RESEARCH PAPER

Pandemic Wave-Driven Dynamics of Disability-Adjusted Life Years Attributable to Coronavirus in India

Gaurav Anand [1], Prabir Maity [1], Soumarshi Das [1], Sharad Upadhyay [1], Pratima Kumari [1], Ravinder Singh [1*], Sanjay Goyal [2*]

[1]Chitkara College of Pharmacy, Chitkara University, Punjab, India.
Email: ravi.jaura@gmail.com, ravinder.singh@chitkara.edu.in
[2]Government Medical College, Rajindra Hospital, Patiala, Punjab, India.
Email: drsanjaymedi@gmail.com

Abstract:

Background:

COVID-19 introduced an unprecedented public health catastrophe in India with a high population density and a diverse demographic profile, along with heightened vulnerability to disease burden of the health care system. Although early evaluations concentrated on single-year estimates, scant information is available about how direct health loss changed over time at the national level, and numerical estimates for different pandemic waves are available only on the basis of standard and burden-of-disease metrics.

Objective:

To estimate the year-wise and total direct health burden of COVID-19 in India for 2020-August 2025 based on disability adjusted life years (DALYs).

Methods:

We performed a retrospective, population-based burden of disease study in the framework of the Global Burden of Disease. National data on COVID-19 morbidity and mortality were sourced from official Indian government and standardized with GBD life tables and disability weights. DALYs were based on the sum of YLLs from premature death and YLDs resulting from symptomatic infections. The estimates were calculated per year and then synthesized over the study period.

Results:

The disease caused an estimated 18.1 million DALYs between 2020 to august 2025 in India. The burden was overwhelmingly constituted by premature mortality, with YLLs accounting for approximately 94% of total DALYs. The peak burden was in 2021, associated with the delta wave, and then there was a sharp decrease in the subsequent years, fitting with improved vaccination coverage and clinical management.

Conclusions:

COVID-19 resulted in a substantial direct loss of population health in India, dominated by premature mortality and concentrated within a single epidemic year. Year-wise DALY estimation is essential for understanding pandemic dynamics and emphasizes the importance of standardized burden estimates to inform public health preparedness, healthcare planning, and future pandemic responses.

Key Words: COVID-19, Disability Adjusted Life Years (DALYs), Years of Life Lost (YLLs), Years lived with Disability (YLDs), Global Burden of Disease (GBD), Year-wise Burden, Epidemiological Trends

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1. Introduction:

The outbreak of the novel SARS-CoV-2-induced coronavirus disease 2019 (COVID-19) has provoked unprecedented consequences on the global population, almost affecting every population globally[1]. The Covid-19 in India posed a serious challenge as it had a huge population, extreme demographics, and a fragile healthcare system. Systemic weaknesses, such as poor access to clean water and sanitation, poor socioeconomic conditions, contributed to the increased vulnerability to disperse and poor results[2–4]. As of early 2021, India had 155,080 deaths and 43,019,453 cases reported, which is the second-highest infection rate in the global community. The pre-existing socioeconomic inequalities were

revealed and compromised by the pandemic, making its overall health impact more extensive[5]. The Global Burden of Disease framework, specifically Disability-Adjusted Life Years (DALYs) offers a more inclusive measurement of the loss of population health, which integrates both premature mortality and non-fatal morbidity[6]. This will allow evidence-based comparisons of populations and diseases that go beyond a traditional case and death count [7, 8]. Different reports, such as Moran et al. estimated 51,622.8 DALYs in Ireland, with 98.5% of the years of life lost (YLLs) and Gianino et al. reported 4,354 DALYs per 100,000 in 16 European countries, where about 98% were due to mortality [9–12]. The reducing-burden-of-disease framework by Wyper et al. has indicated that COVID-19 has both direct and indirect impacts on health, such as the acute infection, hospitalization, critical illness, and death as direct outcomes, and also the long-term sequelae, complications, and post-acute COVID-19 syndrome in case of long COVID[10, 12–15]. In India, the magnitude and distribution of COVID-19 burden varied substantially across the pandemic, influenced by transmission dynamics, access to healthcare, demographic risk profiles, infection fatality rates, and the emergence of several variants[16].A nationally representative study by Singh et al. found that COVID-19 was responsible for 14.1 million DALYs in India during 2020, with YLLs contributing 99.2% and YLDs only 0.8%. Urban areas had a higher burden than rural areas, and men carried a significantly greater burden than women[12, 17]. The 51–60 years age group had the highest absolute DALY burden, while the greatest rate per 100,000 population was in the age group 71–80 years[17, 18]. The pandemic in India established a strong progressive pattern with devastating peaks in 2021, necessitating a comprehensive year-wise DALY assessment to achieve the dynamic evolution of the pandemic. C. Swain et al. documented that the health burden more than doubled from 2020 to 2021, followed by a sharp decline in 2022, representing life expectancy and severe mortality[19, 20]. Excess mortality analyses have confirmed that the second wave resulted in a massive surge in deaths, potentially doubling all cause mortality in several areas[21, 22].

The objective of the study is to quantify the overall and annual direct health burden of COVID-19 in India since 2020 until August 2025 as an indicator of disability-adjusted life years (DALYs) to quantify the temporal variations in the pandemic waves and fill important gaps in current evidence.

2. Methodology:

2.1. Study Design and Overall Analytical Framework:

This research utilizes a population-based, retrospective burden-of-disease design to measure the direct health effects of COVID-19 in India over a 5-year period, from 1 January 2020 to 1 August 2025. The primary metric for summarizing the health impact is the disability-adjusted life years (DALYs). The conceptual model of this study is based on the Global Burden of Disease (GBD) method and is largely aligned with the organization of Singh et al. who calculated COVID-19 DALYs in India for 2020[17]. However, this work focuses only on the loss of life and health directly caused by the disease. Following the pattern of recent burden of disease studies in India and other countries, COVID-19 has been represented as a distinct cause of health loss, and DALYs are accounted for as the aggregate of years of life lost (YLLs) due to early death and years lived with disability (YLDs) as a result of a symptomatic infection[6].The research follows recent worldwide burden-of-disease directions, and hence it specifies the decisions that it made concerning case definitions, mortality attribution, and disability parameters in order to be compatible with local and global COVID-19 DALY estimates[26].

2.2. Data Sources and Extraction Strategy:

According to earlier Indian studies on COVID-19 DALYs and economic cost, the Ministry of Health and Family Welfare (MoHFW) of the Government of India provided the country's national-level COVID-19 case and death counts. These were cross-validated with the WHO COVID-19 dashboard to make sure the data provided internally constant values for the entire 2020–2025 period. Cumulative totals of laboratory-confirmed cases and deaths were attained for each calendar year, as well as the partial year (August 2025), via the MoHFW and National Centre for Disease Control (NCDC) reports, following the methods of Singh et al.[17]. The GBD 2019 reference life table was used to calculate the standard life expectancy at each age to allow comparability with global studies. Life expectancies at each age were based on the GBD 2019 reference life table in order to be comparable with studies internationally. Because the aim was to measure only direct health effects, as such, excess mortality models and indirect effects for example, deaths from disrupted health care services, were not included, in contrast with certain other multicounty or regional studies that actually modelled excess death or indirect outcomes.

2.3. Estimation of Disability-Adjusted Life Years (DALYs):

These studies demonstrate the application of disability-adjusted life years (DALYs) methodology to quantify COVID-19 burden across different populations. DALYs were consistently computed using standard Global Burden of Disease formulas, which include adding years of life lost (YLLs) and years lived with disability (YLDs)[15, 17].

Disability-Adjusted Life Years (DALY) = Years Of Life Lost (YLLs) + Years Lived With Disability (YLDs)

$$\mathrm{YLL} = \sum_{a=1}^{n} \mathrm{YLL}_a$$

$$\mathrm{YLL} = \sum_{a=1}^{n} \text{number of deaths}_a \times \text{Remaining life expectancy}_a$$

Equation 1: Years of life lost (YLL) were estimated by multiplying the number of COVID-19 related deaths by the residual standard life expectancy at the age of death, with both mortality counts and conditional life expectancy defined at the age group level. In this equation a is age group, and n is the number of age groups

$$\mathrm{YLD} = \sum_{h=1}^{l} \mathrm{YLD}_h$$

$$\mathrm{YLD} = \sum_{h=1}^{l} \text{number of cases}_h \times \text{Duration}_h \times \text{Disability weight}_h$$

Equation 2: Years lived with disability (YLDs) were calculated by summing, across all COVID-19 health states, the product of the number of incident cases, disease duration (in years), and corresponding disability weight. In this equation, h is the health status, and l is the number of health status.

The YLLs were calculated by adding the remaining life expectancy at the average age of death to the number of reported COVID-19 deaths within each of the age-sex strata according to the GBD 2019 standard life table. YLDs were calculated based on only symptomatic cases of acute COVID-19 infection, including both long COVID or post-acute sequelae and intensive severity-level modelling which was employed in previous DALY analyses to prevent double-counting, as well as to remain specific to the direct, clinically manifest burden [6]. An estimate of the number of symptomatic infections was made by multiplying an assumed fixed proportion (mid-range of published estimates of this proportion in India and international meta-analyses) of the annual number of confirmed cases by the proportion of these cases with symptoms, which compares with the methods used in recent multi-country DALY estimates that based on pragmatic case-severity assumptions where detailed clinical data are unavailable[6, 12].

Other studies discuss the health burden of COVID-19 in the disability-adjusted life years (DALYs) methodology of various populations. With years of life lost (YLLs) accounting 99.2 per cent of the COVID-18 burden and 0.8 per cent years lived with disability (YLDs), Singh et al. approximated that in 2020 the COVID-18 burden in India was 14.1 million DALYs, with 99.2 per cent of the burden due to YLLs and only 0.8 per cent due to YLDs with a higher burden in the urban areas and in men[17]. The result of this method is DALY estimates where YLLs are dominant, as have been the topic of several recent COVID-19 DALY syntheses, though the non-fatal symptomatic disease still contributes to the total.

2.4. Year-Wise Burden Estimation Approach:

DALYs were calculated (in 2020, 2021, 2022, 2023, 2024 and the 1 st January to 1 st August 2025) to estimate the temporal patterns in the direct health impact of COVID-19 and then added together to obtain a cumulative 5-year burden. YLLs have been derived based on the reported mortality and age structure of that year and represent the steep increase in mortality in the 2021 Delta wave and the attenuation of it with increasing vaccination coverage and less virulent variation, also reflected in Indian and global DALY trend analyses[17, 27]. YLDs had also been calculated based on that year of symptomatic infection, so that the fatal and non-fatal parts exhibit a trend of rising and falling incidence, testing, and clinical management over time. DALYs of the same were, in turn, normalized per 100,000 population by year-specific denominators to be used across years and compared with other causes of disease in India, in keeping with the interpretive framework that has been suggested in recent reviews of burden-of-disease of COVID-19. This perspective is multiyear, which enables the quantification of the acute shock of the pandemic in the peak year and the remaining direct health burden of the post-pandemic period [28].

2.5. Uncertainty Handling and Ethical Considerations:

Due to the main emphasis on the immediate impact, and the use of the official national data, simplified forms of statistics were used over fully probabilistic one: deterministic calculation of point estimates of YLLs and YLDs were done, and uncertainty explored via systematic sensitivity analysis of key parameters, including the proportion of symptomatic people, range of disability weights, and duration of the disease, in the pragmatic suggestion presented in recent burden-of-disease methods articles of COVID-19[29]. A qualitative analysis was conducted to determine the impact of alternative parameter values on total DALYs and the relative contribution of YLLs versus YLDs. These values were taken from published global and regional DALY studies as well as from Indian modelling work that reported plausible ranges for case severity and duration. In a semi-systematic review, the reported incidence of YLD was reported to be 31.9%[17, 29, 30]. Consistent with the ethical handling of data in previous Indian COVID-19 DALY investigations, no individual-level data were accessible; all inputs were aggregated and publicly available statistics, negating the need for formal ethical approval and informed consent. However, as advised by recent cooperative efforts to standardize national COVID-19 burden-of-disease studies, the analysis complies with good scientific practice by openly disclosing data sources, assumptions, and limitations[31, 32].

3. Results:

3.1. Direct impact on DALY Due to COVID-19:

The overall health loss due to COVID-19 specifically was found to be 18,061,878 DALYs attributable directly between January 2020 and August 2025, with the major proportion of loss contributed predominantly by YLL estimated at close to 94%, with a lesser contribution from YLD (6%). To enumerate the non-fatal health burden of COVID-19, published Indian evidence on post-acute sequelae was used to characterize disability prevalence. A recent semi-systematic review synthesizing Indian evidence up to March 2023 reported an integrated 31.9% incidence of long COVID among confirmed COVID-19 cases. In accordance with the Global Burden of Disease approach, years lived with disability (YLDs) were estimated by combining this incidence with a disability weight of 0.219 and a median disease duration of 0.16 years. Applying these values to national case amounts yielded an estimated approximately 499669 YLDs attributable to COVID-19 in India, with year-wise variation indicating infection strategy and higher values during peak transmission periods[29].The cumulative burden of 13,088 DALYs per million population indicates an enormous direct health loss relative to other leading communicable and non-communicable sexually transmitted diseases in the country[17]. Crucially, these estimates are limited to the direct and clinically apparent effects of COVID-19 and do not include the indirect or excess mortality associated with healthcare disruption, deferred health interventions, impair socioeconomic status, making this conservative but robust estimate of health loss restricted to infection-mediated mortality and morbidity quantified by standardized disability weights applied by GBD together with disability duration calculated following GBD methods and Wyper et al. methodologies[6, 33–35].

3.2. Year-wise Burden across the Pandemic Period:

Our study findings demonstrate a pattern that closely aligns with the predominantly mortality-focused burden reported earlier from India and worldwide. According to published estimates of the burden of disease in India, COVID-19 has had a significant direct impact, primarily due to premature mortality. Singh et al. registered 14.1 million DALYs in 2020, and this position was driven by nearly 99% YLL and less than 1% YLD, making India one of the highest burden countries in absolute values[17]. The findings of the present study demonstrates a distinctly year-based analysis that highlighting substantial year-to-year variation over the course of the pandemic whereas the burden amplified from 4.9 million DALYs in 2020 to a drastic maximum of 11 million DALYs in 2021 due to severe Delta wave and then vigorously declined to 1.8 million in 2022, 0.09 million in 2023, 0.012 million in 2024, and 0.0006 million in 2025 that indicates how a single severe wave may drive multi-year losses. When the framework is applied to the entire period from 2020 to August 2025, the total direct burden amounts to 18 million DALYs, largely driven by YLL loss. The whole evaluation is figured out in “**Figure 1”**.

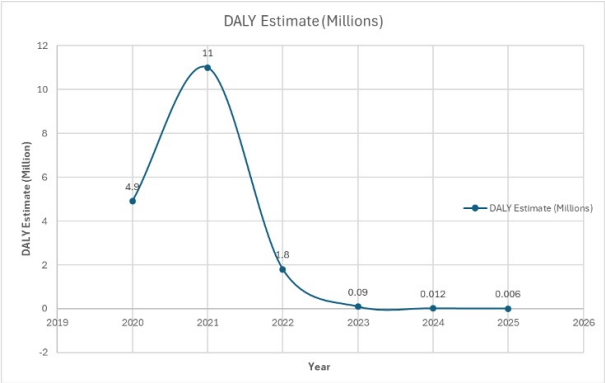

Figure 1: This integrated evaluation indicates the acute mortality shock of 2021, the moderate initial burden of 2020, and the gradually lower losses from 2022–2025, associated with better clinical management, vaccination coverage, and epidemiological control. Collectively, these findings underscore that the COVID-19 burden of India was rigorous in its major waves, shaped predominantly by mortality patterns, and substantially higher in extent than many other infectious disease burdens naturally observed in the country.

4. Discussion:

This study estimates a broad-spectrum multi-year assessment of health burden of COVID-19 in India by combining both direct impact of DALYs and year wise trends from 2020 to August 2025. Our assessment indicates that India endured with moderate burden during the first pandemic year followed by rapidly receding contributions in the following years. The high burden in a single epidemic wave illustrates how intense outbreaks may impact long-term population health. By accounting for temporal variation, this method overcomes the limitations of single period estimates and illustrates how changing transmission intensity and mortality risk affect overall burden over time. Our findings are largely compatible with national estimates, that were driven by burden due to mortality and together support the validity of DALY- based estimations for sample based estimation of COVID-19 impact in India.

The main strength of this study is the attribution to post, acute sequelae in standardized severity classification using disability weights consistent with Global Burden of Disease protocols and methodological comparison. The most striking result of this work is the consistently high YLL- attributable DALY rate, which persists during the entire pandemic period. Though the share of YLD was a lesser and around 6%, it was not negligible [17]. The estimated YLD burden indicates high prevalence of long COVID among survivors and demonstrated that the COVID-19 leads to substantial health loss not only due to acute disease, but also through prolonged illness. Even under uncertain durations of disability , when multiplied with huge infected population of India, they translate into significant absolute YLDs.

These results highlight the need to consider post-acute sequelae in burden of disease calculations, particularly for health planning, rehabilitation services and long-term follow-up of individuals who have survived COVID-19[29].

Findings from our analysis suggest that the spread and time horizon of postacute effects vary greatly between studies, and adjusting these assumptions in individual analyses has a large impact on YLD estimates. The potential for higher long COVID incidence, in particular during the pre-vaccination period, indicates that the non-fatal burden could be underestimated, reinforcing the need for regular updates as new clinical evidence emerges. In India, even modest increases in long-COVID rate could substantially increase DALYs due to the large population and health system constraints. Mortality assumptions remain a critical while we used reported deaths for consistency, excess-mortality assessments suggest higher cumulative DALYs[17]. Our analysis depends upon reported deaths for internal consistency across years, but it is likely that the cumulative burden would be substantially higher under alternative mortality results. Accordingly, we recommend presenting scenario estimates based on reported deaths, IHME-based excess-mortality adjustments, and an intermediate midpoint scenario to document uncertainty and support policymakers. This study provides a year-wise analysis, by integrating multi-year data and adherence to standard DALY protocols, offering a consistent and accurate assessment of the pandemic situation of India while reflecting specific epidemiological conditions than single-year studies.

However, several limitations include improvement. First, although our severity distribution assumptions were consistent with national and international literature, the actual proportions likely varied temporally with vaccination poll data, viral variants, and testing capacity. Adjusting severity proportions by more or less than 10–20% in sensitivity analyses should be considered to quantify their effect on DALY which was not under assumption. Secondly mortality under-reporting remains a major challenge. While our study analysis used reported data for consistency, excess-death adjustments would increase total DALYs, especially for 2020 and 2021.

Finally, indirect effects like health-system disruption, which were excluded from the aim of this study but likely contributed substantially to the overall pandemic burden. In spite of these limitations, the findings have important policy implications. The DALY burden of a single wave emphasizes the critical role of early detection systems, surge capacity planning and adaptable clinical infrastructure. The large YLLs component suggests the importance of equitable vaccination coverage and mortality monitoring. The year-wise data reflects sustained reductions in burden from later years that relate to better clinical management, increasing vaccination, and decreased viral virulence. Embedding DALY metrics into regular health policy planning enables the preparedness for future pandemics to be enhanced by quantifying fatal and non-fatal outcomes in one comparable framework.

5. Conclusion:

The study represents a national level multi-year estimate of direct health burden due to COVID-19 in India based on a standard DALY calculation method and captures the complete temporal dynamism of pandemic spread since 2020 up to August 2025. Results demonstrate COVID-19 caused substantial population health loss, driven by premature mortality and with major burden concentrated during the Delta wave in 2021. The sudden decline in DALYs from the following year onwards represents a composite effect of enhanced vaccination coverage, better patient care and emerging viral strains. However, when also taking year-on-year variation into account it is still a way of interpreting the effect of the pandemic that is more policy relevant than using a single year assessment and allows for clearer attribution of health gains to control measures or system responses. Methodologically, this study reinforces DALYs as a universal measure to contextualize COVID-19 within larger epidemiological disease burden of India and enabling comparisons over time and with other diseases. Despite focusing direct, clinical outcomes, the findings provide a potent baseline for incorporating excess mortality and long-term sequelae in future analysis. Overall, the study emphasizes that monitoring the burden of disease at a very detailed level over a long period is necessary to be prepared for the next pandemic. Systematically including DALY evaluations by year into regular health development can be instrumental in enhancing early warning systems, facilitating the efficient use of resources during epidemic waves, and providing a basis for implementing measures that can prevent deaths in future public health crises.

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Conflict of Interest

All the authors have no conflict of interest.

Data availability

The analyzed data are available along with the manuscript.

Ethical Consideration

Informed consent for the collection of epidemiological data was not necessary because the information was already coded and publicly accessible. The study did not involve any identifiable personal information.

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