19 pandemic on tuberculosis case notification and treatment outcomes in Eswatini. Int J Public Health. 2022;67:1605225. doi: 10.3389/ijph.2022.1605225.

134. Andom AT, Fejfar D, Yuen CM, Ndayizigiye M, Mugunga JC, Mukherjee JS**.** The impact of COVID-19 on tuberculosis program performance in the Kingdom of Lesotho. Trop Med Infect Dis. 2023;8(3):165. doi: 10.3390/tropicalmed8030165.

135. Berra TZ, Ramos ACV, Alves YM, Tavares RBV, Tartaro AF, Nascimento MCD, et al. Impact of COVID-19 on tuberculosis indicators in Brazil: a time series and spatial analysis study. Trop Med Infect Dis. 2022;7(9):247. doi: 10.3390/tropicalmed7090247.

136. Chiang CY, Islam T, Xu C, Chinnayah T, Garfin AMC, Rahevar K, et al. The impact of COVID-19 and the restoration of tuberculosis services in the Western Pacific Region. Eur Respir J. 2020;56(4):2003054. doi: 10.1183/13993003.03054-2020.

137. Dlangalala T, Musekiwa A, Brits A, Maluleke K, Jaya ZN, Kgarosi K, et al. . Evidence of TB services at primary healthcare level during COVID-19: a scoping review. Diagnostics (Basel). 2021;11(12):2221. doi: 10.3390/diagnostics11122221.

138. Fuady A, Houweling TAJ, Richardus JH**.** COVID-19 and Tuberculosis-Related Catastrophic Costs. Am J Trop Med Hyg. 2020;104(2):436-40. doi: 10.4269/ajtmh.20-1125.

139. Khan AW, Khan B, Shah SK, Kazi GN, Quadir A, Ghafoor A, et al. The impact of covid-19 on TB care in Pakistan during 2020. Pak J Public Health. 2022;12(1):8-11. doi: 10.32413/pjph.v12i1.997.

140. Khobragade RN, Kelkar RU, Sunilkumar M, Cency B, Murthy N, Surendran D, et al. Health system resilience: ensuring TB services during COVID-19 pandemic in Kerala, India. Indian J Tuberc. 2022;69(4):427-31. doi: 10.1016/j.ijtb.2021.10.004.

141. Kim B, Kang YA, Lee J**.** Heterogeneous impact of Covid-19 response on tuberculosis burden by age group. Sci Rep. 2022;12(1):13773. doi: 10.1038/s41598-022-18135-6.

142. Klinton JS, Oga-Omenka C, Heitkamp P**.** TB and COVID - Public and private health sectors adapt to a new reality. J Clin Tuberc Other Mycobact Dis. 2020;21:100199. doi: 10.1016/j.jctube.2020.100199.

143. Manhiça I, Augusto O, Sherr K, Cowan J, Cuco RM, Agostinho S, et al. COVID-19-related healthcare impacts: an uncontrolled, segmented time-series analysis of tuberculosis diagnosis services in Mozambique, 2017-2020. BMJ Glob Health. 2022;7(4):e007878. doi: 10.1136/bmjgh-2021-007878.

144. Mihika FA, Jubayer Biswas MAA, Khan MMH, Islam SS, Haque MA, Banu S, et al. The effect of the COVID-19 pandemic on pulmonary tuberculosis control in the selected Upazila health complexes of Dhaka Division, Bangladesh. Trop Med Infect Dis. 2022;7(11):385. doi: 10.3390/tropicalmed7110385.

145. Min J, Kim HW, Koo HK, Ko Y, Oh JY, Kim J, et al. Impact of COVID-19 pandemic on the National PPM Tuberculosis Control Project in Korea: the Korean PPM Monitoring Database between July 2019 and June 2020. J Korean Med Sci. 2020;35(43):e388. doi: 10.3346/jkms.2020.35.e388.

146. Nhari LG, Dzobo M, Chitungo I, Denhere K, Musuka G, Dzinamarira T**.** Implementing effective TB prevention and treatment programmes in the COVID-19 era in Zimbabwe. A call for innovative differentiated service delivery models. Public Health Pract (Oxf). 2020;1:100058. doi: 10.1016/j.puhip.2020.100058.

147. Oga-Omenka C, Sassi A, Vasquez NA, Baruwa E, Rosapep L, Daniels B, et al. Tuberculosis service disruptions and adaptations during the first year of the COVID-19 pandemic in the private health sector of two urban settings in Nigeria-A mixed methods study. PLOS Glob Public Health. 2023;3(3):e0001618. doi: 10.1371/journal.pgph.0001618.

148. Petersen E, Seif Al-Abr S, Chakaya J, Goletti D, Parolina L, Wejse C, et al. World TB Day 2022: Revamping and reshaping global TB control programs by advancing lessons learnt from the COVID-19 pandemic. Int J Infect Dis. 2022;124(Suppl 1):S1-3. doi: 10.1016/j.ijid.2022.02.057.

149. Reid MJA, Silva S, Arinaminpathy N, Goosby E**.** Building a tuberculosis-free world while responding to the COVID-19 pandemic. Lancet. 2020;396:1312-13. doi: 10.1016/S0140-6736(20)32138-3.

150. Tran CH, Moore BK, Pathmanathan I, Lungu P, Shah NS, Oboho I, et al. Tuberculosis treatment within differentiated service delivery models in global HIV/TB programming. J Int AIDS Soc. 2021;24(Suppl 6):e25809. doi: 10.1002/jia2.25809.

151. van Rensburg AJ, Petersen I, Awotiwon A, Bachmann MO, Curran R, Murdoch J, et al. Applying learning health systems thinking in codeveloping integrated tuberculosis interventions in the contexts of COVID-19. BMJ Glob Health. 2022;7(10):e009567. doi: 10.1136/bmjgh-2022-009567.

152. Cronin AM, Railey S, Fortune D, Wegener DH, Davis JB**.** Notes from the field: effects of the COVID-19 response on tuberculosis prevention and control efforts - United States, March-April 2020. MMWR Morb Mortal Wkly Rep. 2020;69(29):971-2. doi: 10.15585/mmwr.mm6929a4.

153. Bouaddi O, Hasan MM, Sahito AM, Shah PA, Mohammed AZA, Essar MY**.** Tuberculosis in the middle of COVID-19 in Morocco: efforts, challenges and recommendations. Trop Med Health. 2021;49(1):98. doi: 10.1186/s41182-021-00388-y.

154. Roberts T, Sahu S, Malar J, Abdullaev T, Vandevelde W, Pillay YG, et al. Turning threats into opportunities: how to implement and advance quality TB services for people with HIV during the COVID-19 pandemic and beyond. J Int AIDS Soc. 2021;24(4):e25696. doi: 10.1002/jia2.25696.

155. Yadav P, Vohra C, Gopalakrishnan M, Garg MK**.** Integrating health planning and primary care infrastructure for COVID-19 and tuberculosis care in India: challenges and opportunities. Int J Health Plann Manage. 2022;37(2):632-42. doi: 10.1002/hpm.3393.

156. Ruiz-Grosso P, Cachay R, De La Flor A, Schwalb A, Ugarte-Gil C**.** Association between tuberculosis and depression on negative outcomes of tuberculosis treatment: A systematic review and meta-analysis. PLOS ONE. 2020;15(1):e0227472. doi: 10.1371/journal.pone.0227472.

157. Loveday M, Cox H, Evans D, Furin J, Ndjeka N, Osman M, et al. Opportunities from a new disease for an old threat: Extending COVID-19 efforts to address tuberculosis in South Africa. S Afr Med J. 2020;110(12):1160-7. doi: 10.7196/SAMJ.2020.v110i12.15126.

158. Ferrer JP, Suzuki S, Alvarez C, Berido C, Caballero M, Caraig B, et al. Experiences, challenges and looking to the future in a clinical tuberculosis cohort in the time of COVID-19 in the Philippines. Trans R Soc Trop Med Hyg. 2021;115(6):579-82. doi: 10.1093/trstmh/trab025.

159. Malik AA, Hussain H, Maniar R, Safdar N, Mohiuddin A, Riaz N, et al. Integrated tuberculosis and COVID-19 activities in Karachi and tuberculosis case notifications. Trop Med Infect Dis. 2022;7(1):12. doi: 10.3390/tropicalmed7010012.

160. Zimmer AJ, Heitkamp P, Malar J, Dantas C, O'Brien K, Pandita A, et al. Facility-based directly observed therapy (DOT) for tuberculosis during COVID-19: a community perspective. J Clin Tuberc Other Mycobact Dis. 2021;24:100248. doi: https://doi.org/10.1016/j.jctube.2021.100248.

161. Sunjaya DK, Paskaria C, Pramayanti M, Herawati DMD, Parwati I. The magnitude of anxiety and depressive symptoms among tuberculosis patients in community health centers setting during the peak of COVID-19 pandemic. J Multidiscip Healthc. 2022;15:755-64. doi: 10.2147/jmdh.S359530.

928 162. ACTION Global Health Advocacy Partnership et al. The impact of COVID-19 on the TB epidemic: a
929 community perspective, 2020. Accessed from: https://spark.adobe.com/page/xJ7pygvhrIAqW/
930 163. Mandal A, Verma AK, Kar SK, Bajpai J, Kant S, Kumar S, et al. A cross-sectional study to determine the
931 psychological distress among pulmonary tuberculosis patients during COVID-19 pandemic. Monaldi Arch
932 Chest Dis. 2022;93(1) doi: 10.4081/monaldi.2022.2255.
933 164. Millones AK, Lecca L, Acosta D, Campos H, Del Águila-Rojas E, Farroñay S, et al. The impact of the COVID-
934 19 pandemic on patients' experiences obtaining a tuberculosis diagnosis in Peru: a mixed-methods study.
935 BMC Infect Dis. 2022;22(1):829. doi: 10.1186/s12879-022-07832-2.
936 165. Santos FLD, Souza LLL, Bruce ATI, Crispim JA, Arroyo LH, Ramos ACV, et al. Patients' perceptions regarding
937 multidrug-resistant tuberculosis and barriers to seeking care in a priority city in Brazil during COVID-19
938 pandemic: A qualitative study. PLoS One. 2021;16(4):e0249822. doi: 10.1371/journal.pone.0249822.
939 166. Tinoco EM, Vasconcelos A, Alves F, Duarte R**.** Impact of COVID-19 on extrapulmonary TB and the benefit
940 of decentralised TB services. Int J Tuberc Lung Dis. 2022;26(2):178-80. doi: 10.5588/ijtld.21.0675.
941 167. Togun T, Kampmann B, Stoker NG, Lipman M**.** Anticipating the impact of the COVID-19 pandemic on TB
942 patients and TB control programmes. Ann Clin Microbiol Antimicrob. 2020;19(1):21. doi: 10.1186/s12941-
943 020-00363-1.
944 168. Zhang G, Yu Y, Zhang W, Shang J, Chen S, Pang X, et al. Influence of COVID-19 for delaying the diagnosis
945 and treatment of pulmonary tuberculosis-Tianjin, China. Front Public Health. 2022;10:937844. doi:
946 10.3389/fpubh.2022.937844.
947 169. Mwamba C, Kerkhoff AD, Kagujje M, Lungu P, Muyoyeta M, Sharma A**.** Diagnosed with TB in the era of
948 COVID-19: patient perspectives in Zambia. Public Health Action. 2020;10(4):141-6. doi:
949 10.5588/pha.20.0053.
950 170. Beyene NW, Sitotaw AL, Tegegn B, Bobosha K**.** The impact of COVID-19 on the tuberculosis control
951 activities in Addis Ababa. Pan Afr Med J. 2021;38:243. doi: 10.11604/pamj.2021.38.243.27132.
952 171. Buonsenso D, Iodice F, Sorba Biala J, Goletti D**.** COVID-19 effects on tuberculosis care in Sierra Leone.
953 Pulmonology. 2021;27(1):67-9. doi: 10.1016/j.pulmoe.2020.05.013.

954 172. Fatima R, Akhtar N, Yaqoob A, Harries AD, Khan MS**.** Building better tuberculosis control systems in a post-
955 COVID world: learning from Pakistan during the COVID-19 pandemic. Int J Infect Dis. 2021;113(Suppl
956 1):S88-90. doi: 10.1016/j.ijid.2021.03.026.
957 173. Islam M**.** Extensively drug-resistant tuberculosis in the time of COVID-19-How has the landscape changed
958 for Pakistan? Disaster Med Public Health Prep. 2020;14(4):e9-10. doi: 10.1017/dmp.2020.230.
959 174. Kumar P, Goyal JP**.** Tuberculosis during Covid-19 pandemic: challenges and opportunities. Indian Pediatr.
960 2020;57(11):1082. doi: 10.1007/s13312-020-2047-8.
961 175. Maroof M, Pamei G, Bhatt M, Awasthi S, Bahuguna SC, Singh P**.** Drug adherence to anti-tubercular
962 treatment during COVID-19 lockdown in Haldwani block of Nainital district. Indian J Community Health.
963 2022;34(4):535-41. doi: 10.47203/IJCH.2022.v34i04.016.
964 176. Oga-Omenka C, Tseja-Akinrin A, Boffa J, Heitkamp P, Pai M, Zarowsky C**.** Commentary: Lessons from the
965 COVID-19 global health response to inform TB case finding. Healthc (Amst). 2021;9(2):100487. doi:
966 10.1016/j.hjdsi.2020.100487.
967 177. Soko RN, Burke RM, Feasey HRA, Sibande W, Nliwasa M, Henrion MYR, et al. Effects of coronavirus
968 disease pandemic on tuberculosis notifications, Malawi. Emerg Infect Dis. 2021;27(7):1831-9. doi:
969 10.3201/eid2707.210557.
970 178. Uwishema O, Badri R, Onyeaka H, Okereke M, Akhtar S, Mhanna M, et al. Fighting tuberculosis in Africa:
971 the current situation amidst the COVID-19 pandemic. Disaster Med Public Health Prep. 2022;June 8:1-3.
972 doi: 10.1017/dmp.2022.142.
973 179. Zimmer AJ, Klinton JS, Oga-Omenka C**.** Tuberculosis in times of COVID-19. J Epidemiol Community Health.
974 2022;76(3):310-6. doi: 10.1136/jech-2021-217529.
975 180. Dheda K, Perumal T, Moultrie H, Perumal R, Esmail A, Scott AJ, et al. The intersecting pandemics of
976 tuberculosis and COVID-19: population-level and patient-level impact, clinical presentation, and corrective
977 interventions. Lancet Respir Med. 2022;10(6):603-22. doi: 10.1016/s2213-2600(22)00092-3.
978 181. Nkereuwem O, Nkereuwem E, Fiogbe A, Usoroh EE, Sillah AK, Owolabi O, et al. Exploring the perspectives
979 of members of international tuberculosis control and research networks on the impact of COVID-19 on

tuberculosis services: a cross sectional survey. BMC Health Serv Res. 2021;21(1):798. doi: 10.1186/s12913-021-06852-z.

182. Chapman HJ, Veras-Estévez BA**.** Lessons learned during the COVID-19 pandemic to strengthen tb infection control: a rapid review. Glob Health Sci Pract. 2021;9(4):964-77. doi: 10.9745/ghsp-d-21-00368.

183. Anigbo AR, Gambhir L**.** Two years of the pandemic: Impact of COVID-19 on tuberculosis management in Nigeria. J Appl Pharm Sci. 2022;12(8):001-008. doi: 10.7324/japs.2022.120801.

184. Chen H, Zhang K**.** Insight into the impact of the COVID-19 epidemic on tuberculosis burden in China. Eur Respir J. 2020;56(3):2002710. doi: 10.1183/13993003.02710-2020.

185. Lipman M, McQuaid CF, Abubakar I, Khan M, Kranzer K, McHugh TD, et al. The impact of COVID-19 on global tuberculosis control. Indian J Med Res. 2021;153(4):404-8. doi: 10.4103/ijmr.IJMR_326_21.

186. Lungu PS, Kerkhoff AD, Muyoyeta M, Kasapo CC, Nyangu S, Kagujje M, et al. Interrupted time-series analysis of active case-finding for tuberculosis during the COVID-19 pandemic, Zambia. Bull World Health Organ. 2022;100(3):205-15. doi: 10.2471/blt.21.286109.

187. Rodrigues I, Aguiar A, Migliori GB, Duarte R**.** Impact of the COVID-19 pandemic on tuberculosis services. Pulmonology. 2022;28(3):210-9. doi: 10.1016/j.pulmoe.2022.01.015.

188. Tale S, Meitei Soibam P**.** Care of tuberculosis patients in the times of COVID-19. Indian J Tuberc. 2021;68(2):285-6. doi: 10.1016/j.ijtb.2020.09.004.

189. Wingfield T, Karmadwala F, MacPherson P, Millington KA, Walker NF, Cuevas LE, et al. Challenges and opportunities to end tuberculosis in the COVID-19 era. Lancet Respir Med. 2021;9(6):556-8. doi: 10.1016/s2213-2600(21)00161-2.

190. Shahnavazi M, Rigi F, Heydarikhayat N**.** Adherence to the treatment and influencing factors in patients with tuberculosis during the Covid-19 pandemic: a mixed method study. Health Educ Health Promot. 2022;10(4):633-42.

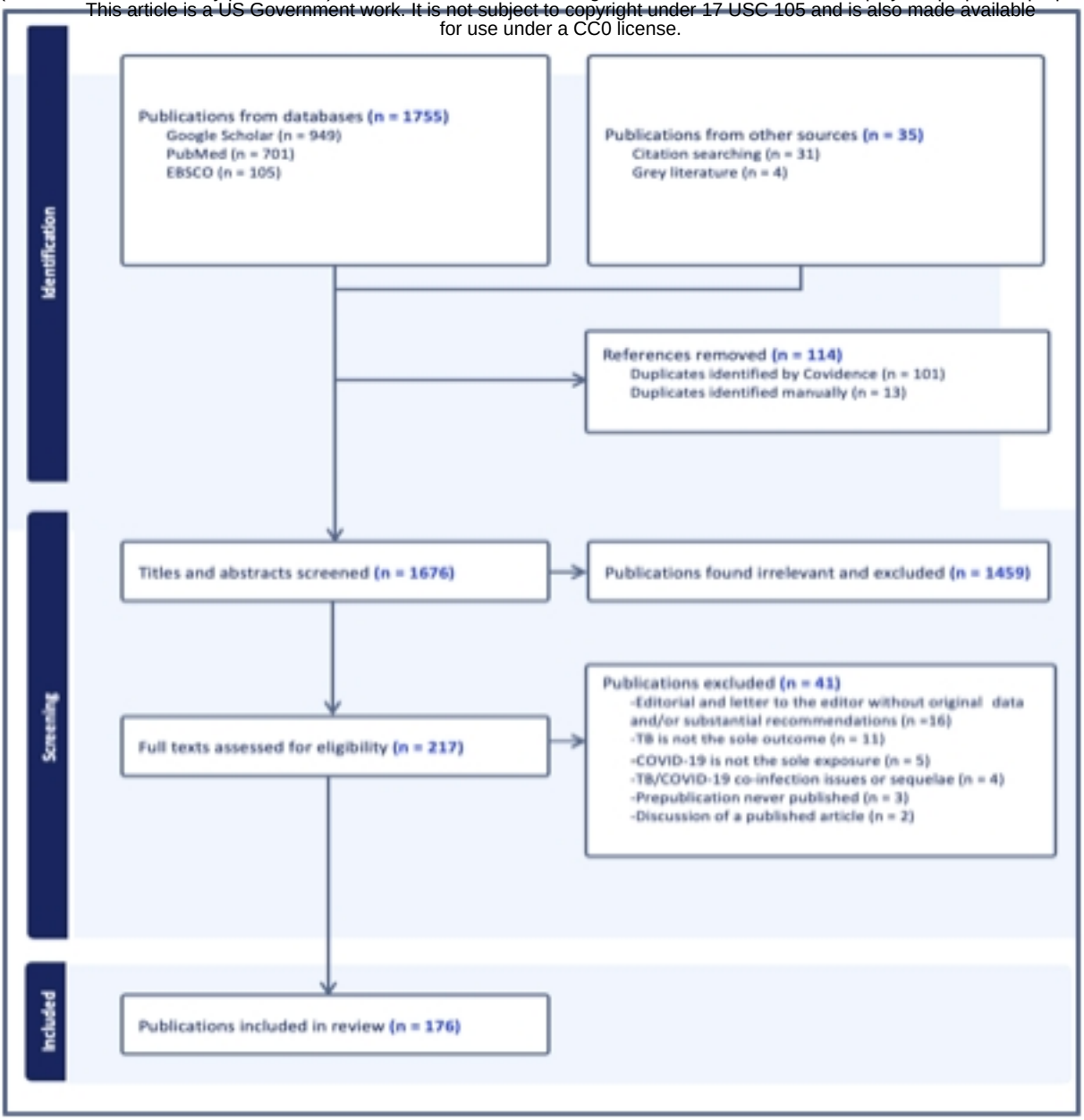
SUPPORTING INFORMATION

S1. Fig. 1. This is the legend for Figure 1. Scoping Review Schema (Courtesy of COVIDENCE)

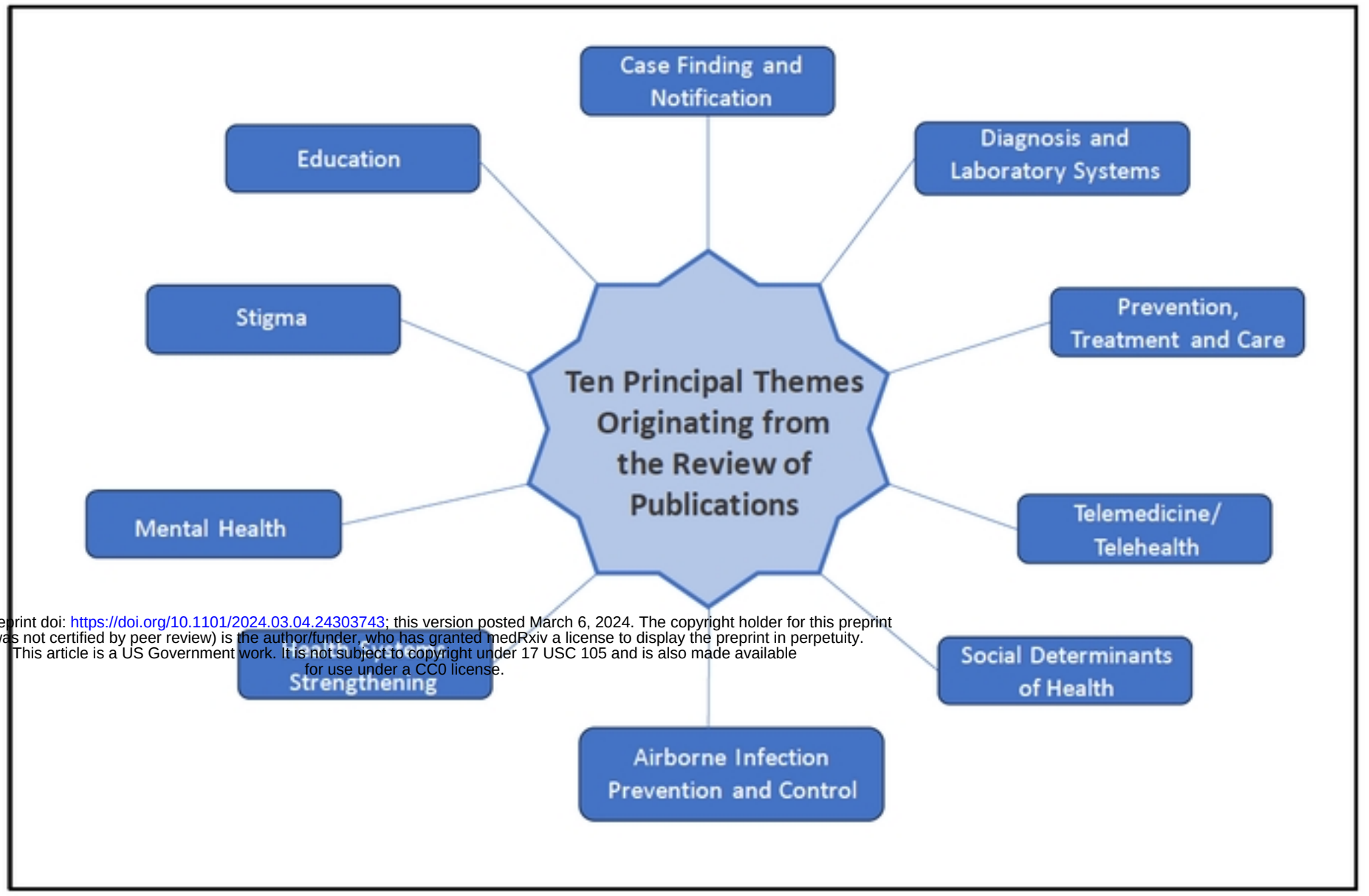
S1. Fig. 2. Ten Themes Characterizing the Global Impact of COVID-19 on TB

S2. Appendices

1. **Appendix 1. Scoping Review Protocol**
2. **Appendix 2: Prisma ScR Checklist**
3. **Appendix 3. Thematic Categorization of Publication**
4. **Appendix 4. Policy Recommendations Derived from the Ten Principal Themes Highlighted in the Scoping Review of the Global Impact of COVID-19 on TB**



Figure



Figure