Changing epidemic of tuberculosis amidst the COVID-19 pandemic in the Western Pacific Region: analysis of tuberculosis case notifications and treatment outcomes from 2015 to 2022

Kyung Hyun Oh,[a,*] Manami Yanagawa,[a] Fukushi Morishita,[a] Philippe Glaziou,[b] Kalpeshsinh Rahevar,[a] and Rajendra Prasad Yadav[a]

[a]World Health Organization Regional Office for the Western Pacific, Manila, Philippines
[b]Independent Consultant, Paris, France

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Summary

Background Coronavirus disease-2019 (COVID-19) pandemic has deeply impacted tuberculosis (TB) services globally. This study aims to assess the COVID-19 pandemic's impact on TB diagnosis and care and explore associated factors in the Western Pacific Region.

Methods We analysed TB case notifications and treatment outcomes for the Region and 14 selected countries and areas from 2015 to 2022. We further explored differences in reported cases from predicted cases by the UHC service coverage index and Human Development Index (HDI), and the relationship between the Stringency Index and TB case notifications during the pandemic.

Findings TB case notifications declined in 2020 (21%) and 2021 (23%) compared to predicted cases and partly recovered in 2022 (18%). The shortfalls in 2020 and 2021 were more prominent in priority countries with high TB burden, where the decrease in clinically diagnosed pulmonary cases and paediatric cases was particularly pronounced. In priority countries, TB case notifications have a positive relationship with UHC service coverage index and HDI in 2021 and an inverse relationship with Stringency Index during the pandemic. In contrast, treatment outcomes have not changed significantly due to the pandemic across countries in the Region.

Interpretation The COVID-19 pandemic has adversely impacted TB diagnosis and care in the Western Pacific Region, especially TB case detection. Stringent government policies against the pandemic, coupled with weak health systems and suboptimal socio-economic development, may have brought a more profound and prolonged impact in priority countries.

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Keywords: Tuberculosis; Covid-19; Western Pacific Region

Introduction

Tuberculosis (TB) continues to be a significant global health challenge, causing many deaths worldwide. Approximately 10 million new TB cases are reported annually, with well over 1 million resulting in fatalities.[1] Since the End TB Strategy was adopted in 2015, concerted global efforts have aimed to eliminate TB, marked by significant events like the World Health Organization (WHO) Global Ministerial Conference in Moscow (2017) and the high-level meeting at the United Nations General Assembly in New York (2018).[2,3] Despite progress, reductions in TB incidence and mortality have fallen short of the milestones and targets outlined in the End TB Strategy.[1,2] The emergence of the coronavirus disease 2019 (COVID-19) has further threatened these collective efforts.

Since its onset in 2020, the COVID-19 pandemic has exerted a profound impact not only on public health but also on politics, economies, and society worldwide. These far-reaching consequences have substantially altered the landscape of TB services.[4–9] Many TB personnel and resources have been

*Corresponding author.
E-mail address: ohk@who.int (K.H. Oh).

Research in context

Evidence before this study

We searched PubMed on 1 December 2022, using the search terms "COVID-19", "tuberculosis" and "Western Pacific Region" without language or date restrictions. We identified one publication, which is a correspondence sharing the experience of a national response to the impact of COVID-19 on tuberculosis (TB) in three countries (China, Malaysia, and the Philippines) presented in an online meeting in the Western Pacific Region on 23–24 June 2020.

Added value of this study

This is the most comprehensive study to assess the COVID-19 impact on TB diagnosis and care by monitoring trends in TB diagnosis and treatment and to explore associated factors in the Western Pacific Region, considering variations between countries. This study demonstrates a markedly negative impact of the COVID-19 pandemic on TB diagnosis and care in the Western Pacific Region, particularly in priority countries with a high TB burden. Significant effects are observed in case detection, particularly in clinically diagnosed pulmonary and paediatric cases, while the impact on treatment remains marginal. Stringent government policies, coupled with weak health systems and lower socio-economic development, amplify the COVID-19 impact on TB services in priority countries.

Implications of all the available evidence

Several critical implications arise from our study. Firstly, there is a crucial need for further research to explore the extended effects of the pandemic, encompassing TB incidence and mortality, given the uncertainty surrounding its long-term impact on the TB epidemic. Secondly, the study emphasises the importance of understanding and exploring the positive outcomes of innovative approaches in TB treatment and patient monitoring. These insights can be instrumental in preparing for future pandemic situations. Lastly, the study underscores the necessity for proper contingency planning within health systems, particularly in countries with weak health systems and suboptimal socio-economic development. Such planning should be informed by a thorough analysis of the anticipated impact of future crises.

redirected to support the COVID-19 response, leading to the suspension of screening activities and disruptions in the supply chain of TB diagnostics and drugs. Lockdowns and mobility restrictions have impeded access to TB diagnosis and treatment. Fear of COVID-19 infection has deterred individuals from seeking healthcare at medical facilities. However, preventive measures such as mask-wearing, physical distancing, and restricted public gatherings may have decreased TB transmission outside households. Globally, the reported number of newly diagnosed TB cases declined from 7.1 million in 2019 to 5.8 million in 2020, partially recovered to 6.4 million in 2021, and rebounded to 7.5 million in 2022, above the pre-pandemic levels.[1]

The Western Pacific Region, one of WHO's six regions, encompasses 37 countries and areas housing nearly 1.9 billion people. The Region exhibits great diversity, ranging from highly populous countries like China (with over 1.4 billion people) to small Pacific Island nations with only a few thousand inhabitants, and includes both high-income and lower-middle-income countries. The burden of TB within the Region varies, with some countries experiencing high TB prevalence while others have made progress towards elimination.[10] The Western Pacific Region has been grappling with the most prolonged and profound effects of the pandemic. Originating in Wuhan, China of the Region, the COVID-19 pandemic has presented numerous challenges, including limited and delayed access to effective vaccines, insufficient data for informed decision-making, and a deficiency in capacity to respond to the pandemic on a large scale over an extended period in the Region.[11]

The impact of the COVID-19 pandemic on TB diagnosis and care may differ across settings, influenced by factors such as the robustness of health systems, the level of socio-economic development, and the stringency of government policies against the pandemic.[12] Therefore, it is crucial to assess the impact by monitoring trends in TB diagnosis and treatment and develop appropriate recovery plans accordingly. This study aims to assess the overall impact of the COVID-19 pandemic on TB diagnosis and care and explore associated factors within the Western Pacific Region, considering variations between countries.

Methods

Study population

This study focused primarily on the Western Pacific Region, with specific attention given to 14 countries and areas within the region, each having a population of 1 million or more. These countries and areas included Australia, Cambodia, China, Hong Kong (Special Administrative Region of China), Japan, Lao People's Democratic Republic (PDR), Malaysia, Mongolia, New Zealand, Papua New Guinea, the Philippines, the Republic of Korea, Singapore, and Viet Nam. Eight of them (Cambodia, China, Lao PDR, Malaysia, Mongolia, Papua New Guinea, Philippines, and Viet Nam) belong to TB-priority countries of the Western Pacific regional framework to end TB: 2021–2030, which are defined for monitoring purposes based on TB burden.[13]

Data collection

Data on yearly case notifications and treatment outcomes (categorised as treatment success, failure, loss to follow-up, and not evaluated) for the Western Pacific Region and the 14 selected countries and areas were obtained from the WHO database spanning 2015 to 2022.[14] 2015 was established as the baseline for milestones and targets of the End TB Strategy, and consistent global efforts had been directed towards achieving these milestones and targets since 2015, prior to the onset of the pandemic.[2] Additionally, monthly TB case notification data for the same 14 countries and areas from January 2020 to December 2022 were collected from provisional data reported to the WHO or publicly available national reports.

As a proxy for the robustness of health systems and the level of socio-economic development of each selected country and area, we utilised the Universal Health Coverage (UHC) service coverage index and Human Development Index (HDI) in 2019, respectively.[15,16] The UHC service coverage index is an index on a scale from 0 to 100, calculated as the geometric mean of 14 tracer indicators reflecting health service coverage. The HDI is a composite measure of overall achievement on a scale from 0 to 1, encompassing three dimensions of human development: health, education, and standard of living.

To assess the stringency of COVID-19 containment measures, the Stringency Index for the 14 selected countries and areas between January 2020 and December 2022 was extracted from the Oxford Covid-19 Government Response Tracker (OxCGRT).[17] This index considers nine ordinal containment and closure policy indicators on a scale from 0 to 100, indicating the strictness of lockdown-style policies primarily intended to restrict people's behaviour. The monthly mean Stringency Index, calculated from daily indexes, was used in the analysis.

Data analysis

The study assessed trends in yearly notifications from 2015 to 2022 and treatment success rates from 2015 to 2021 of people newly diagnosed with TB. In addition, a comparison was conducted between trend-adjusted predicted cases and yearly notified cases during the pandemic (from 2020 to 2022). To calculate trend-adjusted predicted cases for 2020, 2021, and 2022, a log-linear regression trend analysis was performed using annual case notification data from 2015 to 2019, assuming a continuation of the observed trend in 2015–2019 from 2020 onwards. The study also examined trends of proportion by case type in case notifications between 2015 and 2022. Furthermore, trends in case notification rates by age group were explored by comparing reported rates for 2020, 2021, and 2022 with those of 2019.

To examine correlations between differences in reported cases from predicted cases in 2020 and 2021 and the UHC service coverage index and HDI, Spearman correlation coefficients were calculated. Furthermore, a cross-correlation analysis was performed to assess the correlation between monthly provisional TB case notifications and the monthly mean Stringency Index. The cross-correlation function (CCF) is a method to quantify the degree of correlation and to identify lags or leads between two time-series.[18] The CCF was calculated at various lag times from −36 to 36 months between January 2020 and December 2022.

Statistical significance was set at $p < 0.05$. All data analyses and visualisations were performed using the statistical software package R 4.1.1 (Comprehensive R Archive Network at https://cran.r-project.org/).

Ethical clearance was not required because the analysis was based on publicly available data with no personally identifiable information.

Role of the funding source

This project was funded by the Government of the Republic of Korea through the Korea Disease Control and Prevention Agency and the Government of Japan through the Ministry of Health, Labour and Welfare. The funders had no role in the paper design, collection, analysis, and interpretation of data and writing the paper.

Results

Changes in TB case notifications

In the Western Pacific Region, the number of reported cases of new and relapse TB in 2020 (1,119,426) was lower than the predicted cases (1,418,555, 95% CI 1,366,948–1,472,111), representing a 21% (95% CI, −24 to −18) shortfall. The gap between reported cases (1,108,080) and predicted cases (1,434,014, 95% CI 1,367,620–1,503,631) widened in 2021, reaching 23% (95% CI, −26 to −19) (Fig. 1). However, in 2022, the gap between reported cases (1,182,766) and predicted cases (1,449,641, 95% CI 1,367,873–1,536,297) narrowed to 18% (95% CI, −23 to −14), although it has not yet fully rebounded to the pre-pandemic levels.

Among the 14 selected countries and areas, 9, 13, and 10 countries and areas reported fewer cases than predicted in 2020, 2021 and 2022, respectively (Fig. 2). Among those that experienced a sudden drop in case notifications in 2020 or 2021 (13 countries and areas), seven countries and areas showed a recovery in 2022, and Cambodia, Papua New Guinea, and Viet Nam even exceeded the predicted cases. However, China showed a more profound gap between reported and predicted cases in 2022 (30%) compared to 2021 (19%), largely influencing the regional case notification trend. Australia, Hong Kong, Japan, New Zealand, and the Republic of Korea also had a wider gap between reported and predicted cases in 2022 compared to 2020 or 2021.

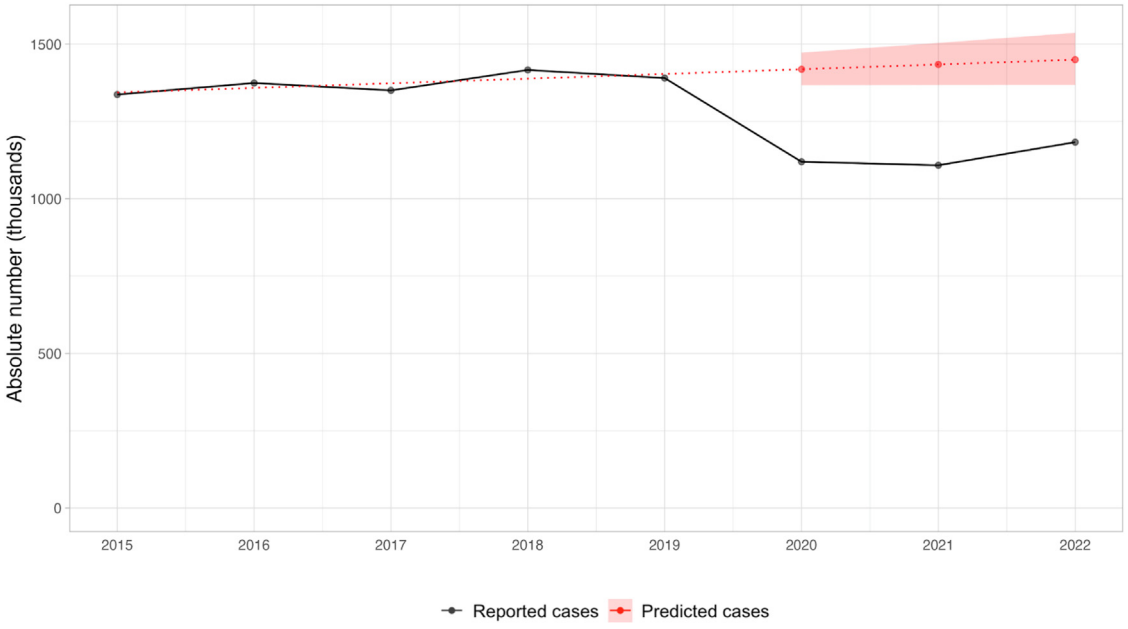

***Fig. 1:* Number of reported and predicted cases of people newly diagnosed with TB in the Western Pacific Region, 2015–2022**. Shaded areas indicate 95% confidence intervals.

In 2020, the Philippines only recorded a deficit exceeding 20% in case notifications compared to the prediction (–42%, 95% CI, –49 to –34) (Table 1). Lao PDR (–29%, 95% CI –35 to –23), Malaysia (–21%, 95% –25 to –16)), Mongolia (–28%, 95% CI –38 to –17), the Philippines (–34%, 95% CI –43 to –22), and Viet Nam (–24%, 95% CI –27 to –21) experienced deficits exceeding 20% in case notifications in 2021, while Australia (–26%, 95% CI –32 to –19), China (–30%, 95% CI –36 to –22) and Mongolia (24%, 95% CI –36 to –8) experienced shortfalls exceeding 20% in 2022.

Regarding the type of TB cases notified, there was a gradual increase in the proportion of laboratory-confirmed pulmonary cases from 2015 to 2019 (Fig. 3). This trend sharply escalated in 2020 and continued to rise subsequently (42% in 2019, 50% in

***Fig. 2:* Number of reported and predicted cases of people newly diagnosed with TB in selected countries and areas of the Western Pacific Region, 2015–2022**. Shaded areas indicate 95% confidence intervals.

Country or area	Year	Reported cases	Predicted cases (95% CI)	Difference (%, 95% CI)
Australia	2020	1611	1579 (1491–1672)	2 (−4 to 8)
	2021	1468	1644 (1527–1770)	−11 (−17 to −4)
	2022	1272	1712 (1564–1874)	−26 (−32 to −19)
Cambodia	2020	29,050	27,857 (24,788–31,306)	4 (−7 to 17)
	2021	21,589	26,551 (22,868–30,826)	−19 (−30 to −6)
	2022	32,772	25,306 (21,077–30,384)	30 (8–55)
China	2020	624,715	737,416 (691,673–786,185)	−15 (−21 to −10)
	2021	585,340	725,516 (668,451–787,452)	−19 (−26 to −12)
	2022	501,261	713,807 (645,666–789,140)	−30 (−36 to −22)
Hong Kong SAR, China	2020	3642	4011 (3897–4128)	−9 (−12 to −7)
	2021	3711	3916 (3775–4063)	−5 (−9 to −2)
	2022	3190	3824 (3656–4000)	−17 (−20 to −13)
Japan	2020	12,739	13,809 (13,347–14,287)	−8 (−11 to −5)
	2021	11,519	13,016 (12,461–13,595)	−11 (−15 to −8)
	2022	10,235	12,268 (11,631–12,940)	−17 (−21 to −12)
Lao PDR	2020	8013	7838 (7343–8365)	2 (−4 to 9)
	2021	6171	8739 (8040–9499)	−29 (−35 to −23)
	2022	8534	9745 (8799–10,792)	−12 (−21 to −3)
Malaysia	2020	22,973	26,246 (25,052–27,496)	−12 (−16 to −8)
	2021	21,186	26,695 (25,152–28,332)	−21 (−25 to −16)
	2022	24,795	27,151 (25,242–29,205)	−9 (−15 to −2)
Mongolia	2020	3861	3904 (3475–4386)	−1 (−12 to 11)
	2021	2709	3783 (3260–4391)	−28 (−38 to −17)
	2022	2803	3667 (3055–4401)	−24 (−36 to −8)
New Zealand	2020	316	314 (309–319)	1 (−1 to 2)
	2021	302	319 (313–325)	−5 (−7 to −3)
	2022	267	324 (316–331)	−18 (−19 to −16)
Papua New Guinea	2020	28,227	30,459 (27,789–33,384)	−7 (−15 to 2)
	2021	28,873	31,434 (27,954–35,347)	−8 (−18 to 3)
	2022	35,240	32,440 (28,098–37,453)	9 (−6 to 25)
Philippines	2020	256,541	442,446 (391,603–499,890)	−42 (−49 to −34)
	2021	321,564	483,755 (413,818–565,512)	−34 (−43 to −22)
	2022	435,890	528,922 (436,852–640,397)	−18 (−32 to 0)
Republic of Korea	2020	23,110	26,436 (25,177–27,758)	−13 (−17 to −8)
	2021	21,433	24,527 (23,042–26,107)	−13 (−18 to −7)
	2022	19,128	22,756 (21,081–24,564)	−16 (−22 to −9)
Singapore	2020	2357	2188 (1887–2537)	8 (−7 to 25)
	2021	2461	2161 (1788–2612)	14 (−6 to 38)
	2022	2674	2135 (1693–2693)	25 (−1 to 58)
Viet Nam	2020	99,852	101,843 (98,745–105,038)	−2 (−5 to 1)
	2021	77,657	101,942 (97,992–106,051)	−24 (−27 to −21)
	2022	102,479	102,041 (97,220–107,101)	0 (−4 to 5)

Table 1: **Percentage of difference between reported and predicted TB cases in selected countries and areas of the Western Pacific Region, 2020–2022.**

2020, 51% in 2021, and 53% in 2022). Conversely, the proportion of clinically diagnosed pulmonary cases declined, particularly in 2020 (50% in 2019, 41% in 2020, 40% in 2021, and 38% in 2022). Among the 14 selected countries and areas, upward trends in the proportion of laboratory-confirmed pulmonary cases were particularly prominent during the pandemic in the Philippines and Viet Nam (Fig. 4). Remarkably, China had already experienced a surge in the proportion of laboratory-confirmed pulmonary cases starting in 2018.

Regarding the percentage changes in case notification rates by age group in the Region, a reduction compared to 2019 was the greatest in the age group 0–14 in 2020 and 2021. However, the reduction mostly recovered in this group in 2022, while the recovery in the other age groups in 2022 was unremarkable (Fig. 5).

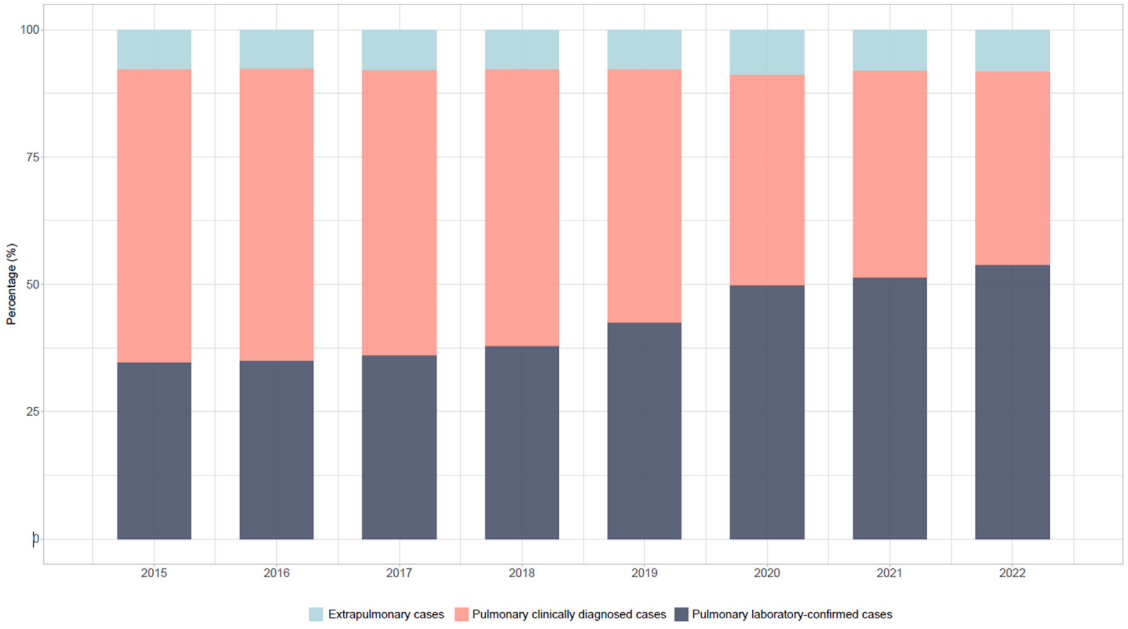

Fig. 3: **Proportion by case type in case notifications of people newly diagnosed with TB in the Western Pacific Region, 2015–2022.**

Among the 14 selected countries and areas, a reduction compared to 2019 was remarkable in the age group 0–14 in 2020 and 2021 in Australia, Lao PDR, the Philippines, the Republic of Korea, and Viet Nam, whereas the reduction was considerable in the older age groups in Malaysia and Papua New Guinea (Fig. 6).

UHC service coverage index, HDI and TB case notifications

Fig. 7 illustrates the association between the level of shortfalls in TB case notification (based on predicted and reported cases in 2020 and 2021) and the UHC service coverage index and HDI in 2019 for the selected

Fig. 4: **Proportion by case type in case notifications of people newly diagnosed with TB in selected countries and areas of the Western Pacific Region, 2015–2022.**

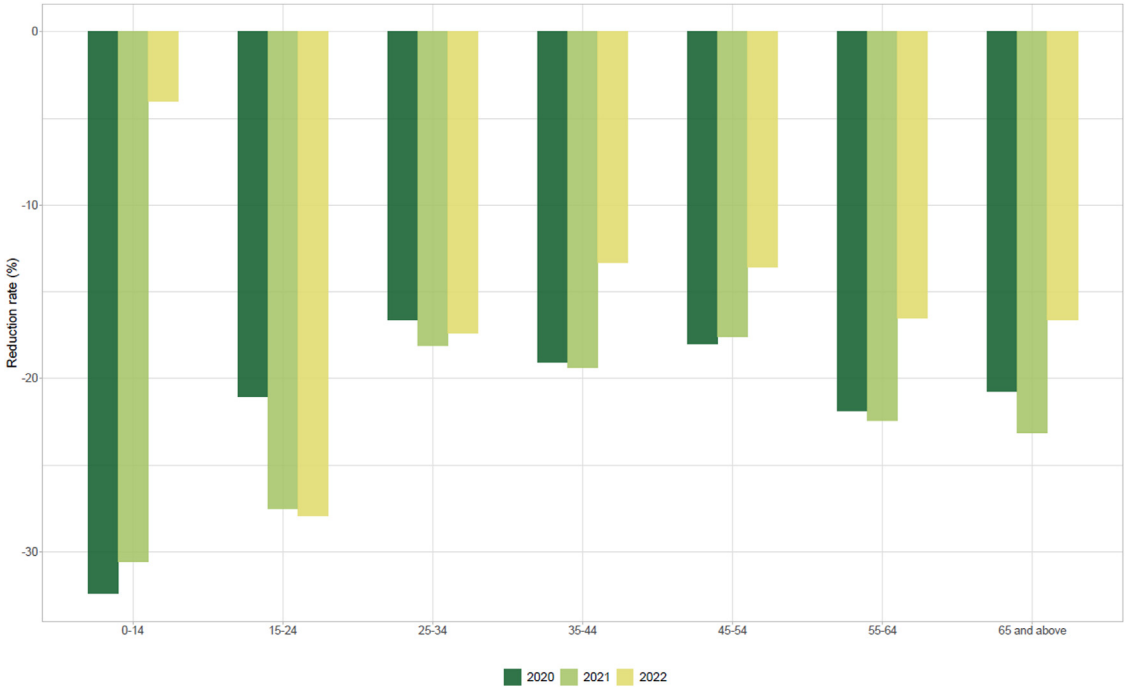

Fig. 5: **Percentage of changes in case notification rates by age group in the Western Pacific Region in 2020–2022, compared to 2019.**

countries and areas. A correlation is not observed between the level of shortfalls in TB case notification in 2020 and the UHC service coverage index (R = –0.016, p = 0.96), while a moderate positive relationship is seen in 2021 (R = 0.53, p = 0.067). Similarly, a correlation is not observed between the difference in reported cases

Fig. 6: **Percentage of changes in case notification rates by age group in selected countries and areas of the Western Pacific Region in 2020–2022, compared to 2019.**

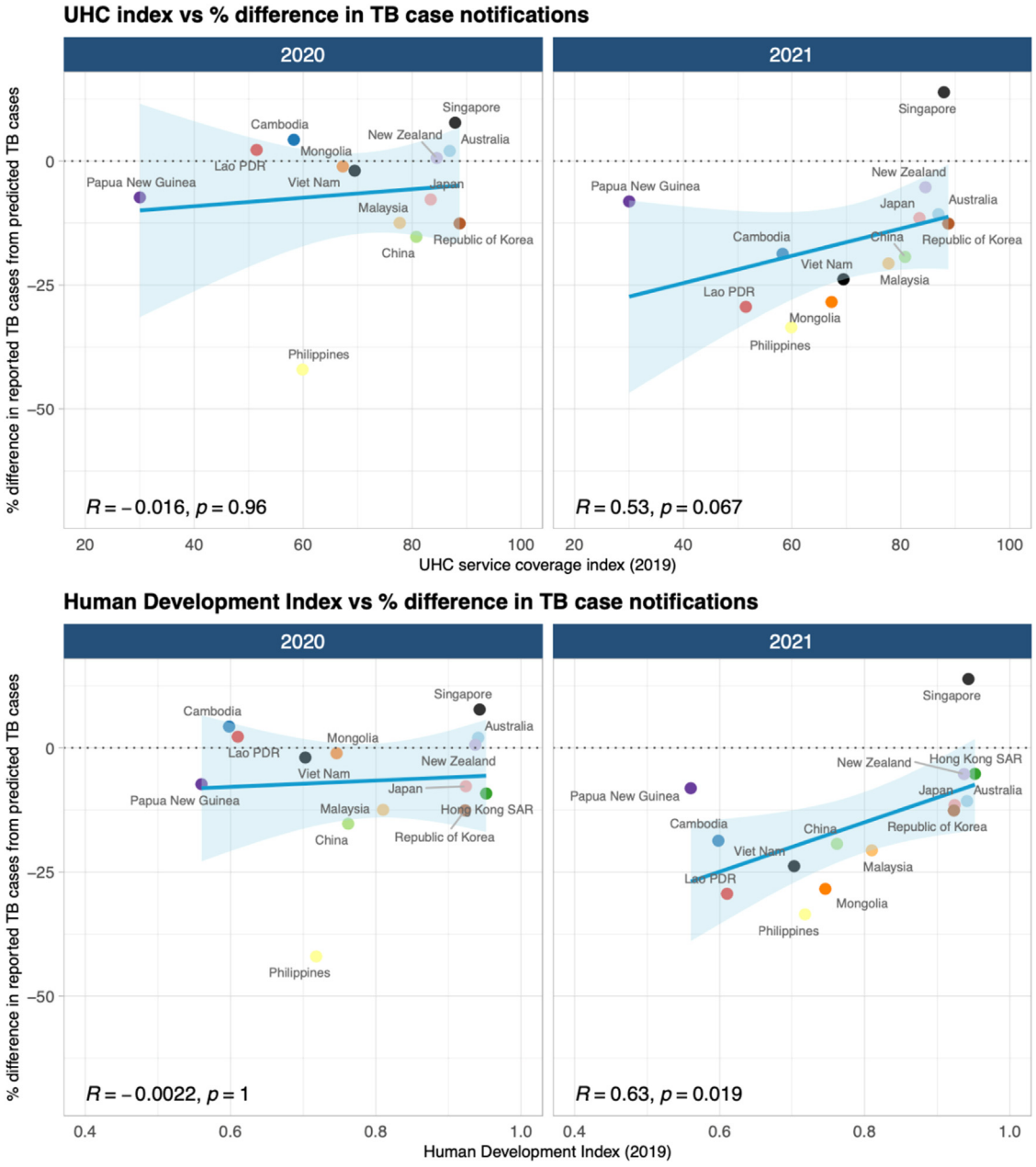

Fig. 7: **Percentage of difference between reported and predicted TB cases in 2020 and 2021 by UHC service coverage index and Human Development Index in 2019 in selected countries and areas of the Western Pacific Region.**

from predicted cases and HDI in 2020 (R = –0.0022, p = 1), while there is a statistically significant linear relationship in 2021 (R = 0.63, p = 0.019).

Stringency index and TB case notifications

Fig. 8 presents monthly TB case notifications and the monthly mean Stringency Index in the selected countries and areas from January 2020 to December 2022. An inverse relationship between the Stringency Index and TB case notifications is prominent in Cambodia, Lao PDR, Malaysia, Mongolia, the Philippines, Singapore, and Viet Nam. Fig. 9 shows CCF values between monthly TB case notifications and the monthly mean Stringency Index from January 2020 to December 2022 at various lag times from –36 to 36 months. Negative CCF values, indicating negative correlations between the Stringency Index and TB case notifications, exceeded 95% significance level at a lag time of 0 and

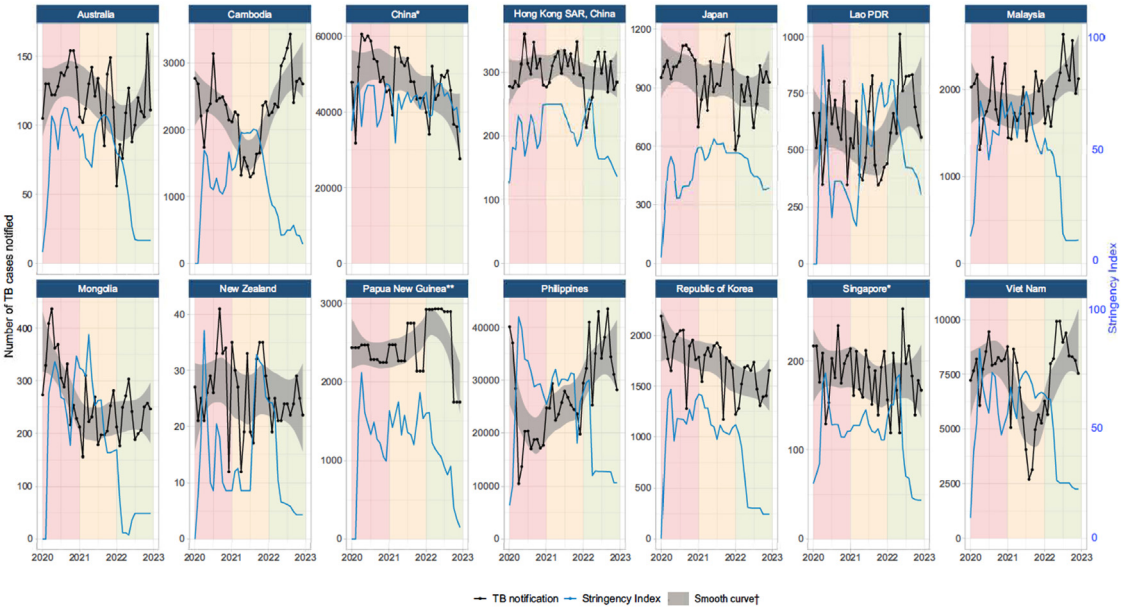

Fig. 8: **Monthly TB case notification and Stringency Index in selected countries and areas of the Western Pacific Region, January 2020–December 2022**. *Monthly notified cases in China (2019–2021) and Singapore (2019–2022) were extracted from weekly or monthly reports, adjusted by a factor of 0.7 and 1.6, respectively. This is to account for the historical relationship between reported and notified cases. In China, the sum of monthly case notifications is typically higher than the annual case notifications because some cases are excluded after being reported to the national authority due to diagnosis with other diseases. In Singapore, monthly case notification is typically lower than annual one due to a time lag in reporting. Monthly notified cases in China in 2022 were reported to WHO. **Monthly notified cases were calculated by dividing quarterly reported cases. †Locally Weighted Scatterplot Smoothing (LOESS) method was used to estimate a smooth curve to show less fluctuation and identify underlying trends in the data.

persisted for several months from lag 0 in Cambodia, Malaysia, the Philippines, and Viet Nam.

Changes in TB treatment outcomes

There was no significant change in the treatment success rate in the Western Pacific Region in 2020 and 2021 compared to 2019 (Fig. 10). Regarding the 14 selected countries and areas, the treatment success rate in 2020 and 2021 remained similar to the levels recorded in 2019, except for the Philippines, where there was a substantial decrease (76%) in 2020 compared to 2019 (86%) and a partial recovery (80%) in 2021 (Fig. 11).

Discussion

Since the onset of the COVID-19 pandemic, there has been a profound transformation in the landscape of TB services in the Western Pacific Region, particularly in priority countries with a high burden of TB. TB case notifications experienced a remarkable decline in 2020 and/or 2021 in such priority countries, with a particularly noticeable reduction in clinically diagnosed pulmonary cases and paediatric cases. The vulnerability of priority countries, characterized by weak health and socio-economic systems, intensified the impact of the COVID-19 pandemic on TB services. The severity of lockdown-style policies showed a meaningful correlation with TB case notifications in those countries, amplifying the impact and prolonging its duration. As the pandemic gradually waned in 2022, TB case notifications commenced a recovery. However, they have not yet reached pre-pandemic levels in the Region, despite a global rebound in newly diagnosed cases surpassing pre-pandemic levels in 2022.[1] This discrepancy can be attributed primarily to the stagnant case detection in China. In contrast, treatment success rates have remained relatively stable, demonstrating a level of resilience despite the challenges posed by the pandemic.

During the pandemic, several factors likely influenced TB case notifications, varying across countries. In high-income countries, travel restrictions might have curtailed the influx of migrants from high TB-burden countries, resulting in a decline in TB case notifications. As depicted in Fig. 2, there was a notable decline in TB notifications in 2021, followed by a widening gap in 2022 in Australia and New Zealand, where the majority of TB cases are attributed to foreign-born individuals. This trend could be linked to the decreased influx of migrants from high TB-burden countries.[19] In low- and middle-income countries, where paper-based recording and reporting systems persist or human resources are limited, reporting challenges may have

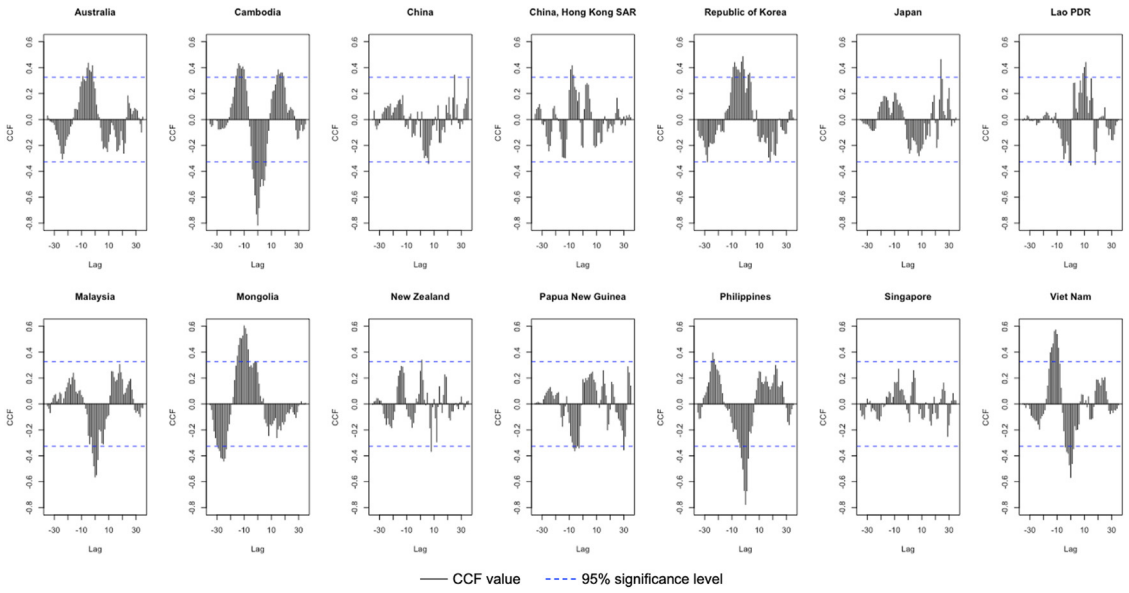

Fig. 9: **Cross-correlation function (CCF) values between monthly TB case notification and mean stringency index (Lag: −36 ~ +36) in selected countries and areas of the Western Pacific Region, January 2020–December 2022**.

contributed to reduced TB case notifications. However, we posit that changes in TB case notifications are primarily driven by reductions in both TB detection and transmission in the Region. The extent to which the decrease in TB case notifications is influenced by reduced detection versus reduced transmission remains uncertain. Undoubtedly, disrupted health services, interrupted supply chains, and decreased healthcare utilisation—whether voluntary or involuntary—have contributed to a decline in TB detection. Our analysis suggests a correlation between the Stringency Index and TB case notifications in priority countries, supporting the hypothesis that the reduction in TB case notifications is linked to decreased TB detection. This decline may lead to sustained TB transmission from undiagnosed cases within the community. On the other hand,

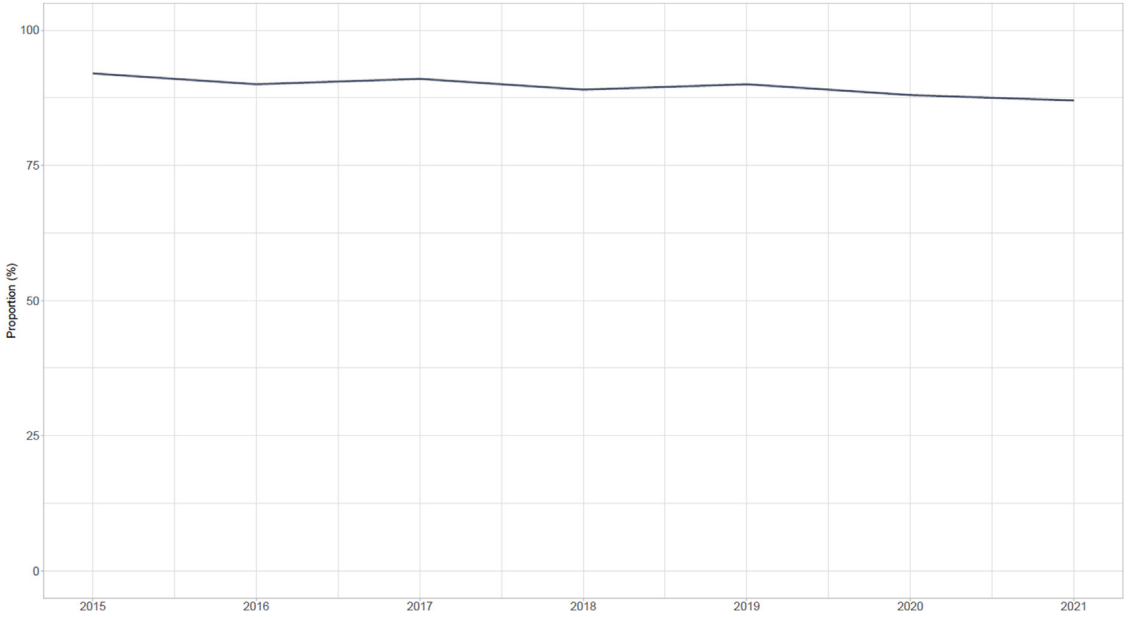

Fig. 10: **Proportion of successfully treated cases among new and relapse TB cases in the Western Pacific Region, 2015–2021**.

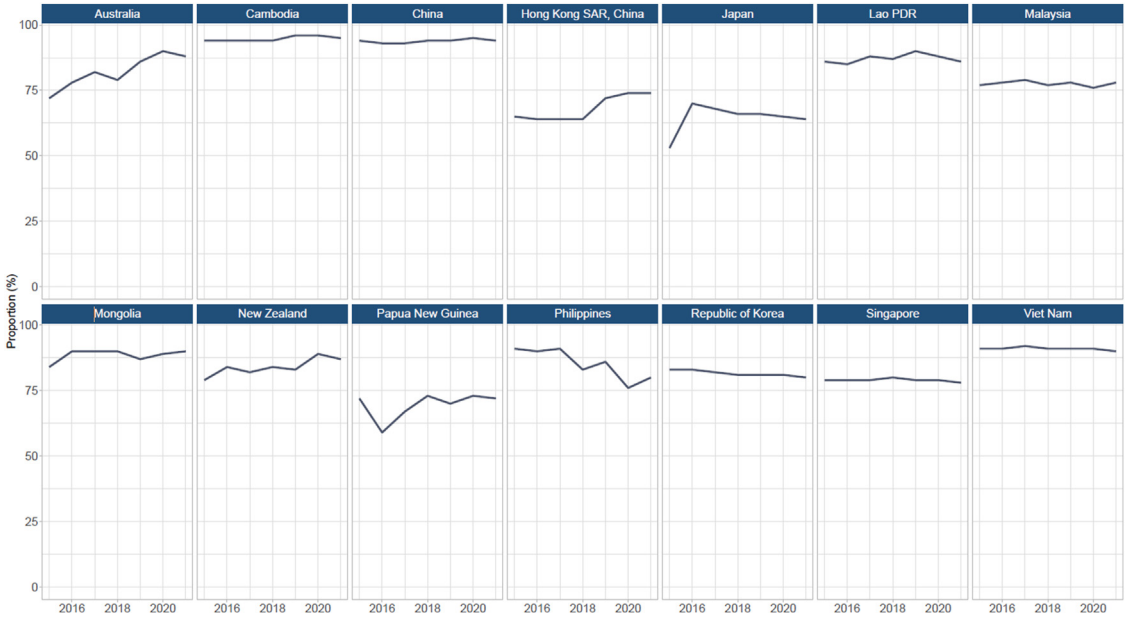

Fig. 11: **Proportion of successfully treated cases among new and relapse TB cases in selected countries and areas of the Western Pacific Region, 2015–2021.**

physical distancing, mask use, and gathering restrictions may have reduced TB transmission in the community. This reduction in TB transmission may lead to an immediate reduction in TB incidence among certain high-risk groups with rapid progression from infection to disease.[20] However, its broader effects may be constrained in two ways. First, in the Western Pacific Region, a substantial proportion of TB is reported among older adults, in which much of TB incidence arises from reactivation rather than recent infection.[20–23] Second, the latent period from infection to disease spans months or even years, implying that a reduction in TB transmission may not promptly manifest across entire populations.[24,25] Consequently, it is reasonable to attribute the decline in TB case notifications primarily to a decrease in TB detection rather than an immediate impact on TB transmission.

Our analysis revealed an enormous impact on TB case finding and diagnosis during the pandemic. Lockdown-style policies, including restricted transportation, curfew, and gathering restrictions, reluctance to visit health facilities due to COVID-19 fears, and the suspension of active case-finding due to staff reallocation and insufficient funding may have contributed to the decline in case detection.[5] Disruptions in the supply chain of Xpert MTB/RIF cartridges, challenges in specimen referral, and the reallocation of GeneXpert machines for COVID-19 diagnosis may have limited TB testing.[7] The reduction in TB case finding and diagnosis is particularly notable among clinically diagnosed pulmonary cases and paediatric cases. These types of diagnosis involve multiple steps in the diagnostic process, requiring multiple visits to health facilities.[26,27] Consequently, the decreased utilisation of health services during the pandemic likely impacted this reduction. In certain countries such as Malaysia and Papua New Guinea, the decline in TB case notifications was more pronounced in older age groups, compared to other age groups. Older individuals, being considered a high-risk group for COVID-19, may have curtailed their visits to health facilities during the pandemic, leading to a decrease in TB diagnoses.[28,29]

Contrary to the impact on TB case finding and diagnosis, the influence on TB treatment and patient monitoring appears to be relatively insignificant. This observation can be analysed from two perspectives. Firstly, the treatment success rate, utilised as an indicator to assess the impact on TB treatment and patient monitoring, lacks differentiation between cured and completed cases in the WHO database. It is reported that treatment was not properly monitored and follow-up tests at the end of the treatment were not done as usual but reported as treatment success in some priority countries during the pandemic (personal communication). Therefore, it is crucial to confirm this using the national data and examine the long-term implications of the reduction in cured cases in those countries. Second, many countries have implemented countermeasures to address the disruptions in TB treatment and patient monitoring services during the pandemic. For instance, they have adopted digital tools for patient monitoring, shifted from facility-based directly observed treatment (DOT) to community-based (or family-based) DOT, extended the duration of medicine supply for patients

during visits, and swiftly introduced shorter all-oral regimens for drug-resistant TB patients.[30–32] These proactive measures may have alleviated the adverse effects of the pandemic. In the case of the Philippines in 2020, the treatment success rate was reduced compared to 2019. However, this is considered not due to the pandemic but due to increased case notifications from private facilities where treatment outcomes are largely not evaluated (WHO Regional Office for the Western Pacific, unpublished).

Our analysis demonstrated that the impact of COVID-19 was swifter, more potent, and longer-lasting in priority countries with a high burden of TB compared to non-priority countries with an intermediate or low TB burden. The disparity between reported and predicted cases during the pandemic was more pronounced in these priority countries. As illustrated in Fig. 7, these countries exhibit lower levels of UHC service coverage index and HDI, indicating weaker health systems and lower socio-economic development. Several studies indicate that the pandemic's impact on various sectors was more substantial in lower income countries.[12,33,34] As shown in Fig. 9, stringent government policies against the pandemic had a more immediate, profound and prolonged damage on TB services in these countries. These findings suggest that high-income countries may have coped better due to their robust health systems and higher levels of socio-economic development. It is noteworthy that Papua New Guinea experienced a lesser impact on TB case notifications than other priority countries during the pandemic. The comparatively low peak of the Stringency Index and positive CCF in the country, in contrast to other priority countries, imply that government restrictions might have been less stringent and inconsistent.

Our study comes with a set of limitations. Firstly, we could not include indicators for TB prevention in our analysis due to the lack of available data in the database. The significant influence of the COVID-19 pandemic on TB preventive treatment in many countries in the Region may have long-term implications for the TB epidemic. Secondly, we could not include indicators related to treatment enrollments, such as initial loss to follow-up (LTFU) or initial deaths, as they were unavailable in the database. In certain countries, the pandemic may have obstructed treatment enrollments after diagnosis, potentially leading to heightened initial LTFU or initial deaths. Third, regional indicators are predominantly shaped by the substantial case numbers reported in China and the Philippines, underscoring the need to consider variations between countries in interpreting regional findings. Fourth, monthly case notifications are provisional data with potential inaccuracy. However, they serve a valuable purpose in illustrating monthly trends. Fifth, other factors beyond the three upstream determinants (UHC service coverage index, HDI, and Stringency Index) examined in our study may have impacted TB care and prevention differently across countries during the pandemic. For example, health behaviours like the fear of COVID-19 infection could have varied, potentially leading to diverse effects on TB notifications and treatment outcomes. Nevertheless, there was a dearth of systematic data on these additional factors across various countries in the Region. Sixth, each index used for our study has inherent limitations. The UHC service coverage index employs some proxy indicators instead of direct measures of service coverage due to data constraints.[15] The HDI, while capturing certain aspects of human development, omits critical elements such as inequalities, poverty, human security, and empowerment.[16] The Stringency Index merely records the strictness of government policies and does not gauge the appropriateness or effectiveness of a country's response.[17] Despite these constraints, our analysis offers a comprehensive and practical insight into the regional TB epidemic before and after the pandemic. This insight is based on several years of data reported by nearly all the countries in the Region, following well-established case definitions.

Our study underscores several key considerations. Firstly, despite a rebound in TB case notifications to pre-pandemic levels in some priority countries by 2022, the long-term impact of the pandemic on the TB epidemic remains uncertain. Further research is essential to investigate the extended effects, encompassing TB incidence and mortality. Secondly, innovative approaches have demonstrated positive outcomes in TB care and prevention, particularly in the realm of TB treatment and patient monitoring. Exploring and understanding these effects can be invaluable in preparing for future pandemic situations. Thirdly, the study highlights the vulnerability of essential health services to stringent government policies, such as lockdowns and mobility restrictions, during crises, especially in countries with weak health systems and suboptimal socio-economic development. The findings emphasise the necessity for proper contingency planning within health systems in anticipation of future crises, coupled with a well-informed analysis of the anticipated impact.

In summary, the COVID-19 pandemic has had a markedly negative impact on TB diagnosis and care in the Western Pacific Region, particularly in TB-priority countries. While significant effects have been observed in case detection, especially in clinically diagnosed pulmonary and paediatric cases, the impact on treatment has been marginal. The stringent government policies against the pandemic, coupled with weak health systems and lower socio-economic development, have contributed to a greater COVID-19 impact on TB services in priority countries. To regain momentum in ending TB in these countries, a recovery plan should be implemented with a focus on political commitment, health system strengthening, and multisectoral collaboration.

Contributors

KHO conceptualised and designed the study, collected the data, interpreted the results, and drafted the manuscript. MY and FM designed the study, collected the data, interpreted the results and critically revised the manuscript. PG, KR, and RPY critically revised the manuscript. All authors contributed to the final version of the manuscript, reviewed, and approved the manuscript.

Data sharing statement

All data included in this paper are available from the reference list.

Declaration of interests

The authors declare that they have no competing interests.

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