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The COVID-19 Impact on Tuberculosis Incidence Notification in India- A Comparative Study (2017-2022)

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Research Article

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ABSTRACT

Despite modern drugs treatment with 60 years of chemotherapy and 90 years of vaccination with various strategies to prevent and control Tuberculosis (TB), globally TB ranks 13th in leading causes of mortality. In recent year 2021 Worldwide, TB ranks 2nd after COVID-19, in leading causes of infectious killer, killing about 1.6 million people in 2021 (including 187000 people infected with HIV). During COVID-19 era 2020, very significant global reduction in TB incidence was detected, which suddenly reduced from 7.1 million in 2019, to 5.8 million in 2020 (-18%). Globally, India is listed among the top three countries accounting for 67% of this global reduction in TB incidence, besides Indonesia and the Philippines. As per data of The World Bank, India's annual TB incidence was falling continuously since 2000, rose again and reached 210/100,000 in 2021 from 204/100,000 in 2020. A modelling analysis study found that lockdown has induced 80% reduction in TB notification rates in India. India ranks fourth in infection and death from COVID-19; hence there is a possibility that slowing down of COVID-19 will unmask the TB cases and deaths leading to increase in the count of TB in future years. In spite of several similarities in manifestation and differences in aetiology, there is still lack of full knowledge about the epidemiological relationship between TB and COVID-19 .To know the real situation and scenario of TB cases this study was started with aim to alert policy maker for needful action to control TB effectively in time. This study aimed to know the impact of COVID-19 on annual TB notifications incidence in India. This is a cross-sectional, quantitative, retrospective, deductive study. This research study included all the 36 states and UTs of India. We performed a linear regression study of the existing data of pre pandemic years included in this study for calculating a counterfactual analysis in order to find out the possible real incidence of TB cases notifications, which may have been notified if the current natural intervention of

COVID-19 had not taken place. The annual number of new (TB) cases detected during the pre-COVID-19 period as well as COVID-19 period of this study has shown similar trends separately. During both periods the number of new (TB) cases increased in consecutive years. Another significant finding of this study is that the number of new (TB) cases detected during the first two COVID-19 years *i.e.,* 2020 and 2021 decreased in comparison to last pre-COVID-19 year *i.e.,* 2019. The base year of this study *i.e.,* 2017 are having least whereas the last year of this study *i.e.,* 2022 are having the largest number of new (TB) cases detected in one individual year. There is an increase of 7.79% in TB case detection during the COVID-19 period of this study. This study revealed that during first COVID-19 year *i.e.,* 2020 there is significant reduction in number of new (TB) cases detected by 580869 numbers or 24.29% in comparison to last pre-COVID-19 year *i.e.,* 2019. The number of new (TB) cases detected increased continuously during pre-COVID-19 years by 29.59% in 2018 and 18.49% in 2019. The question arises from this study is that, is it possible to achieve the goal of NTEP by year 2025 in current scenario reality?

Keywords: COVID-19; Tuberculosis; Incidence; TB; Health; Annual; Notification

Abbreviations: TB: Tuberculosis; COVID-19: Coronavirus Disease 2019; HIV: Human Immunodeficiency Virus; UTs: Union Territories; NTEP: National Tuberculosis Elimination Program; SDG: Sustainable Development Goal; WHO: World Health Organization; LMICs: Lower Middle Income Countries; GoI: Government of India; NI-KSHAY:Ni=End, Kshay=TB

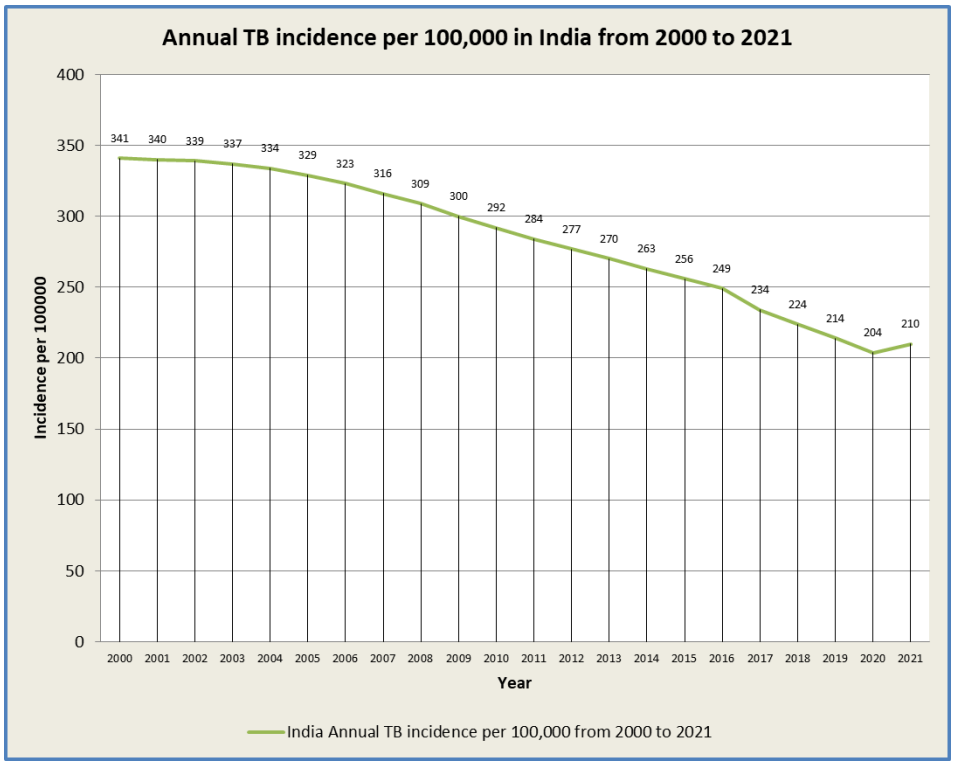
INTRODUCTION

Background/rationale

Despite modern drugs treatment, 60 years of chemotherapy and 90 years of vaccination as well as various strategies to prevent and control tuberculosis, globally Tuberculosis (TB) ranks 13th in leading causes of mortality [1]. In recent year 2021 Tuberculosis (TB) ranks 2nd after COVID-19, in leading causes of infectious killer, about 1.6 million people died in 2021 from TB (including 187,000 people infected with HIV) [2]. The recent emergence of COVID-19 pandemic in 2019 December overburdened health care system of India [3]. This COVID-19 overburden may have affected TB cases detection and notification, treatment, setting back the achievements made previously in order to eliminate TB by 2025 [4]. The COVID-19 affected healthcare services of developed countries also having advanced technologies and enough human resource [5]. The global TB incidence was reducing slowly at the rate of 2% every year, and in period between 2015 and 2020 it decreased by 11%, which was only half of the target required to achieve the elimination goal of 20% reduction between 2015 and 2020. During COVID-19 era 2020, very significant global reduction in TB incidence was detected, which suddenly reduced from 7.1 million in 2019, to 5.8 million in 2020 (-18%) [6]. Globally, India is listed among the three countries accounting for major reduction in TB incidence in 2020 besides Indonesia and the Philippines (total 67% of the global reduction) [7]. India annual TB incidence which was falling continuously since 2000 rose again and reached 210/100,000 in 2021 from 204/100,000

in 2020, as per data of the world bank (Figure 1) [8].

Figure 1: Annual TB incidence per 100,000 populations in India from 2000 to 2021*.



*World Health Organization, Global Tuberculosis Report-Incidence of tuberculosis (per 100,000 people)-India

Viewing the burden of TB in India, curbing TB in India is an essential element for eradicating Tuberculosis (TB) globally. India alone accounts for 25% of the global burden of TB cases [9]. India has committed to achieve by 2025 (five years before the global deadline in 2030) the SDG (Sustainable Development Goal) targets of meeting 80% reduction in TB incidence and 90% reduction in TB mortality [10]. The key author researcher has done some research work (available at WHO COVID-19 research database) which revealed that the phase wise unlocking from 1 June 2020, and a nationwide lockdown implemented in India (to control the COVID-19 pandemic) for 68 days (beginning from 25 March to 31 May 2020) had disrupted regular essential healthcare services in India [11].

Studies found that lockdown induced poverty and under nutrition may worsen the TB burden situation by affecting poor population nutritional status by pushing population in vulnerable economic crisis Below Poverty Line (BPL) [12,13]. Even before COVID-19 era only 58% of overall new and relapsing TB cases were notified in India as per 2019 global TB report of World Health Organization (WHO) [14]. A modelling analysis study found that lockdown has induced 80% reduction in TB notification rates in India [15]. This underreporting of TB cases may affect TB epidemiology and NTEP (National Tuberculosis Elimination Program) goal for TB elimination by 2025 [16]. One study found that the $CD4^+$ T-cell depletion in COVID-19 cases may promote the emergence of active tuberculosis infection from the latent TB infections similar to its development in HIV patients [17]. One study revealed that COVID-19 and TB co-infection is associated with high mortality (11%), as well as Mycobacterium Tuberculosis (causing TB) infection also resulted in more severe COVID-19 disease with faster progression of the disease [18]. The world bank marked $3.2 a day earning as poverty line for LMICs like India (lower middle income

countries), and it is estimated that the economic crisis due to COVID-19 will push additional 104 million Indians into poverty [19]. The COVID-19 disease as well as pulmonary TB present with almost similar respiratory symptoms hence timely diagnosis and treatment of TB, or TB co-infection with COVID-19 may be compromised [20].

It is found that COVID-19 affects children less severely (compared to elder age groups) whereas TB is leading cause of mortality in children, evident from the fact that globally in 2017, 1,94,000 children died from TB infection [21,22]. The India TB report 2019, estimated 2,24,000 new paediatric TB cases every year accounting for 22% of global burden [23]. India ranks fourth in infection and death from COVID-19, hence there is a possibility that slowing down of COVID-19 will unmask the TB cases and deaths leading to increase in the count of TB in future years [24]. In spite of several similarities in manifestation and differences in aetiology, there is still a lack of full knowledge about the epidemiological relationship between TB and COVID-19 [25].

To know the real situation and scenario of TB cases this study was started with aim to alert policy maker for needful action to control TB effectively in time.

MATERIALS AND METHODS

This study aimed to know the impact of COVID-19 on annual TB (new) notifications incidence in India. This is a cross-sectional, quantitative, retrospective as well as deductive study. Our research study included all the 36 states and UTs of India. The first case of COVID-19 in India was notified in the month of January 2020 [26]. Hence for our study we have considered the pre COVID-19 era as any period before 1st January 2020. For our study this pre COVID-19 period was from 1st of January 2017 to 31st December 2019. Our study considered period from 1st of January 2020 till 31st of December 2022 *i.e.,* end of this study, as COVID-19 era (Tables 1 and 2).

This version of study is to assess the new TB cases notifications from India at country level. Our next version of this continuous study will analyze the impact of COVID-19 on TB cases notifications from individual states and UTs.

All the new cases of TB (Tuberculosis) is notified in India, from the 36 states and UTs through electronically web based NIKSHAY platform, established by the GoI (Government of India) [27]. For the study purpose we collected the data from NIKSHAY platform. The annual TB case notifications from the individual 36 states and UTs of India were collected instead of collecting single annual incidence notification.

We have also found a little difference in the two notifications count. The single annual TB incidence notification count available at data source mentioned below is 15,25,036; 19,97,811; 23,91,665; 18,10,811; 21,43,822 and 24,23,573 for years 2017, 2018, 2019, 2020, 2021, and 2022 respectively whereas adding the individual count from different states and UTs it is 15,25,045; 19,97,873; 23,91,703; 18,10,834; 21,45,678; 24,19,047; for years 2017, 2018, 2019, 2020, 2021, and 2022 respectively (Tables 1 and 2).

Table 1: Pre COVID-19 era annual TB case notifications from the 36 states and UTs of India*.

State wise total notified from 01/01/2017 to 31/12/2019	2017	2017	2018	2018	2019	2019	Pre-COVID era
State	2017-Total	2017-Total private	2018-Total	2018-Total private	2019-Total	2019-Total private	Total public & private

	public notified	notified	public notified	notified	public notified	notified	notified
Andaman and Nicobar Islands	615	13	544	18	573	7	1770
Andhra Pradesh	62731	5787	65645	19142	76239	22222	251766
Arunachal Pradesh	3297	2	3045	4	2908	36	9292
Assam	36066	618	36929	4115	40612	7982	126322
Bihar	55906	9298	66337	32282	77922	44240	285985
Chandigarh	4225	85	5124	176	6457	496	16563
Chhattisgarh	31280	3764	29901	8736	31536	11679	116896
Dadra and Nagar Haveli and Daman and Diu	1282	59	1244	83	1357	130	4155
Delhi	57255	1667	69911	9731	79743	27852	246159
Goa	1409	116	1833	431	1921	463	6173
Gujarat	97002	17115	106001	36750	104921	53865	415654
Haryana	35060	3350	47836	11727	50895	21835	170703
Himachal Pradesh	13477	542	15181	1244	15785	1560	47789
Jammu and Kashmir	8218	571	10499	764	10493	904	31449
Jharkhand	36155	1991	38487	6884	43677	12544	139738
Karnataka	63636	5705	67316	11942	71861	19619	240079
Kerala	17160	3671	20926	3227	20659	4884	70527
Ladakh	274	2	355	57	360	29	1077
Lakshadweep	49	0	19	0	15	0	83
Madhya Pradesh	116574	6067	120681	29650	139013	47445	459430
Maharashtra	123919	18877	139098	52196	143187	82282	559559
Manipur	1626	304	2165	413	2004	551	7063
Meghalaya	3171	222	4025	573	4709	724	13424
Mizoram	2457	41	2561	36	2939	40	8074
Nagaland	2439	275	3678	471	4149	696	11708
Odisha	48319	1933	45807	2683	48889	4479	152110
Puducherry	1890	5	3485	30	4564	72	10046
Punjab	36252	3251	42232	8211	43891	13940	147777
Rajasthan	85440	8161	111042	37519	121574	51374	415110
Sikkim	1199	2	1507	11	1427	24	4170
Tamil Nadu	77815	8708	75392	19359	82290	27229	290793
Telangana	37009	1713	42087	8922	50554	20551	160836
Tripura	2036	0	2624	19	2719	46	7444
Uttar Pradesh	235505	18069	303728	82555	326306	159771	1125934
Uttarakhand	13393	3496	16951	3872	19744	6157	63613
West Bengal	82118	3306	86951	12893	84897	25185	295350
Total	1396259	128786	1591147	406726	1720790	670913	5914621

Note: *Due to periodic update of NIKSHAY database there may be slight difference in figure, a copy of downloaded data is available with key/1st author.

For this study we have taken equal continuous period of two eras to reduce bias *i.e.,* from 1st January 2017 to 31st

December 2019 and 1st January 2020 to 31st December 2022. Another attempt to reduce bias is to compare equal pre-pandemic period with COVID-19 pandemic period *i.e.,* three years. The key objective is to deduct any positive/negative impact of COVID-19 period on the TB notification incidence annually (Tables 1 and 2).

Our study considered the fact that COVID-19 is an intervention enforced by nature in the routine health and other services delivery like transportation, social security, etc., which has hampered several essential health and other services in India [28-41].

Hence we performed a linear regression study of the existing data of pre pandemic years of this study for getting a counterfactual analysis in order to find out the possible real incidence of TB cases notifications, which may have been notified if the current natural intervention COVID-19 had not taken place. The data for this study were collected and analysed by utilizing Microsoft office as well as Stata 15.1 software.

Study variable and operational definition

For this study we considered any notification on NIKSHAY dashboard, by any of the 36 participant's states and UTs of India in a specified year, as new TB case notification or a new Tuberculosis (TB) cases detected by that participant. The incidence rate of TB in India calculated below is totally as per this above mentioned new Tuberculosis (TB) cases detected. Any change, in the count of above mentioned variable *i.e.* TB case notification during the COVID-19 period compared to pre-pandemic period in TB case notification is considered as impact of COVID-19 situation for this study purpose. Beside TB case notification other variable is population which is mentioned below with data source.

Data sources

The data source is available below:

- TB case notifications from India.
- Population of India data source-the world bank.

Table 2: COVID-19 era annual TB case notifications from the 36 states and UTs of India*.

State wise total notified from 01/01/2020 to 31/12/2022	2020	2020	2021	2021	2022	2022	COVID-19 era
State	Total public notified	Total private notified	Total public notified	Total private notified	Total public notified	Total private notified	Total public and private notified
Andaman and Nicobar Islands	481	0	506	6	510	24	1527
Andhra Pradesh	46868	17235	62124	24765	62010	30106	243108
Arunachal Pradesh	2522	1	2750	16	2715	141	8145
Assam	29271	6202	29729	8385	36662	10972	121221
Bihar	52317	47521	62365	70260	78619	82052	393134
CHANDIGARH	3767	537	4245	506	5653	399	15107
Chhattisgarh	20981	8400	23695	8882	26739	11684	100381
Dadra and Nagar Haveli and Daman and Diu	869	81	947	65	1293	105	3360
Delhi	59631	27086	68274	35256	76790	29757	296794

Goa	1340	326	1631	381	1612	455	5745
Gujarat	77184	43305	92852	51853	100903	50911	417008
Haryana	41472	21482	45620	23546	51152	24493	207765
Himachal Pradesh	12194	1273	13062	1515	14439	1630	44113
Jammu and Kashmir	7943	881	9503	1395	9995	1783	31500
Jharkhand	30516	15349	35455	17155	43573	13612	155660
Karnataka	48716	17262	52972	19745	59446	20840	218981
Kerala	15076	5822	15437	6628	16725	6590	66278
Ladakh	231	6	282	10	311	9	849
Lakshadweep	18	0	12	0	11	0	41
Madhya Pradesh	104682	33284	111154	55870	130140	55364	490494
Maharashtra	95748	64693	110116	90320	133590	102293	596760
Manipur	1151	433	1256	544	1627	917	5928
Meghalaya	3455	689	3278	892	4054	920	13288
Mizoram	1991	131	1486	273	1696	388	5965
Nagaland	2906	689	2971	741	3341	750	11398
Odisha	40435	5264	45156	7369	50331	9967	158522
Puducherry	2684	88	3407	49	3731	102	10061
Punjab	34694	11720	36737	14482	43218	11684	152535
Rajasthan	95855	41374	102979	46507	126480	42712	455907
Sikkim	1158	180	1305	102	1282	108	4135
Tamil Nadu	54008	16522	64534	18611	71842	21909	247426
Telangana	40540	22703	41488	19311	52264	20556	196862
Tripura	1995	73	2448	111	2860	156	7643
Uttar Pradesh	242722	125317	315422	140843	372651	149230	1346185
Uttarakhand	14292	5798	17356	5610	21157	6328	70541
West Bengal	61905	17489	69644	21476	76751	23927	271192
Total	1251618	559216	1452198	693480	1686173	732874	6375559

Note: *Due to periodic update of NIKSHAY database there may be slight difference in figure, a copy of downloaded data is available with key/1st author.

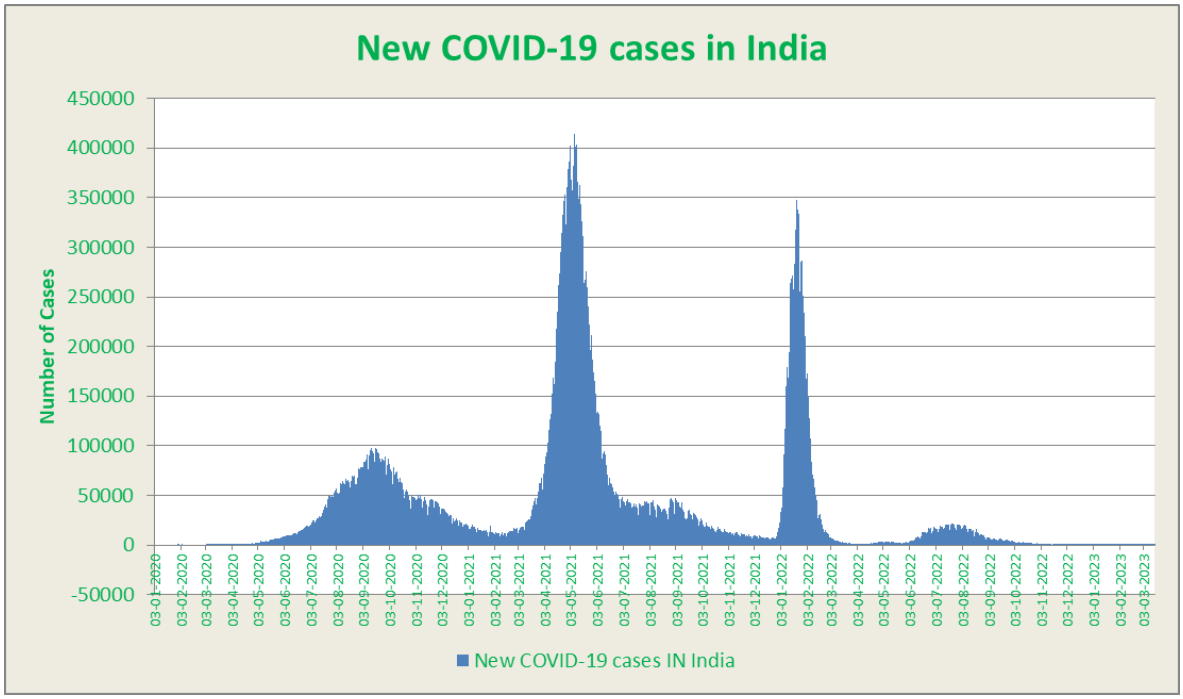
RESULTS

The total number of new Tuberculosis (TB) cases detected by all public and private health facilities during the study period *i.e.,* from 1st January 2017 to 31st December 2022 is 1,22,90,180 (n), which is obtained by adding individual cases detected by the 36 participants (states and UTs of India) (Tables 1 and 2). The total number of this newly detected TB cases by all public and private health facilities during pre-COVID-19 period (2017-2019) is 59,14,621 whereas during the COVID-19 period of this study (2020-2022) it increased to 6375559. There is an overall increase of 7.79% in TB case detection during the COVID-19 period of this study. The mean newly detected TB cases by all public and private health facilities during pre-COVID-19 period is 19, 71,540 whereas during COVID-19 period it increased to 21,25,186.

The mean newly detected TB cases increased by same 7.79% during COVID-19 period. The annual number of new

Tuberculosis (TB) cases detected (including public and private healthcare facilities) by the 36 participants (states and UTs of India), during a year *i.e.,* 1st January to end *i.e.,* 31st December is 15,25,045; 19,97,873; 23,91,703; 18,10,834; 21,45,678; 24,19,047; for years 2017, 2018, 2019, 2020, 2021, and 2022 respectively (Tables 1 and 2). The annual number of new Tuberculosis (TB) cases detected during the pre-COVID-19 period as well as COVID-19 period of this study has shown similar increasing trends separately. During both pre-COVID-19 and COVID-19 periods of this study the number of new Tuberculosis (TB) cases detected increased in consecutive years. The base year of this study *i.e.,* 2017 are having least whereas the last year of this study *i.e.,* 2022 are having the largest number of new Tuberculosis (TB) cases detected in one individual year. This study revealed that during first COVID-19 year *i.e.,* 2020 there is significant reduction in total number of new Tuberculosis (TB) cases (including public and private healthcare facilities) detected by 5,80,869 numbers or 24.29% in comparison to last pre-COVID-19 year *i.e.,* 2019 (Figure 2).

Figure 2: Chart showing daily new COVID-19 cases in India from 03-01-2020 to 15-03-2023*.



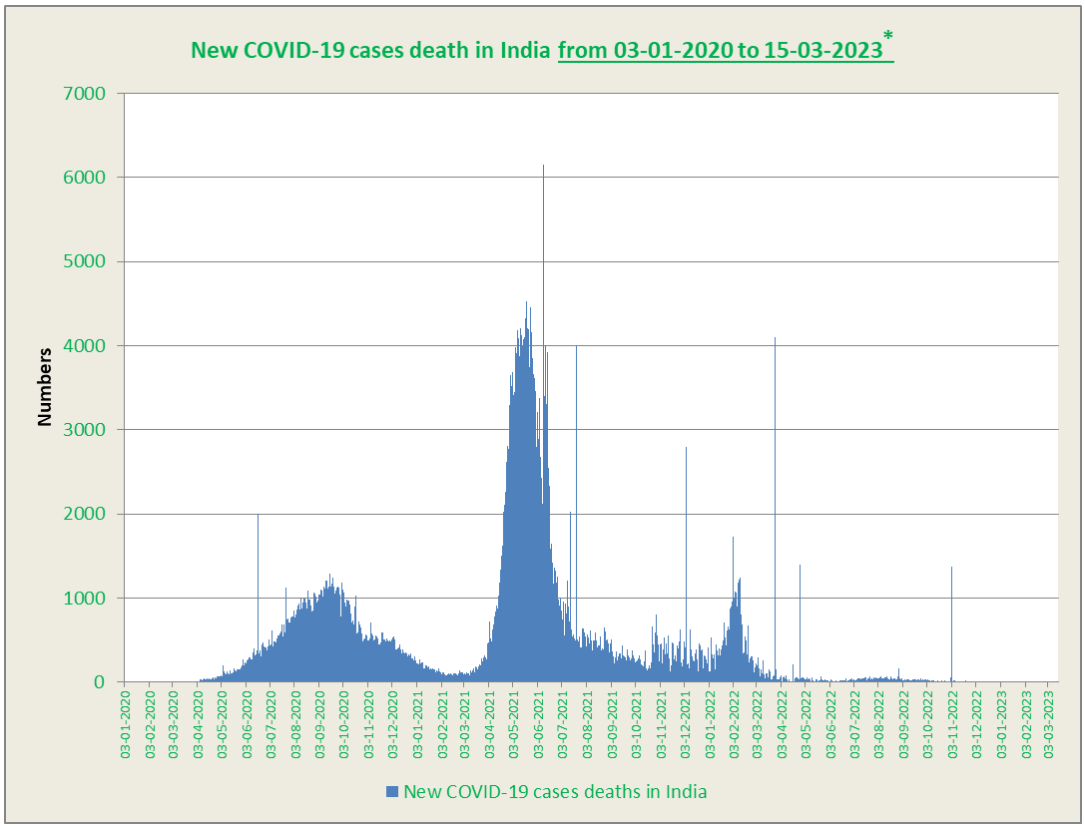
One significant fact finding of this study is that the total number of new Tuberculosis (TB) cases detected (including public and private healthcare facilities) increased continuously during pre-COVID-19 years by 29.59% in 2018 and 18.49% in 2019 in comparison to previous years *i.e.,* 2017, 2018 respectively. The same trend of continuous increase is found in COVID-19 years in which the total number of new Tuberculosis (TB) cases detected (including public and private healthcare facilities) increased continuously during COVID-19 years also by 17.55% in 2021 and 11.28% in 2022 in comparison to previous years *i.e.,* 2020, 2021 respectively.

As per findings of this research study the total number of new (TB) cases detected (including public and private healthcare facilities) is increasing continuously even during 2022 as mentioned above, when the COVID-19 negative impact on health services delivery may be reduced due to lesser number of its cases and death. At this continuous increasing pace in number of new (TB) cases detected again from 2021 how it is possible to eliminate TB in next 2 years by 2025 to achieve elimination or SDG goal by 2025 as declared by GoI. The question arises here that is it possible to achieve the goal of NTEP

by year 2025 in current scenario reality?

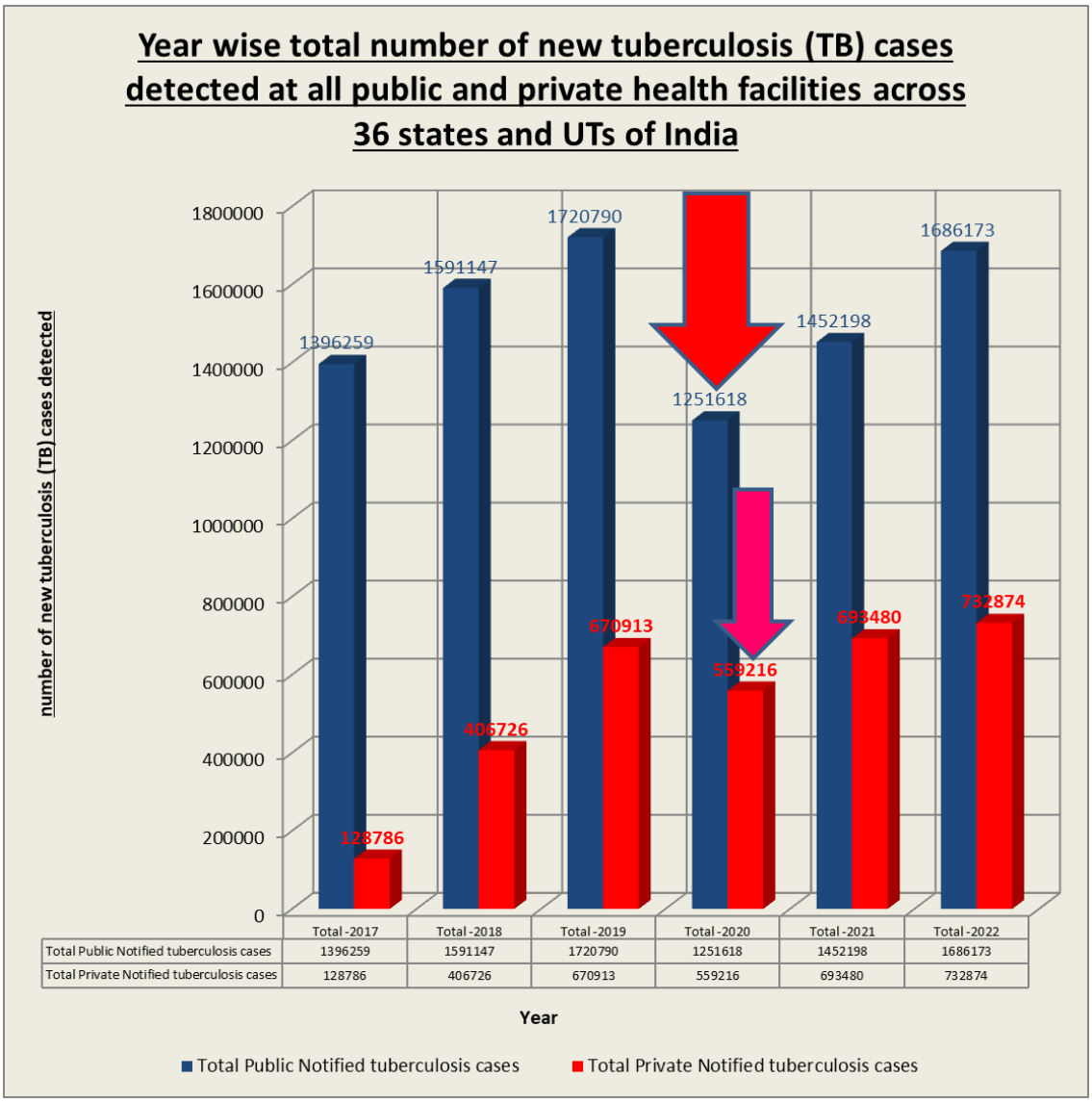
Hence a review of NTEP is need of the hour, to at least plan a novel control strategy first to achieve a reduction in total number of new (TB) cases detected (including public and private healthcare facilities), followed by elimination strategy (Figure 3).

Figure 3: Chart showing daily new COVID-19 death in India from 03-01-2020 to 15-03-2023*.



Another significant finding of this study is that the total number of new (TB) cases detected (including public and private healthcare facilities) during the first two COVID-19 years *i.e.,* 2020 and 2021 decreased in comparison to last pre-COVID-19 year *i.e.,* 2019. We know that the COVID-19 cases and death incidence was quite high in India during 2020 and 2021 (Figures 2 and 3) [42]. This huge burden of high COVID-19 cases and death incidence of pandemic on large scale may have disturbed the routine detection process of TB cases on a large scale countrywide, like other health services delivery cited above. Hence, this high COVID-19 cases and death incidence may have caused lower numbers of TB case detection (including public and private healthcare facilities) during these two years, 2020 and 2021, in the light of cited facts mentioned above. As the incidence of COVID-19 cases and death decreased in India during 2022, the total number of new (TB) cases detected (including public and private healthcare facilities) increased again during 2022 crossing the highest incidence of last pre- COVID-19 year *i.e.,* 2019 by 27,344 numbers or 1.14% (Figure 4 and Tables 1 and 2).

Figure 4: Year wise total number of new Tuberculosis (TB) cases detected at all public and private health facilities across 36 states and UTs of India.



A brief analysis of public and private number of new (TB) cases detected

The public hospitals are usually the government hospitals in India whereas the private hospitals are owned by individuals/groups/companies etc. This study mentioned public notifications are from public health facilities and private notifications from private health facilities.

The total number of new (TB) cases detected by public health facilities during the study period is 90,98,185 whereas the private health facilities detected 31,91,995 TB cases; (Figure 4 and Table 3). The public health facilities detected 59,06,190 numbers or 185% more TB cases in comparison to private health facilities. This data analysis shows how significant are public hospitals for TB elimination under NTEP. Public Health facilities detected 13,96,259; 15,91,147; 17,20,790; 12,51,618; 14,52,198 and 16,86,173 numbers of new (TB) cases during years 2017, 2018, 2019, 2020, 2021, 2022 respectively. The percentage of TB cases detected by public health facilities increased during pre-COVID-19 years by 13.96% and 8.15% in 2018, 2019 respectively in comparison to previous year counts for individual year. This study

revealed that the incidence of TB cases detected by public health facilities was increasing in the pre-COVID-19 years. During first COVID-19 year 2020 it decreased by -27.26% compared to previous pre-COVID-19 years 2019.

Table 3: Percent increase or decrease of total public and private health facilities notified new TB cases in India from 2017 to 2022.

Year	Total public notified new TB cases	Total private notified new TB cases	Percent increase or decrease of TB case detection in comparison to immediate previous year at public facility	Percent increase or decrease of TB case detection in comparison to immediate previous year at private facility
Total-2017	1396259	128786	Base year	Base year
Total-2018	1591147	406726	13.96	215.82
Total-2019	1720790	670913	8.15	64.95
Total-2020	1251618	559216	-27.26	-16.65
Total-2021	1452198	693480	16.03	24.01
Total-2022	1686173	732874	16.11	5.68
Total	9098185	3191995		

Lockdown and other COVID-19 induced situation seem to be largely responsible for this reduction in the light of several above mentioned cited facts. During subsequent years *i.e.,* 2021 and 2022 TB cases detected increased again by 16.03%, 16.11% respectively in comparison to previous individual years (Table 3 and Figure 4). The majority of TB cases *i.e.,* 74.03% of total TB cases are detected by public health facilities in India during this study period. The most significant finding is that the TB cases detected by public health facilities in India is rising again and the single dip in cases seen in 2020 seems to be a direct negative impact of COVID-19. The question arises again here that, is it possible to achieve the goal of NTEP by year 2025 in current scenario reality?

The TB cases detected at private health facilities increased during pre-COVID-19 years by 215.82% and 64.95% in 2018, 2019 respectively in comparison to previous year count for individual year. Here it is significant that this study revealed that there is a huge increase in TB cases detected at private health facilities during pre-COVID-19 years 2018, 2019 in comparison to public health facilities. This study revealed that the incidence of TB cases detected by private health facilities was also increasing like public health facilities but at a higher rate, in the pre-COVID-19 years. During first COVID-19 year 2020 it decreased like public facilities but at lower percent *i.e.,* by -16.65% compared to previous pre-COVID-19 years 2019. Lockdown and other COVID-19 induced situation seem to be largely responsible for this reduction like public facilities, in the light of several above mentioned cited facts. During subsequent years *i.e.,* 2021 and 2022 TB cases detected increased again by 24.01%, 5.68% respectively in comparison to previous individual years. The majority of TB cases *i.e.,* 74.03% of total TB cases are detected by public health facilities in India during this study period.

The most significant finding is that the TB cases detected by public and private health facilities in India is rising again and the single dip in cases seen in 2020 seems to be a direct negative impact of COVID-19. The question arises again here that, is it possible to achieve the goal of NTEP by year 2025 in current scenario reality?

A brief analysis of annual newly detected tuberculosis cases

Pre- COVID-19 years

2017–The base year of study: During the base year 2017 the total newly detected new TB notifications from all the public and private healthcare facilities of 36 participants were 13,96,259; and 1,28,786; respectively while for the years 2018, 2019, 2020, 2021, 2022 it was (15,91,147; 4,06,726;), (17,20,790; 6,70,913;), (12,51,618; 5,59,216;) (14,52,198; 6,93,480;) and (16,86,173; 7,32,874;) respectively (Tables 1 and 2).

The mean newly detected tuberculosis notifications from public healthcare facilities of 36 states and UTs of India during 2017 was 38,784.97 (Std. Err.-8,202.51; (95% Conf. Interval)-22,132.99 -55,436.95; Std. Dev.-49,215.05) whereas for private health facilities it was 3,577.39 (Std. Err.-860.98; (95% Conf. Interval)–1,829.51-5,325.26; Std. Dev.–5,165.85).
Among public facilities of 36 states and UTs of India, Lakshadweep reported minimum 49 newly detected tuberculosis cases notifications whereas maximum 2,35,505 was reported from UP (Uttar Pradesh) during 2017. Among private healthcare facilities Lakshadweep reported minimum 0 newly detected tuberculosis cases notifications whereas maximum 18,877 was reported from Maharashtra during 2017 (Table 4).

2018: The mean newly detected tuberculosis notifications from public health facilities of 36 states and UTs of India, during 2018 is 44,198.53 (Std. Err.-9905.34; (95% Conf. Interval)-24,089.62-64,307.44; Std. Dev.- 59,432.04) whereas from private facilities it was 11,297.94 (Std. Err.-2,985.37; (95% Conf. Interval) –5,237.322-17,358.57; Std. Dev.–17,912.22).
Among public facilities of 36 states and UTs of India, Lakshadweep detected minimum 19, new TB cases whereas maximum 3, 03,728 is reported from UP (Uttar Pradesh) in 2018. Among private facilities also, Lakshadweep reported minimum *i.e.,* 0, newly detected TB notifications whereas maximum 82,555 TB notifications was reported from UP during 2018 (Table 4).

2019: The mean new detected tuberculosis notifications from public facilities of 36 states and UTs of India, during 2019 is 47,799.72 (Std. Err.–10,636.6; (95% Conf. Interval)–26,206.28 -69,393.16; Std. Dev.–63,819.58) whereas from private healthcare facilities it was 18,636.47 (Std. Err. –5,203.06; (95% Conf. Interval)–8,073.698-29,199.25; Std. Dev. –1,218.36).
Among public facilities of 36 states and UTs of India, public facilities of Lakshadweep reported minimum 15 newly detected tuberculosis cases notifications whereas maximum 3,26,306 was reported from UP (Uttar Pradesh) during 2019. Among private healthcare facilities of 36 states and UTs of India, Lakshadweep reported minimum 0 newly detected tuberculosis cases notifications whereas maximum 1,59,771 was reported from UP during 2019 (Table 4).

The mean newly detected TB cases notifications from all public and private healthcare facilities of 36 states and UTs of India, during pre-COVID-19 era (2017-2019) was 1,64,295 (Std. Err. –37,404.92; (95% conf. Interval)–88,359.01-24,0231; Std. Dev. –2,24,429.5). Among all public and private healthcare facilities Lakshadweep reported minimum 83 newly detected tuberculosis cases notifications whereas maximum 11,25,934 was reported from UP (Uttar Pradesh) during Pre COVID-19 era (2017-2019) (Table 4).

Table 4: Statistical analysis of new TB cases notifications of Pre-COVID era.

Variable	Obs	Mean	Std. Err.	Confidence interval mean (95% conf. Interval)	Std. dev.	Min	Max
2017-Total public notified	36	38784.97	8202.51	22132.99 -55436.95	49215.05	49	235505
2017-Total private notified	36	3577.39	860.98	1829.51- 5325.26	5165.85	0	18877
2018-Total public notified	36	44198.53	9905.34	24089.62-64307.44	59432.04	19	303728
2018-Total private notified	36	11297.94	2985.37	5237.322- 17358.57	17912.22	0	82555
2019-Total public notified	36	47799.72	10636.6	26206.28 -69393.16	63819.58	15	326306
2019-Total private notified	36	18636.47	5203.06	8073.698- 29199.25	31218.36	0	159771
Pre-COVID-19 total public and private notified	36	164295	37404.92	88359.01- 240231	224429.5	83	1125934

COVID era

2020: The mean newly detected TB cases notifications from public health facilities of 36 states and UTs of India, during 2020 is 34,767.17 (std. err. –7,838.52; (95% conf. interval) –18,854.13-50,680.21; std. dev. –47,031.11) whereas from private facilities it is 15533.78 (std. err. –4,142.46; (95% conf. interval) –7,124.13 -23,943.43; Std. Dev. –24,854.78).
Among public facilities of 36 states and UTs of India, Lakshadweep detected minimum 18 new TB cases whereas maximum 2,42,722 was detected from UP (Uttar Pradesh) during 2020. Among private facilities Lakshadweep detected minimum 0 new TB cases whereas maximum 1, 25,317 is notified from UP during 2020 (Table 5).

2021: The mean new detected TB cases notifications from public health facilities of 36 states and UTs of India, during 2021 is 40,338.83 (std. err. –9,743.34; (95% conf. interval) -20,558.81 -60,118.86; std. dev.-58,460.02) whereas from private facilities it is 19,263.33 (std. err.- 5,064.32; (95% conf. interval) –8,982.22-29,544.45; std. dev. –30,385.93).
Among public facilities of 36 states and UTs of India, Lakshadweep reported minimum 12 TB cases notifications whereas maximum 3,15,422 is detected from UP (Uttar Pradesh) in 2021. Among private health facilities, Lakshadweep detected minimum 0 new TB cases whereas maximum 1, 40,843 is reported from UP in 202 (Table 5).

2022: The mean new TB cases notifications from all public health facilities of 36 states and UTs of India, in 2022 is 46,838.14 (std. err. –11,485.15; (95% conf. interval) –23,522.05- 70,154.23; std. dev. –68,910.89) whereas from private healthcare facilities it is 20,357.61 (std. err. –5,426.21; (95% conf. interval) –9,341.82 -31,373.41; std. dev. –32,557.27).
Among public facilities Lakshadweep detected minimum 11 whereas maximum 3,72,651 TB cases is reported from UP (Uttar Pradesh) during 2022. Among private facilities Lakshadweep reported 0 newly detected TB cases notifications whereas maximum 1, 49,230 is reported from UP in 2022 (Table 5).

Table 5: Statistical analysis of new TB cases notifications of COVID-19 era.

Variable	Obs	Mean	Std. Err.	Confidence interval mean (95% Conf. Interval)	Std. Dev.	Min	Max
2020-Total public notified	36	34767.17	7838.52	18854.13- 50680.21	47031.11	18	242722
2020-Total private notified	36	15533.78	4142.46	7124.13 -23943.43	24854.78	0	125317

2021-Total public notified	36	40338.83	9743.34	20558.81 -60118.86	58460.02	12	315422
2021-Total private notified	36	19263.33	5064.32	8982.22-29544.45	30385.93	0	140843
2022-Total public notified	36	46838.14	11485.15	23522.05- 70154.23	68910.89	11	372651
2022-Total private notified	36	20357.61	5426.21	9341.82 -31373.41	32557.27	0	149230
COVID-19-Total public and private notified	36	177098.9	43081.17	89639.43 -264558.3	258487	41	1346185

The mean newly detected TB cases notifications from all public and private health facilities of 36 states and UTs of India, in COVID-19 era of this study (2020-2022) is 1,77,098.9 (std. err. –43,081.17; (95% conf. interval) –89,639.43 -2,64,558.3; std. dev. –2,58,487). Among all public and private health facilities of 36 states and UTs of India, Lakshadweep detected minimum 41 new TB cases whereas maximum 13,46,185 is notified from UP (Uttar Pradesh) in COVID-19 era (2020-2022) of this study.

Annual TB incidence rate in India (newly detected tuberculosis notifications per lakh population)

For this study purpose we have calculated the annual TB incidence rate per lakh (100,000) in India by utilizing the below formula (Table 6).

$$\text{Annual TB incidence rate} = \frac{\text{Total newly detected TB cases notifications in a specified year x 100000}}{*\text{Annual Population in that specified year at risk (we considered whole population at risk)}}$$

*(forecasted value for population from accredited source is utilized for above calculation as real census is not done).

Table 6: Incidence rate of newly detected TB notifications in a specified year per lakh population.

Year	Population	Newly detected tuberculosis cases notifications from all public and private	Incidence rate/lakh	World Bank available data Incidence rate/lakh**
2017	1.35E+09	1525045	112.62	234
2018	1.37E+09	1997873	145.94	224
2019	1.38E+09	2391703	172.92	214
2020	1.4E+09	1810834	129.68	204
2021	1.41E+09	2145678	152.44	210
2022	1.43E+09	2419047	169.63	NA***

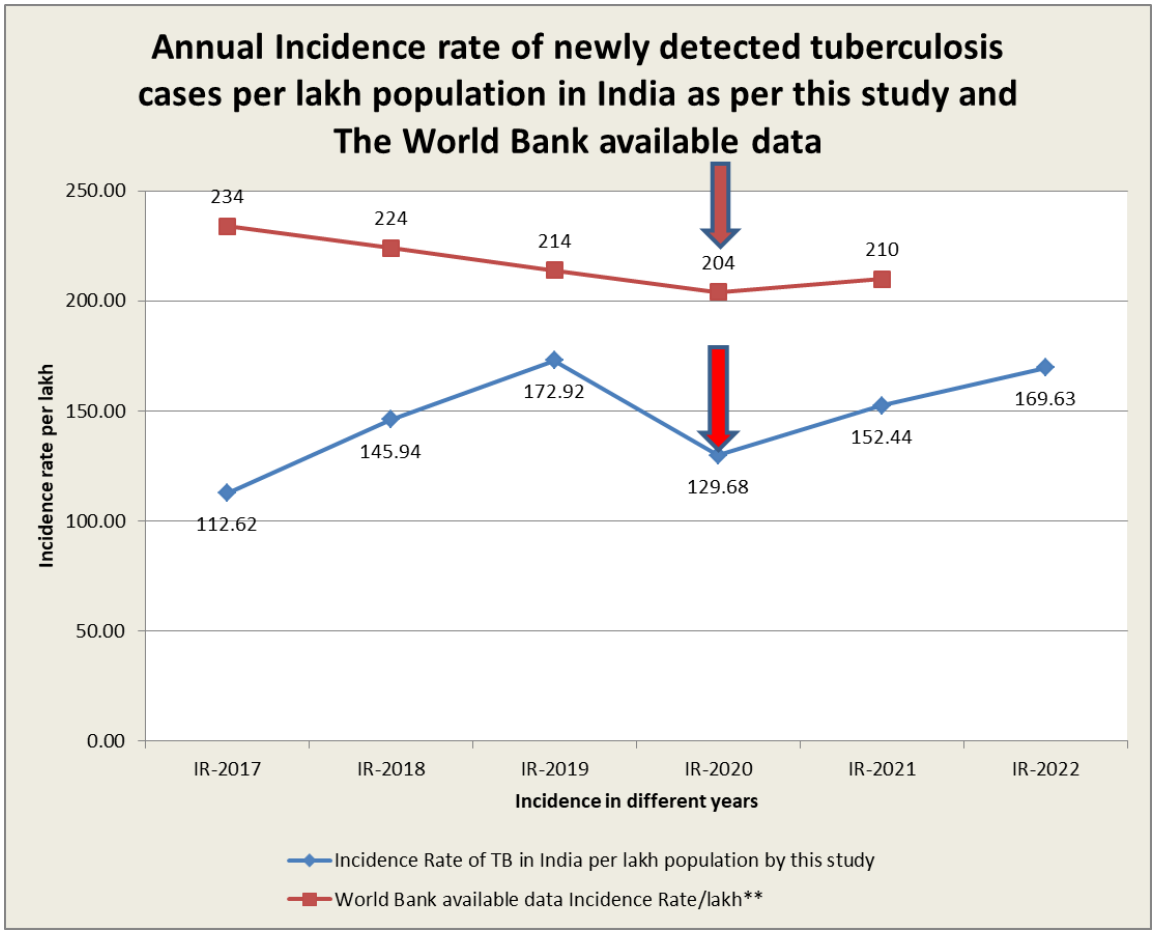
Note: *The populations for year 2022 is forecasted with the help of Microsoft excel by utilizing the previous all year available data from accredited source mentioned in data source.
** World bank data.
***NA–Not Available.

Here it is important to mention that the World Bank available data, show the incidence of new TB (per 100,000 people) in India as 234, 224, 214, 204, and 210 per lakh population for years 2017, 2018, 2019, 2020, 2021 respectively [43].
The incidence rate of new TB per lakh population as per above mentioned cases notifications obtained from this study is 112.62; 145.94; 172.92; 129.68; 152.44; and 169.63 respectively for years 2017, 2018, 2019, 2020, 2021, 2022 (Table 6 and Figure 5).

Of course there is difference in the two output incidence rates of our study and the world bank data. Why? This difference

may be due to utilization of different datasets by the world bank as well as other organizations. We are very much clear in our study as we have stated the operational definition, data sources and counts clearly.

Figure 5: Annual Incidence rate of newly detected tuberculosis cases per lakh population in India as per this study and the world bank available data.



Note: **Source–the world bank.

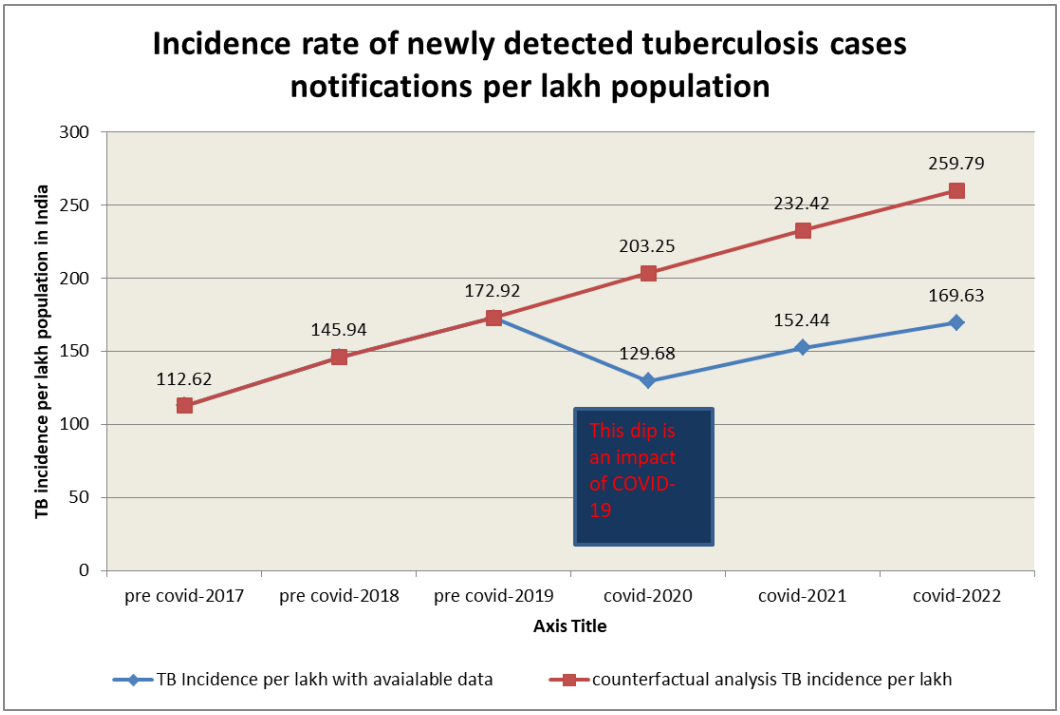
Counterfactual analysis

For this study we Considered COVID-19 as a natural intervention in routine delivery of healthcare services like TB case detection. Hence, we have analyzed about the situation which would be in the absence of this COVID-19 intervention, by doing counterfactual analysis. We have tried to get a real scenario data by this analysis. Through simple linear regression we have forecasted the incidence rate of newly detected tuberculosis through the previous year's data of this study (Figure 6 and Table 7).

This counterfactual analysis suggest that 1027364, 1125849 and 1285810 new tuberculosis cases were missed during 2020, 2021, 2022 respectively as a probable negative impact of COVID-19 in India (Figure 6 and Table 7).

As per our Counterfactual analysis the incidence rate of newly detected tuberculosis for years 2020, 2021, and 2022 will be 203.25; 232.42; and 259.79 respectively.

Figure 6: Comparison of newly detected tuberculosis cases notifications per lakh population with counterfactual analysis.



DISCUSSION

As evidenced by much fewer case notifications than anticipated in 2020, the COVID-19 pandemic has seriously disrupted TB services [44]. Comparing data from 2019 to 2020, TB notifications decreased globally by 21%. Reduced new case detection may eventually result in an increase in tuberculosis incidence and mortality [45]. 2020 saw the first drop in TB notifications in India, which was closely related to the increase in COVID cases and consequent nationwide lockdown. During the second wave of 2021, when we observe a dramatic reduction in the notification of TB cases, a similar pattern was again visible. The total number of TB cases registered in India over the course of May 2021 was at its lowest level in the previous three years. COVID-19 has had a significant negative impact on TB diagnosis and treatment globally by diverting resources and halting routine healthcare services [46]. Many patients had reduced access to TB treatment because of the shutdown. People were terrified of getting COVID-19, which had a significant impact on TB control. It was challenging for people to get to care facilities due to the transportation constraints [47]. In order to combat COVID-19, TB laboratories and TB wards were reassigned, which also disrupted TB services due to delayed diagnosis and treatment beginning. Delayed diagnosis can have the harshest effects and, in the case of contagious diseases like TB, raises the risk of transmission inside the home [48]. COVID-19 significantly hampered the delivery of TB services and access to such services.

This reduction in newly detected TB cases revealed by this study can lead to long-term increase in TB incidence, morbidity and mortality in India. This study found that some recovery is made after 2020 as the COVID-19 restrictions were reduced, but notifications seem to be still lesser than targeted (counterfactual analysis). This study suggests that a large number of TB patients were missed by the NTEP, due to disruptions in TB related health services delivery. These missed cases are still able to increase TB burden by spreading new TB in the community.

There are differences in demographic, clinical, and social characteristics of 36 participants' states and Union Territories of

this study, evident from NITI AAYOG annual reports [49]. Hence information on exposures and potential confounders among different participants is out of scope, so not taken into account, as this is a quantitative study based on secondary data. There were no missing data observed.

This study has included all the 36 states and UTs of India. All states and UTs were equally eligible assuming that they send continuously newly detected TB cases report electronically to the NIKSHAY platform. NI-KSHAY-(Ni=End, Kshay=TB) web services of GoI, are exclusively for TB (Tuberculosis) control and management under the national health program, NTEP-2020 *i.e.,* National Tuberculosis Elimination Programme. NTEP was previously known as RNTCP (Revised Tuberculosis Control Programme). NTEP-2020 aims to eliminate TB from India by 2025. Newly detected TB notifications were collected and analysed from 1st of January 2017 to 31st of December 2022 for this study. Data is collected and analyzed to get an answer to the study objective. It is assumed for this study that all participants' participated equally from beginning to the end of this study. Hence there is no question of missing data. This study included whole population of India and this was not a sample survey as the whole population data was included. Hence tests like t-test or ANOVA etc. of inferential statistics is not needed and there is no scope of generalisability of data due to inclusion of entire population.

This study revealed that the incidence rate of new tuberculosis cases notifications per lakh population kept on increasing during the pre-COVID-19 era. It decreased abruptly during the first COVID-19 year 2020 by 25.00% compared to previous year 2019 and 11.84%, 1.90% for subsequent years 2021, 2022. The incidence rate in pre-COVID-19 era increased continuously by 29.59% and 18.49% compared to previous year, considering 2017 as base year.

The incidence rate during COVID-19 period also kept increasing by 17.55% and 11.28% compared to previous years, considering 2020 as base year. This trend shows that in pre-COVID-19 era as well as in COVID-19 era, the incidence rate kept increasing. In coming years as per trends, it is expected to cross the highest pre-COVID-19 era 2019 incidence rate. There are more chances of massive increase in incidence of TB due to missed cases may kept spreading community infection during COVID-19 era. The TB disease cannot be eliminated in one night; hence the big drop in incidence rate of TB cases notifications is most probably due to prevailing COVID-19 situations/restrictions. India made partial recoveries in 2021, 2022 TB notifications but still reduction is visible compared with 2019 incidence rate.

The statement through PIB (Press Information Bureau) by GoI is based on global TB report 2022 of WHO (World Health Organization) posted on: 28 OCT 2022 6:22 PM by PIB Delhi. This statement is questionable in the light of findings of this study [50]. GoI must consider and analyse COVID-19 effect on the incidence rate of TB cases by visualizing pre-COVID-19 data trends.

There were two significant problems with COVID-19's negative effects. First of all, it made it challenging for patients to use TB services, such as diagnosis, care, and prevention, because insufficient clinicians have the required resources. In addition, it made it challenging for people to get TB services including diagnosis, care, and prevention because they were afraid of contracting COVID-19 from healthcare professionals or because of the stigma associated with their illness [51].

There is global concern about COVID-19 negative impact on TB elimination and control programmes [52]. Quantifying and analysing changes in monthly/annual TB notifications may help to put more targeted focused interventions to restore TB

elimination and control programmes. We have used publicly available data to evaluate the COVID-19 impact on TB notifications. With counterfactual analysis we tried to find the missing new TB cases.

However, these detrimental impacts can be minimized with fast restoration of tuberculosis care, and adoption of specific interventions guided by notification targets. To prevent significant setbacks to the advancements made by NTEP in recent years, we need to substantially enhance case identification and notification.

This research study is intended to alert policy makers. The TB incidence rate/lakh population may keep increasing for next few years. This is due to fact that a large number of TB cases were missed due to COVID-19 erupted situations. Hence, NTEP goal by 2025 seems to be difficult in the light of findings of this research study.

Table 7: Counterfactual analysis results.

Public forecast without COVID-19 newly detected tuberculosis cases	Public forecast new tuberculosis cases	Private forecast without COVID-19 newly detected tuberculosis cases	Private forecast new tuberculosis cases	Total forecast new tuberculosis cases	Counterfactual analysis incidence rate/lakh population COVID-19 era
2020	1893930	2020	944268.7	2838198	203.25
2021	2056195	2021	1215332	3271527	232.42
2022	2218461	2022	1486396	3704856	259.79

Strength and limitations

There are several studies done on this research question but this is the first study which also considered year 2022 [53-55]. The first two years *i.e.,* 2020 and 2021 of pandemic has shattered several routine healthcare services as mentioned above. The COVID-19 is not declared to be over hence it is important to assess the situation of 2022 to know that are the TB services returning to normal functions? This research study uniquely revealed that the TB cases notification has improved during 2022 which suggest that health facilities are returning to normal functions. This is the latest study which has taken into account 6 years with equal distribution among pre-COVID-19 and COVID-19 period. Lack of more details about data on reported cases, including socio-demographic, old non-notified cases missed during COVID-19 years, residence wise data (rural *vs.* urban, etc.) is one major limitation.

CONCLUSION

COVID-19 has exposed the weaknesses in India's public health system. We propose that as the pandemic develops, public health reforms could present a crucial chance to finally fill long standing inadequacies in TB care systems.

The finding of this research study suggests that about over 3439023 new TB cases were not notified in India that would have been expected in the absence of the COVID-19 pandemic. Where are these cases? Factors which may have affected TB cases notifications may be:

- Decreased mobility and increased COVID-19 related hospital admissions per 100,000 population.
- Disruption in TB care delivery services, mask use.
- Further more research is needed to understand and clarify this situation.

- Identification of other key contributors to the observed gap in TB case notification in India during the pandemic.

RECOMMENDATIONS

- GoI need to improve TB case detection and notification on urgent basis to avoid major setbacks to NTEP.
- Rapid restoration of TB care delivery services with implementation of special interventions to find out missed TB cases.
- TB elimination must be considered as public health and political priority.
- A robust integrated framework and effort from policy makers, from government and from NGO (Non-Governmental Organizations) is needed.
- Novel interventions to accelerate TB case finding and notification.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable. This study has not involved any human or animals in real or for experiments. The submitted work does not contain any identifiable patient/participant information.

CONSENT FOR PUBLICATION

The authors provide consent for publication.

AVAILABILITY OF DATA AND MATERIALS

Electronic records from Nikshay, India, and others as mentioned above.

CONFLICTS OF INTEREST/COMPETING INTEREST

There are no conflicts/competing of interest.

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