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MAJOR ARTICLE

Economic Burden of TB Deaths in India (2021): A Retrospective Cross-sectional Study

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Background. We aimed to estimat the economic burden of TB deaths in terms of gross domestic product (GDP) across Indian states, regions, and different demographic groups.

Methodology. Using the Human Capital Approach, we estimated the non-health GDP losses due to TB deaths in India for 2021 at subnational level. The total monetary value for the years of life lost due to TB deaths was calculated.

Results. In 2021, 0.393 million TB deaths occurred in India, which would reduce the non-health GDP by US$9.1 billion. North, West, South, and North Eastern states of India incurred 33.5%, 25.6%, 18.5%, and 9.3% of that economic loss respectively. Each TB death resulted in non-health GDP loss of US$23 161. The economic burden was highest among youngr males (20.5%) followed by males aged >75 years (17.3%). The economic cost was minimal among male adolescents and youth accounting for 3.4%.

Conclusions. Finndings underscore the urgent need for concerted multisectoral efforts, sustained investments and strategies to reduce TB deaths, and mitigate the resulting economic losses at sub-national level.

Keywords. Economic loss; gross domestic product; India; mortality; tuberculosis.

Tuberculosis (TB) remains the major cause of death globally. India accounts for more than 25% of TB cases and TB deaths globally [1]. India had set an ambitious goal of eliminating TB, aiming to reduce its mortality under End TB program [2]. Although progress has been made in reducing TB incidence and mortality in the past few years, India still contributes to significant TB mortality rates in the world with 22 deaths per 100 000 population [3]. TB morbidity and mortality results in high out-of-pocket expenditure. When out-of-pocket expenditure exceeds 20% of income, it turns into catastrophic expenditures for the patients and their family during TB care cascade [4]. TB mortality causes extreme hardships for the family of the deceased and has been known to cause an adverse economic impact on the nation as whole [5]. TB has a negative impact on the productivity of the society, leading to excessive public health expenditure, eroding household savings. While past studies have assessed the economic impact of TB disease at the patient level in India, the gross economic impact of TB mortality in the country has been estimated by Silva et al [6], for a period of 30 years (2020–2050) based on 120 countries including India. But, so far, no studies have estimated the economic burden of TB deaths at the subnational level in India, which have heterogeneous TB disease burden, including mortality rates [7].

India remains the most populous country which spread across 28 different states and 8 Union Territories with diverse geographical and socioeconomic differences. Hence, assessing the economic impact of TB mortality at a sub-national level is important to devise regional- and state-level strategies to mitigate its impact. There is also a lack of evidence on age and gender wise economic burden due to TB deaths in India. Understanding this gap is important to implement differential interventions to reduce TB mortality, as well to implement socioeconomic interventions to mitigate the productivity losses across age and gender groups. Evidences of economic loss at a sub-national level resulting from TB death would also be necessary for undertaking advocacy to diverse stakeholders at regional level to address the economic losses resulting from TB deaths. With this background, the present study aims to estimate the

Received 05 May 2025; editorial decision 02 June 2025; accepted 06 June 2025; published online 21 July 2025

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https://doi.org/10.1093/ofid/ofaf433

economic loss caused by TB deaths in different states and regions of India as well as different age and gender categories.

METHODOLOGY

Study Design

We conducted a retrospective modelling study using secondary data on TB mortality and related factors collected from different sources.

Source of Data

Information on TB deaths for 28 Indian states and 3 Union Territories in 2021 were extracted from the Global Burden of Disease (GBD) database [8, 9]. State-wise gross domestic product (GDP) was obtained from the National Health Accounts 2021 Report [10].

Information Collected

State-specific estimates of TB mortality for all 28 Indian states and 3 Union Territories were collected. In addition, information on age- and gender-specific TB mortality were obtained from the GBD database in Table 1 [11].

Analytical Framework and Analysis Methods

In this analysis, the Human Capital Approach (HCA) was used to measure economic loss, which took into account of individual's economic output to estimate productivity losses caused by years of life lost (YLL) because of TB-related early mortality. HCA is a widely used approach for estimating the economic burden of various diseases. HCA has been applied for estimating economic burden due to TB mortality in Africa [12, 13].

YLL: We followed the procedures provided by Kirigia et al, 2015 to calculate YLLs across all age groups [12, 13]. The YLL is defined as the difference between life expectancy (LE) and average age of death and is given as

$$k_{a,s,t} = \text{LE} - \text{average age of death}_{a,s,t} \quad (1)$$

Where, "a" is age category, "t" is state, "s" is gender, and "k" is YLL.

Monetary Value of Years of Life Lost (MVYLL). The monetary value of years of life lost (MVYLL) for each Indian state (t), gender (s), and age group (a) was estimated by adding the discounted values of lost economic contributions over the years of life lost. This was done by applying a discount factor to account for time value of money and opportunity costs. For each year lost, the contribution was calculated by dividing 1 by 1+ discount rate, raised to the power of the number of years lost (k). This discounted value was then multiplied by the non-health GDP per capita of the respective gender and state, and the total number of TB deaths in that age group. Finally, the sum of these values across all years lost provided the MVYLL estimate using the equation.

$$\text{MVYLL}_{a,s,t} = \sum_{i=1}^{k_{a,s,t}} \{[1/(1+\text{discount rate})^{k_{a,s,t}}] \times \text{non-health GDP per person}_{s,t} \times D_{a,s,t}\} \quad (2)$$

Total Monetary Value of Years of Life Lost (TMVYLL). The TMVYLL for each Indian state (t) and sex (s) was calculated by adding the monetary value of YLL for each age cohort (a) and is given in the equation (3). The estimates ranged from 10 to >95 years in 5-year increments, as required by the algorithm. MVYLL and TMVYLL were calculated for 28 states and 3 Union Territories, across 5-year age cohorts, and for both genders (male and female). The average age of TB mortality in each age category (a) by state (t) and gender (s) was determined using the midpoint of age intervals. Mean LE estimates by state were used to calculate 5-year age intervals for both genders [14].

$$\text{TMVYLL}_{s,t} = \sum (\text{MVYLL}_{a,s,t}) \quad (3)$$

Monetary values were expressed in Indian National Rupees (₹) and US Dollars (US$) at an exchange rate of 1US$ = ₹70.394 for the year 2019. We have used GDP for the year 2019 considering the estimates of 2020 and 2021 were outliers due to COVID-19 lockdown [15]. Since using 2020 and 2021 GDP would adversely impact the economic loss projections in this study, we used pre-COVID GDP estimates. Also, we have not used GDP or inflation trend data because our analysis was focused on a single-year estimate.

Sensitivity Analysis

For the sensitivity analysis, we employed discount rates of 5% and 10% across all age groups based on the World Health Organization (WHO) guidelines for cost-effectiveness analysis 2003 and Health Technology Assessment guidelines [16, 17]. Based on this, we computed the values of MVYLL and TMVYLL. We generated the 95% uncertainty intervals for MVYLL and TMVYLL using the estimates of TB mortality.

Subgroup Analyses by Region

Subgroup analyses were done according to 6 geographically distinct regions of India including North, West, East, South, North-East, and Central. The North Zone included Uttar Pradesh, Rajasthan, Delhi, Uttarakhand, Punjab, Himachal Pradesh, Jammu & Kashmir, and Ladakh. The West Zone included Gujarat, Maharashtra, and Goa. The East Zone included Odisha, West Bengal, Jharkhand, and Bihar. The South Zone included Tamil Nadu, Karnataka, Andhra Pradesh, Telangana, Kerala, and Union Territories. The North-East Zone included Meghalaya, Manipur, Tripura, Nagaland, Arunachal Pradesh, Mizoram, and Sikkim. The Central Zone included Chhattisgarh and Madhya Pradesh [18]. They were averaged to produce

Table 1. Variables and Parameters Included in the Model for Estimating Economic Loss Due to TB Deaths

Variable	Description	Data Source
Number of TB deaths	Mean and 95% confidence intervals of TB deaths by age and sex for India in 2021.	Institute of Health Metrics and Evaluation (IHME)—Global Burden of Disease (GBD) 2021 study [8]
Age group	The WHO classifies age group as follows	WHO [19]
10–24 y	Adolescent and youth	[19]
25–44 y	Young	[19]
45–59 y	Middle age	[19]
60–74 y	Elderly age	[19]
75 and above years	Senior age group	[19]
Indian states Included	Data for 28 Indian states and 3 union territories (UTs) was used and categorized zone wise.	[8]
Chhattisgarh	Center	[8]
Madhya Pradesh	Center	[8]
Bihar	East	[8]
Jharkhand	East	[8]
Odisha	East	[8]
West Bengal	East	[8]
Delhi	North	[8]
Haryana	North	[8]
Himachal Pradesh	North	[8]
Jammu & Kashmir and Ladakh	North	[8]
Punjab	North	[8]
Rajasthan	North	[8]
Uttar Pradesh	North	[8]
Uttarakhand	North	[8]
Arunachal Pradesh	North East	[8]
Assam	North East	[8]
Manipur	North East	[8]
Meghalaya	North East	[8]
Mizoram	North East	[8]
Nagaland	North East	[8]
Sikkim	North East	[8]
Tripura	North East	[8]
Andhra Pradesh	South	[8]
Karnataka	South	[8]
Kerala	South	[8]
Other Union Territories	South	[8]
Tamil Nadu	South	[8]
Telangana	South	[8]
Goa	West	[8]
Gujarat	West	[8]
Maharashtra	West	[8]
Discount rates (r)	3% for base case and 5% and 10% for sensitivity estimates	[16, 17]
Gross domestic product (GDP) per capita	State-wise GDP per capita (2019) for India extracted.	[10]
Government health expenditure (GHE)	State-wise GHE per capital for 2019 was extracted for all states and UTs	…
Nonhealth GDP	Non-health GDP estimated as the difference between GDP and GHE of each state	Author's calculations
Years of life lost (k)	Years of life lost calculated as the difference between life expectancy and mean age at death	Author's calculations
Life expectancy at birth (LE)	State-wise mean LE at birth was extracted for 28 Indian states and 3 UTs.	[8]

national-level data. We excluded 5 Union Territories from these analyses because GDP data were not available.

Subgroup Analysis by Age and Gender

We categorized age into 5 groups as per WHO criteria [19]. The groups were (1) adolescent and youth (0–24 years), (2) younger adults (25–44 years), (3) middle-aged individuals (44–59 years), (4) elderly (60–74 years), and (5) seniors (>75 years).

Ethical Clearance

The study did not require Ethics Review Committee approval as it did not involve human subjects directly. The analysis was done based on published secondary data.

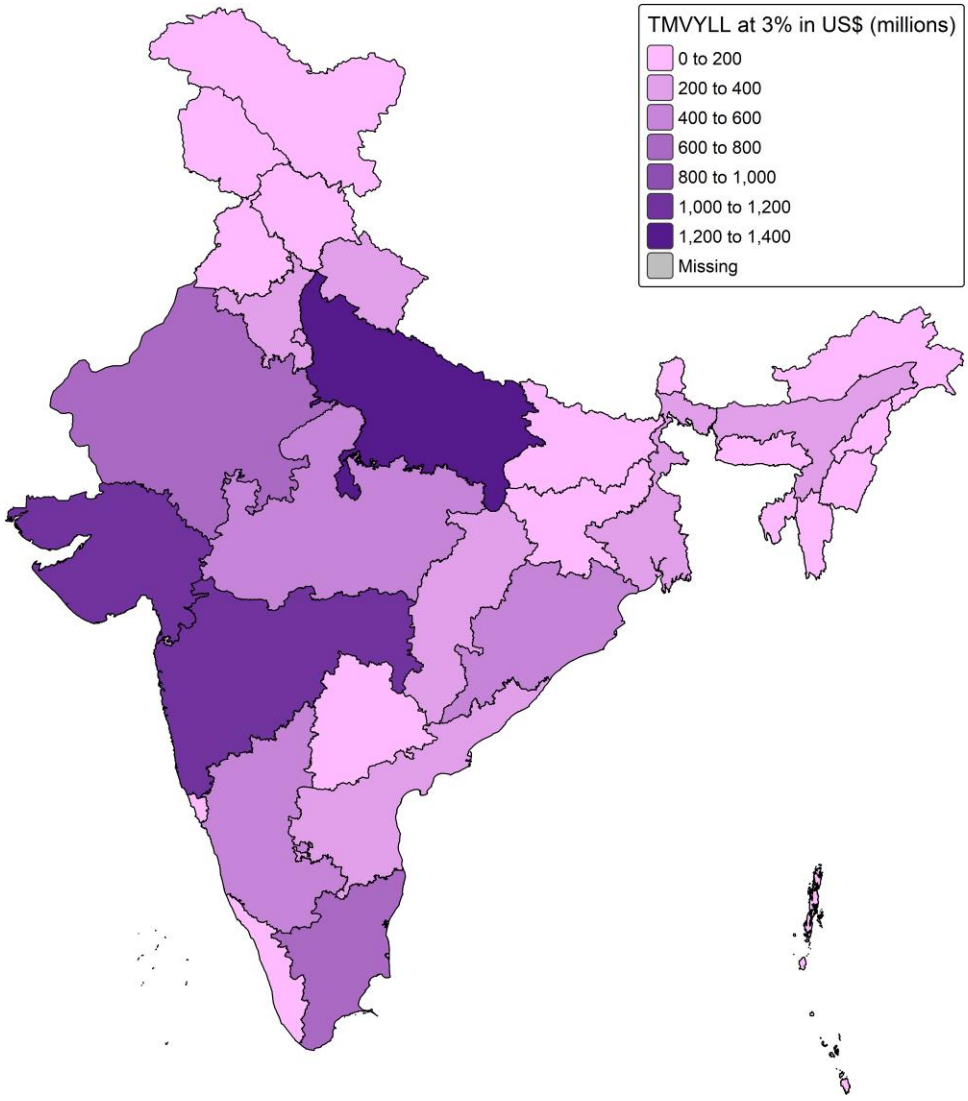

Figure 1. Total monetary value of years of life lost (TMVYLL) from tuberculosis deaths.

RESULTS

State and Regional Level of Economic Loss Due to TB Deaths in India

The overall economic cost of TB mortality in India in 2021 for 393 027 deaths amounted to US$9 102 991 391 (95% confidence interval [CI], 5 813 038 469–13 797 763 658). Every TB death caused an economic loss of US$23 161 (95% CI, 18 529–27 793). The economic cost was highest in Uttar Pradesh with US$1 333 778 459 (95% CI, 876 261 428–1 945 817 699) and lowest in Sikkim with US$7 770 827 (95% CI, 4 657 171–12 356 925). Following Uttar Pradesh, Gujarat (US$1 175 906 553; 95% CI, 772 157 190–1 718 191 548) and Maharashtra (US$1 145 265 812; 95% CI, 756 554 046–1 704 553 277) had the highest burden from TB-related mortality (Figure 1). Uttar Pradesh, Gujarat, and Maharashtra collectively accounted for 40% of the overall economic burden resulting from TB-related fatalities. In terms of Zones, the North Zone experienced the highest economic burden from TB deaths at 33.5%, followed by the West Zone at 25.6%, and the South Zone at 18.5%. The North-East Zone exhibited the lowest economic burden at 9.3% (Supplementary Table 1).

Economic Loss Due to TB Deaths Across Different Age Categories

The younger age group (25–44 years) accounted for the significant economic burden from TB deaths, totalling US$2 995 057 239 (95% CI, 1 952 460 356–4 399 075 235) or 32.9% of the overall burden. The senior age group (>75 years) accounted for 26.5% of the total economic burden (US$2 415 386 452; 95% CI, 1 497 822 384–3 779 585 604) and the middle

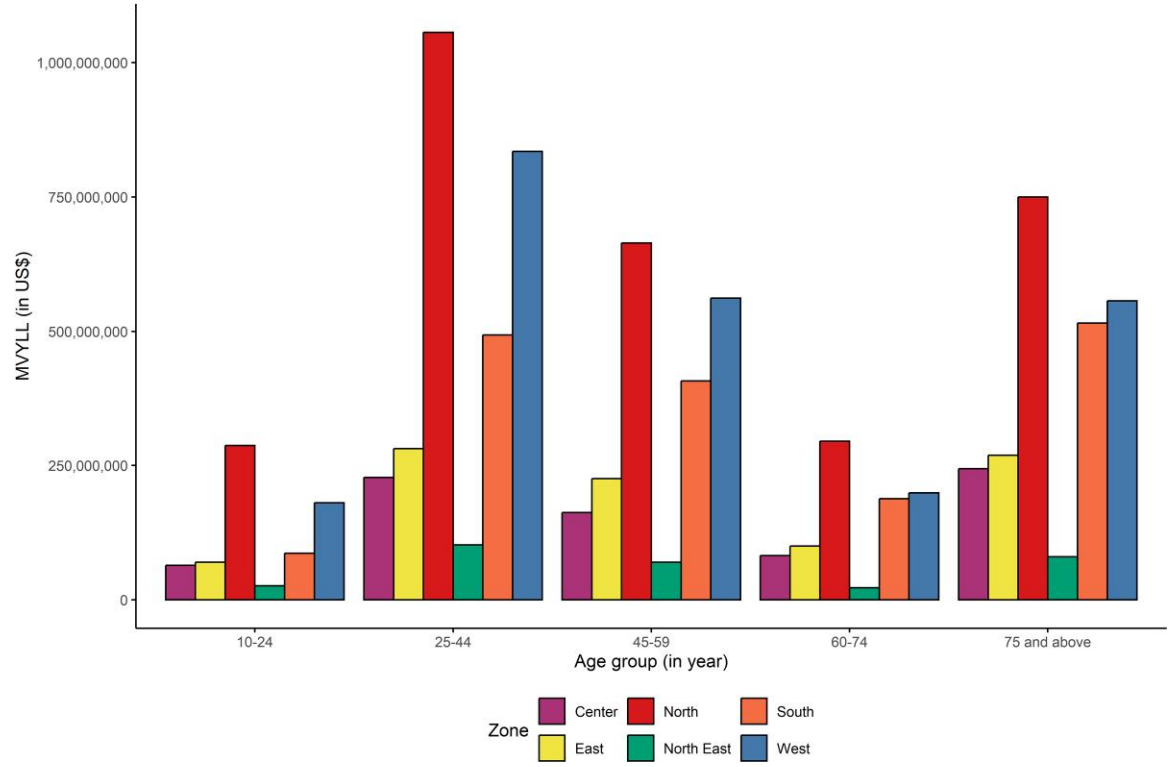

Figure 2. Monetary value of years of life lost (MVYLL) from tuberculosis deaths, categorized by age groups and zone.

age group (45–59 years) contributed 23% of the total burden (US$2 091 614 218; 95% CI, 1 334 304 880–3 181 887 823). The elderly age group (60–74 years) accounted for 9.7% of the total burden amounting to US$886 513 393 (95% CI, 562 864 310–1 364 516 177), whereas the adolescent and youth population contributed the least, with 7.8% of the total burden amounting to US$714 420 090 (95% CI, 465 586 540–1 072 698 818) (Supplementary Table 2).

Economic Loss Due to TB Deaths Across Different Age Categories and Zones

The inter-section of zones and age groups shows that the greatest economic loss attributable to TB among the younger demographics of North Zone accounting for 11.6% of the total burden (US$1 056 488 575; 95% CI, 689 387 241–1 519 019 004). This was succeeded by the West Zone, where the younger age group accounted for 9.2% of the total economic burden (US $834,646,511; 95% CI, 554 619 739–1 195 055 559). The low economic burden attributable to TB in the younger demographic group was observed in the North East Zone, accounting for 1.2% of the total contribution, amounting to US$102 108 133 (95% CI, 66 936 164–151 656 216). Meanwhile, the most significant economic burden among individuals aged >75 years was recorded in the North Zone, representing 8.2% of the total burden (US$750,052,061; 95% CI, 465 434 701–1 158 648 868) (Figure 2).

In South Zone, population aged >75 years contributed to 5.7% of the total economic burden (US$515,352,801; 95% CI, 312 657 709–831 718 855). The minimal economic burden in the >75 year age group was observed in the North-East Zone, accounting for 0.9% of the total burden (US$80,213,093; 95% CI, 49 192 711–127 330 088) (Supplementary Table 3). In the older demographic (60–74 years), the total economic burden contribution was under 2%–3% in the North, South, and West Zones, whereas it was below 2% in the North-East, Central, and East Zones. Among adolescent and youth population (aged 10–24), the economic burden was 2%–3% in the North and West Zone and it was <1% in the Central, Eastern, North-Eastern, and Southern Zones. The overall TB mortality in the younger and middle age groups accounted for 63.5% of the total economic burden of TB in India. The adolescent, youth, and older populations accounted for <20% of the entire economic burden resulting from TB deaths.

Economic Loss Due to TB Deaths Across Gender Categories

Males accounted for 61.3% of the economic burden from TB deaths, totalling US$5 581 402 601 (95% CI, 3 461 314 066–8 736 489 524), whereas females contributed to 38.7% with US$3 521 588 791 (95% CI, 2 351 724 403–5 061 274 133) (Supplementary Table 3). The greatest economic loss attributed to TB among men occurred in the North Zone, accounting for 19.7% and amounted to US$1 791 914 876 (95% CI, 1 108 701

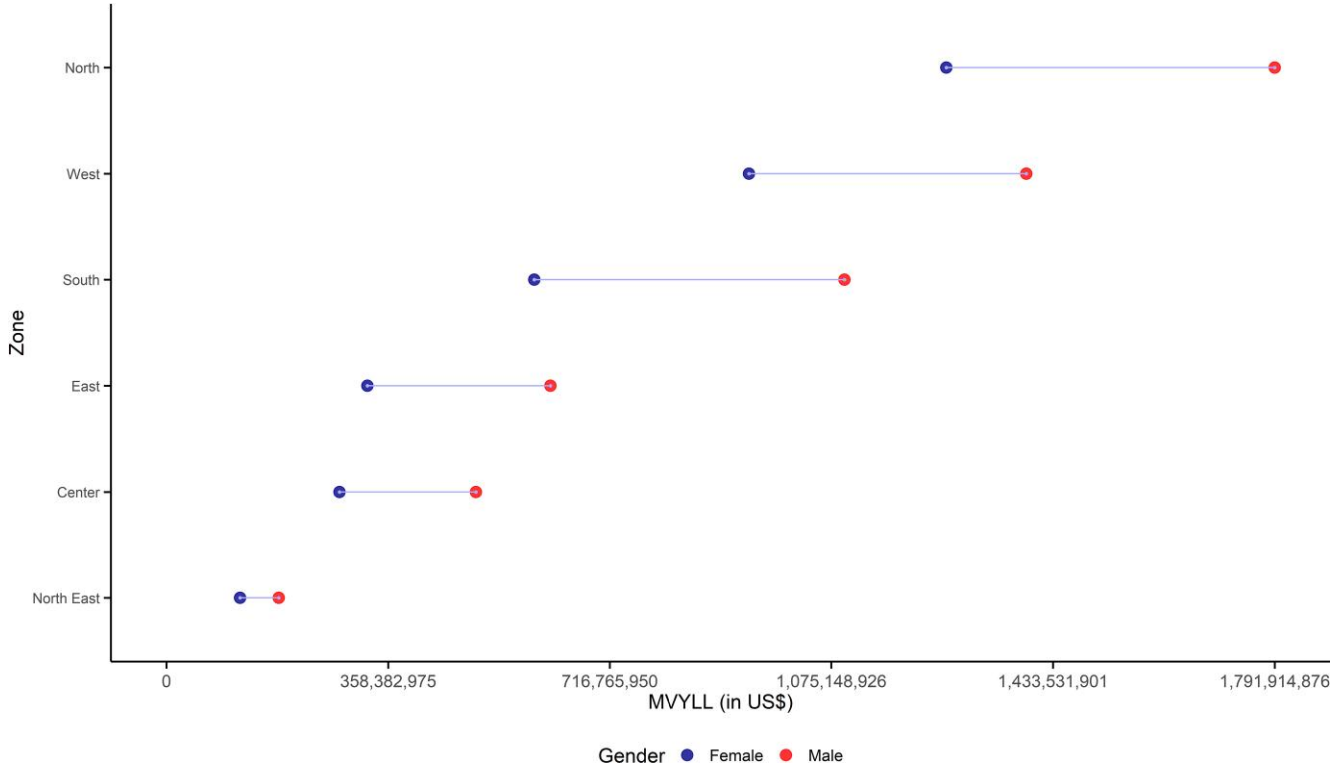

Figure 3. Monetary value of years of life lost (MVYLL) from tuberculosis deaths, categorized by gender and zone.

738–2 741 891 177), followed by males in West Zone with a 15.3% contribution (US$1 390 305 602; 95% CI, 883 122 763−2 127 150 524). The minimal economic burden from TB among males was in the North-East Zone, with a contribution of 2% (US$181 755 801; 95% CI, 113 908 451–285 526 998). The largest economic loss for females was in the North Zone, with a contribution of 13.8% (US$1 261 016 913; 95% CI,840 004 744 −1 798 206 274), followed by a 10.3% contribution in the West Zone (US$942 193 535; 95% CI, 652 238 188–1 313 451 495). The minimal economic burden from TB among females was in North-East Zone, with a contribution of 1.3% amounting to US$119 015 688 (95% CI, 77 022 954–176 867 332) (Figure 3).

Economic Loss Due to TB Deaths Across Age and Gender Intersections

The economic burden was greatest among younger males, contributing 20.5% to the total burden (US$1 865 242 879; 95% CI, 1 190 857 903–2 799 985 911), followed by males aged >75 years, with a contribution of 17.3% (US$1 574 084 585; 95% CI, 942 148 177− 2 547 947 503) (Figure 4). The economic burden was minimal among adolescents and youth males, contributing 3.4% (US$314 222 789; 95% CI, 193 698 916–504 825 303). Similar to males, the economic burden was greater among younger females, accounting for 12.4% (US$1 129 814 360; 95% CI, 761 602 452–1 599 089 324), followed by females aged >75 years, who contributed 9.2% (US$841 301 867; 95% CI, 555 674 207–1 231 638 101). The economic burden was minimal among elderly females, with a contribution of 3.9% (US$356,077,071; 95% CI, 234 673 155–516 072 746) (Supplementary Table 4).

Sensitivity Analysis

In scenario 1, we noted that as discount rates increased to 5% and 10%, the absolute values of TMVYLL diminished in comparison to the 3% discount rate at the national level. Upon comparison by zones, all zones exhibited a comparable trend of TMVYLL at 5% and 10% rates. At a 5% discount rate, the age group >75 years contributed the most to the economic burden at 34.3%, followed by the younger age group at 27.6% of the total burden. There was an 8% point rise in the economic burden contribution of the age group >75 years and a 5% point drop in the younger age group compared to a 3% discount rate. At a 10% discount rate, the age group >75 years exhibited the largest contribution to the economic burden at 54.8%, followed by the younger age group with a contribution of 16.4%. The economic burden contribution of the age group >75 years increased by 28% point, whereas the contribution from the younger age group decreased by 16% point, relative to a 3% discount rate. Overall, across all discount rates, the younger and elderly age groups collectively incurred 60%–70% of the economic burden, highlighting a common trend. With regard to gender, it was found that at a 5% discount rate, males accounted for 62.7% of the economic burden, increasing to 66.1% with a 10% discount rate, which is comparable to their 61.3% contribution

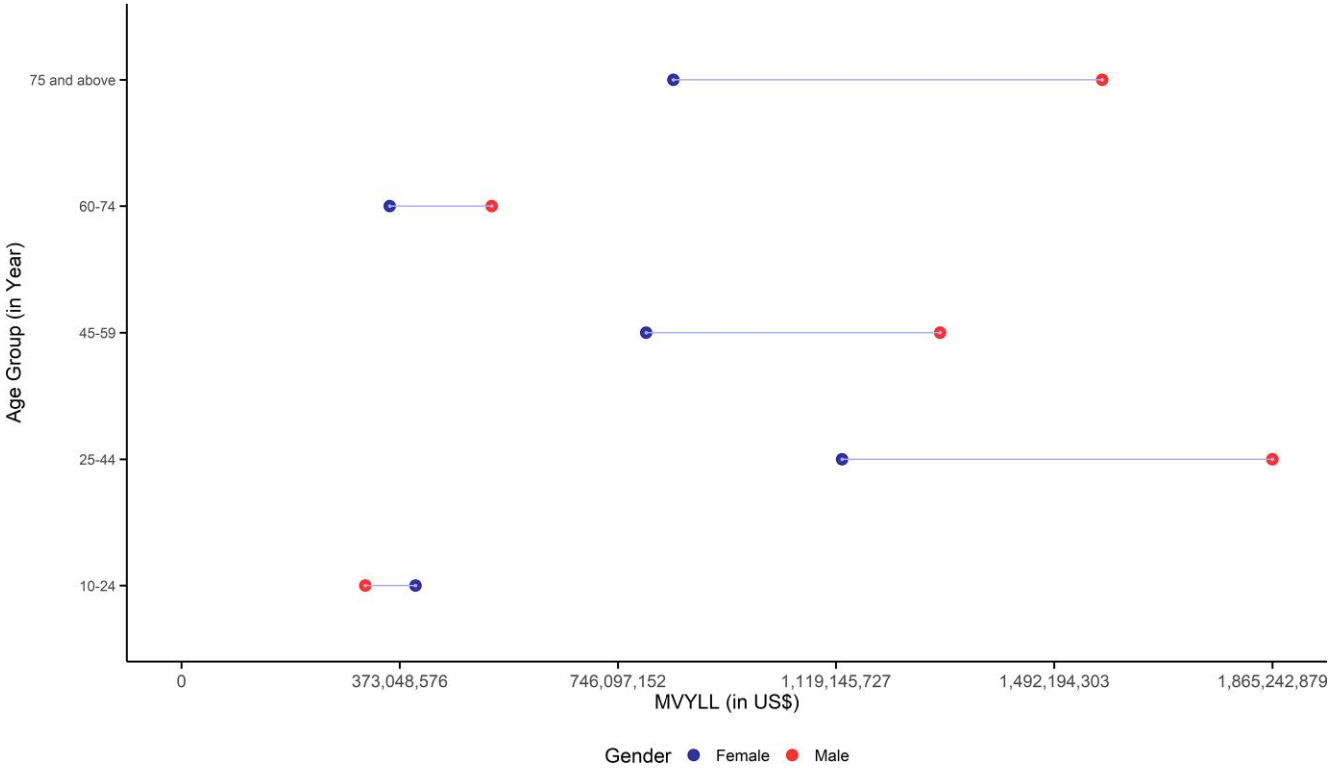

Figure 4. Monetary value of years of life lost (MVYLL) from tuberculosis deaths, categorized by gender and age groups.

at a 3% discount rate. At a 5% discount rate, females accounted for 37.2% of the economic burden, whereas at a 10% discount rate, their contribution was 33.9%, which is comparable to the 38.6% share at a 3% discount rate (Supplementary Table 5).

DISCUSSION

In India, the economic burden resulting from TB death in 2021 was US$9 102 991 391. A greater portion of this burden was shared by males, younger age (25–44 years) and senior age groups (>75 years). Uttar Pradesh, Gujarat, and Maharashtra contributed to 40% of the economic burden from TB deaths. In terms of regions, the North and West Zones contributed to almost 60% of the burden, presenting a skewed regional economic burden due to TB. Similar findings from the previous studies reported that the North and West Zones with higher TB prevalence, notification, high population density, and higher proportion of vulnerable population, which could be attributed to the disproportionate economic burden of TB deaths [20–23]. An economic model published by Silva et al in 2021 found that the estimated economic loss due to TB deaths in India was US$151 billion, which was far higher than our present estimates [24]. The reasons could be the difference in methodology that Silva et al used to estimate the total income loss due to TB deaths based on the statistical value of life estimates, which are far higher than the GDP loss-based estimates we used. Our observation was also shared by another economic modelling study published in 2024 that showed that the total health and macroeconomic burdens of TB death in India between 2021 to 2040 as US$146.4 billion. Our estimate of US$9 billion for single year of TB deaths is comparable to the projected estimate provided in this study by Marcus et al 2024 [25]. The economic burden of TB, which we estimated for India is almost one fifth of the economic burden due to TB in the entire African region (US$50 billion), showing the magnitude of the problem in India [13].

Our study also found that the younger age group (25–44 years) and >75 age group had the highest contribution to economic burden due to TB death, whereas the adolescent population contributed the lowest economic burden. Our estimates are consistent with the national-level TB burden estimates in India that showed that <15 year age group had the lowest TB prevalence in India compared to older age groups [26]. TB burden had remained conventionally more among adult males, which underscores the higher share of death and economic loss in this sub-population [27]. It was found that economic loss among those 25–44 years was higher in the North and West Zones and the loss among >75 year age group was higher in the North and South Zones. Although age >75 years could be considered a non-productive age that may

lead to lower GDP losses, still our analysis shows that economic losses were high in this group. This could be attributed to the extended occupation of the elderly in the informal sector, contribution toward rural and agricultural economy, and values associate with care giving. The care services for TB thus needs to be equitable across age groups that may prevent economic losses. The TB prevalence study in India showed that the North Zone states and Union Territory had the highest prevalence of TB (316 per 100 000 population) that matched with our higher economic impact estimates in the North Zones. But it was observed that states with lower prevalence of TB in the West Zone (Gujarat 141 per 100 000 population and Maharashtra 161 per 100 000 population) had relatively higher economic loss in terms of TB death in our study. Considering these states, which are highly populated, and industrial, mitigating economic loss in productive age group due to TB could be high priority for West and North Zones [28]. The higher contribution to economic burden among age group of >75 years as compared to adolescent and youth is significant. Although youth TB burden in India is found to be 10%, still the economic loss is minimal as compared to >75 year age group [29]. This underscores the higher burden due to TB among >75 year age group in spite of their lower life expectancy. Focusing on geriatric centric TB care could mitigate significant economic loss in this subpopulation of the North and South Zones [30].

Our estimates showed that two third of the economic burden due to TB death was from men, which is consistent with the WHO estimates that men typically account for about 66%–75% of the burden of TB disease among adults in high-burden countries, including India [31]. The higher prevalence of risk factors like alcohol use and tobacco use could be a reason for the higher number of deaths and consequent economic burden among males [32]. Both genders contributed to highest economic burden in the North and Western Zones. Overall, the economic burden due to TB was lowest in North-Eastern Zone compared to other zones. But still 9% of the total burden of economic loss was observed in this region.

The economic burden of TB in India should be an impetus for investing in mortality prevention with a state and region wise focus. The estimated cost from this study highlights the losses that the Indian economy will incur if the TB mortality rates are not reduced significantly per the TB elimination goals. Barriers to reduce TB mortality is mostly from poor treatment compliance to medications, financial disruptions and constraints in continuing treatment, poor nutritional status, and presence of behavioral risk factors such as alcohol use, which disrupts the cascade of care [33–35]. Interventions to address these TB mortality factors require strategic focus beyond the National TB Elimination Program (NTEP) of India. The large economic burden observed necessitates inter-sectoral and inter-departmental collaboration to address the broader societal and behavioral drivers of TB deaths. Addressing malnutrition among TB patients could be achieved by increased resource allocation and strengthened delivery of nutritional supplementation through various service delivery mechanisms. At present, NTEP is providing ₹1000 for those with TB through direct benefit transfer for nutrition related support, which is found to be mired with delays and inconsistencies. TB patients with alcohol use disorder, who are more likely to have poor treatment outcomes, require intensive counselling and psychosocial support that is lacking in the program. Appointing counsellors, establishing tele-mental health interventions, and strengthening referrals to the alcohol de-addiction centers should be a priority [34]. Providing paid leave and economic compensation for TB patients at a low socioeconomic status (wage laborers, factory workers, and unorganized sector workers) could reduce treatment noncompliance and could offset the economic burden from TB deaths. Intersectoral coordination between the Ministry of Labor and private sectors is needed to undertake these policy-level decisions to resolve such issues. Considering the disproportionate economic losses that are experienced by different states in India, there is a need for a differential approach to mitigate the economic losses due to TB mortality in high economic burden states. With respect to states that face high economic burden from TB death among the working age population, there is a need to invest in occupational TB prevention and care.

This is a novel analysis providing a comprehensive estimates of economic burden estimates for TB death across age groups, gender, and geographic regions within India. The sensitivity analysis and CIs we generated ensure the robustness of our estimates. As discussed earlier, we used estimates based on lost productivity for working age population in India. Our estimates are far less than the estimates by Silva et al who had used methods involving value of statistical life year or full-income analysis [36]. The value of statistical life represents the monetary value that people need to be paid to accept additional risk (in this case, TB death) in their lives. However, it has been noted that this method produces much higher estimates of economic loss, which is calculated based on foregone earnings of the individual at TB risk, which could be very high and subject to biases [25].

Limitations of the Study

We considered GBD 2021 estimates over other data sources and did not use the NTEP reports because age-specific death rates were not available. Our study using GBD estimates could makes it possible to compare our findings with other countries in the future because GBD estimates of TB deaths are available at a global level. Our estimates did not consider factors like drug resistance, comorbidity, and other facts that are drivers of TB mortality and focuses only on age, region, and sex. Although our estimates did not provide segregated estimates

of burden for these factors, the overall estimates are inclusive of these factors. Also, the present analysis is a cross-sectional one using GBD estimates from 2021. Considering the nonavailability of age-specific and state-specific mortality rates for this period, our analysis was restricted to this year. Also the impact and disruptions of COVID-19 on TB care services and consequent outcomes on TB mortality were not factored in our analysis [35, 37, 38]. Estimates of economic burden in the post–COVID-19 period of 2022 is required to understand the most recent burden of TB deaths in India. The data limitation was that we have used GDP for the year 2019 considering the GDP estimates of subsequent years 2020 and 2021 were disproportionately affected by COVID-19 lockdown and resulted in outlier estimates. Our model was also constrained by lack of age- and sex-standardized mortality data for those with drug-resistant TB, HIV co-infection, and other vulnerable groups.

Conclusion

The estimated higher economic burden of TB deaths in India underscores the urgent need to reduce TB mortality in India. The present TB elimination goal of India aims to achieve zero death due to TB [2, 37], but recent estimates suggest the total death due to TB in India is 323 200 in 2023, which is still comparable to the GBD estimates we used for this analysis [3]. Hence, the economic burden due to TB deaths will be predictably huge for India in the near future. Although NTEP had introduced interventions to contain TB mortality, our estimates provide insights on specific regions and age group, which could be targeted and prioritized with mortality reduction interventions. Different subpopulations face different risk for TB death, which could be attributed to socioeconomic inequality, comorbidity, demographic differences, and biopsychosocial and health system factors. The current study strongly recommends sustained investments to mitigate TB deaths and the resulting economic loss. More rigorous estimates of TB deaths are also required to develop tailored interventions for other sub-groups with higher risk of TB death and economic loss.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Acknowledgments

Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2021 (GBD 2021). Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2024.

Data availability statement. All data used and generated in this study are available in the manuscript.

Financial support. None.

Authors' Contributions. KN: study conception, design, data collection, analysis & draft manuscript preparation; MM: study conception, design, data collection, analysis & draft manuscript preparation; VJ: Design, data collection, analysis & draft manuscript preparation; KC: Design, data collection, analysis & draft manuscript preparation; SA: Data collection, analysis & draft manuscript preparation; SS: study conception, design & draft manuscript preparation; and MV: study conception, design & draft manuscript preparation. All authors reviewed the results and approved the final version of the manuscript.

Ethical approval. Not required.

Potential conflicts of interest. The authors declare that they have no competing interests.

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