Research in Health & Medical Sciences *Original Article*

2023 Jun; 2(2)

The Burden of Disease due to COVID-19 in Northeast Iran Using Disability-Adjusted Life Years throughout the Pandemic

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Received: 2025/02; Revised: 2025/05; Accepted: 2025/06

Abstract

To understand the impact of COVID-19 on population health, the mortality rate alone is insufficient. It is also necessary to analyze the rate of premature death. We calculate Disability-Adjusted Life Years (DALYs) due to COVID-19 attributable morbidity and mortality.

We used data on confirmed cases and deaths due to COVID-19 between February 22, 2020, and August 18, 2021, provided by the Torbat Heydariyeh University of Medical Sciences, to calculate DALYs by age and sex. The Years of Life Lost (YLLs) due to premature death were calculated by multiplying the number of deaths by a standard life expectancy at the age of death. The Years Lived with Disability (YLDs) were calculated by multiplying the number of incident cases, mean duration, and Disability Weights (DWs). DALYs are the sum of the YLLs and the YLDs

Results: The YLDs were equal in men (103) and women (103), but the YLLs were higher in males (4574) than in females (3426). The total disease burden attributable to COVID-19 in the northeast of Iran during the study period was estimated to be 8206 DALYs, and 23.9 DALYs per 1000 population. The YLDs and the YLLs constituted 2.51% and 97.49% of the total DALYs, respectively. The DALYs per 1000 population were highest in people aged ≥ 80 years, followed by those aged 70–79, 60–69, and 45–59 years.

Conclusion: The impact of COVID-19 on public health can be demonstrated through disease burden indices. Most of the COVID burden of disease was derived from YLL. This suggests that decision makers should focus on reducing mortality in subsequent COVID-19 waves.

Keywords: COVID-19, Burden of Disease, Disability-Adjusted Life Years, Years of Life Lost, Years Lived with Disability

Introduction

The World Health Organization (WHO) announced a pandemic of coronavirus disease 2019 (COVID-19) on March 11, 2020 (1). Between December 2019, when the virus was identified, and August 2021, there were more than 200 million cases of COVID-19 and over 4.4 million deaths globally, along with a rising number of new cases (2). At the onset of the epidemic, it was reported that approximately 80% of confirmed COVID-19 cases were mild, with an estimated case fatality rate of 2.3% (1). The infection rates of COVID- 19 have led to an increased burden of disease worldwide and a rising case fatality rate, which has now surpassed 7. 7.1% (3). The actual number of infections in many countries remains underestimated due to the asymptomatic nature of COVID- 19 and insufficient testing and surveillance systems (4). After the first case in Torbat Heydariyeh was reported, involving a 52- year- old woman on February 22, 2020, Torbat Heydariyeh had 6,070 reported COVID-19 cases and 691 reported COVID- 19 deaths as of August 18, 2021. There continue to be cases due to community spread and new imported infections, with about 70 new cases reported daily; consequently, Torbat Heydariyeh may be experiencing an upward trend in the fifth wave of the COVID- 19 epidemic. The entire community is at the highest level of alert and is practicing measures such as prohibiting travel between cities, conducting extensive testing and tracing, wearing masks in public, and maintaining social distancing, because new case numbers in the fifth wave of COVID- 19 are still likely to rise. Although knowledge about the natural history of COVID- 19 is limited, the burden of disease on our community appears to be significant. To establish a foundation for improved policy decision- making, it is necessary to assess the health level of people based on Summary Measures of Population Health (SMPH) (5). Among these SMPHs, the Disability- Adjusted Life Years (DALYs) are highlighted by the WHO because this indicator addresses the limitations of epidemiological metrics, such as prevalence, incidence, and mortality (5).

The DALY is a combination of years of life lost from premature death and years of life lived with disabilities in one indicator. This indicator was applied in The Global Burden of Disease and Injury (GBD), a study which was started in 1988 the aim of quantifying the burden of disease and injury of human populations and defining the world's main health challenges. DALYs for a disease or health condition are calculated as the sum of the years of life lost due to premature death (YLL) in the population and the equivalent healthy years lost due to disability (YLD) for incident cases of the health condition:

DALY = YLL + YLD

The loss of healthy life due to non-fatal health conditions needs to estimate the incidence of that state (disease or injury) in the specified time period(6).

Therefore, this study aimed to calculate the burden of disease due to COVID-19 between February 22, 2020, and August 18, 2021, in Torbat Heydariyeh using DALYs.

Methods

We quantified the burden of COVID-19 in Torbat Heydariyeh using the Disability-Adjusted Life Years (DALYs) metric, based on data from February 22, 2020, to August 18, 2021 (7). DALYs were calculated as the sum of Years of Life Lost (YLLs) due to premature death and Years Lived with Disability (YLDs) due to illness. Years of Life Lost (YLL): YLLs were calculated by multiplying the number of deaths in each age-sex group by the standard life expectancy at the age of death. Life expectancy data were obtained from the WHO life tables. We applied a 3% discount rate and used age-weighting with $\beta = 0.04$, consistent with the GBD 2000 methodology (5).

The YLL was calculated based on the equation 1, here:

N: number of deaths in a given age and sex

L: The standard life expectancy of the dead people at the same age and sex

α: age at death

r: discount rate (0.03)

β: age-weighting parameter (0.04)

C: constant (0.1658)

Years Lived with Disability (YLD): YLDs were calculated by multiplying the number of incident cases by the average duration of disease and the disability weight (DW). Due to a lack of COVID-19-specific DWs, we adopted a value of 0.5 from analogous respiratory infections. A sensitivity analysis using DW = 0.1 for mild and 0.5 for severe cases was also conducted.

The YLD was calculated based on the equation 2, here:

I: Number of incident cases

DW: disability weight

L: average duration of disease

α: age at onset (4).

Equation 1. The calculation of Years of Life Lost (YLL).

$$YLL = N \times C \times e^{r \cdot a} \div (\beta + r)^2 \times \left[e^{-(\beta+r)(L+a)} \cdot (-(\beta + r)(L + a) - 1) - e^{-(\beta+r)\cdot a} \cdot (-(\beta + r) \cdot a - 1)\right]$$

Equation 2. The calculation of Years Lived with Disability (YLD).

$$YLD = I \times DW \times C \times e^{r \cdot a} \div (\beta + r)^2 \times \left[e^{-(\beta+r)(L+a)} \cdot (-(\beta + r)(L + a) - 1) - e^{-(\beta+r)\cdot a} \cdot (-(\beta + r) \cdot a - 1)\right]$$

Data Sources:

Confirmed COVID-19 case and death data were obtained from the Torbat Heydariyeh University of Medical Sciences database.

Population data were drawn from the 2016 national census.

WHO and GBD sources were used for life expectancy, and DW references.

DALYs per 1,000 population were calculated for comparison. Uncertainty intervals (95% UI) were derived using 1,000 bootstrap iterations. Statistical differences between age and sex groups were evaluated using chi-square tests.

One DALY represents the loss of one healthy year due to disease, premature death, or disability. The demographic data was obtained from the national census of population in 2016. The numbers of confirmed cases of COVID-19 by age or sex group were obtained from the Torbat Heydariyeh University of Medical Sciences database.

In this study, for estimating the years of life lost due to death at each age, we applied the standard life expectancy at that age. By means of the patterns of the table with Excel format, which is available from the main designers of the GBD, and using the GBD weights in the year 2000, the YLLs, YLDs, and DALYs are subjected to the calculations (8).

To compare study results with previous studies, we estimated the YLDs, YLLs, and DALYs per 1000 population.

This study received ethical approval from the institutional review board of Torbat Heydariyeh University of Medical Sciences (approval no. IR.THUMS.REC.1401.005)

Results

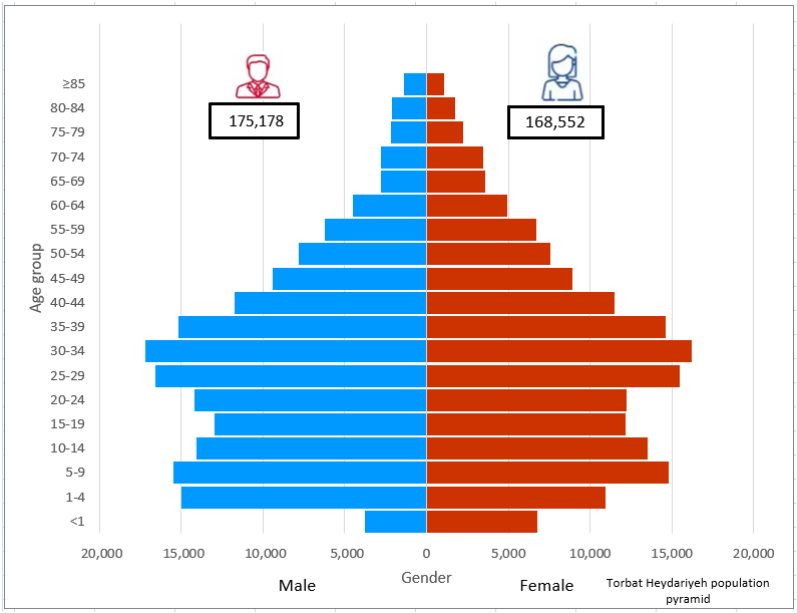

Figure 1. The population pyramid of Torbat Heydariyeh by sex and age group

The total population of Torbat Heydariyeh was 343,730, including 175178 (50.96) men and 168552 (49.03) women (Figure 1). Between February 22, 2020 when the first case of COVID-19 was reported, and August 18, 2021 a total of 6070 confirmed cases of COVID-19 (17.66 per 1000 population) were reported in Torbat heydariyeh, comprising 3087 (50.9%) males and 2983 (49.1%) females.

During the study period, there were 206 YLDs attributable to COVID-19 in Torbat Heydariyeh, and 0.599 YLDs per 1000 population. The YLDs were equal in men (103) and women (103). The YLDs per 1000 population caused by COVID-19 were 0.587 in males and 0.613 in females. The burden of YLDs was highest in those aged 45–59 as 22 in males, and the burden of YLDs was highest in those aged 45–59 years, as 22 in females, and the 5-14 and year-old age group had the lowest proportion of YLDs, as 1 in males and females (Table 1) (Figure 2).

The total number of YLLs caused by COVID-19 was 8000, and YLLs per 1000 people were 23.27. The YLLs were greater in males (4,574) than in females (3,426). The YLLs per 1000 population caused by COVID-19 were 26.1 in males and 20.3 in females. The YLLs was the highest in 65–69 years age group (472) in males, and the in 65–69 years age group (511) in females (Table 2) (Figure 3A). The YLLs per 1000, increased with age in males and females (Table 2) (Figure 3B). The total DALYs for COVID-19 were 8206, and 23.9 DALYs per 1000 population. YLDs and YLLs constituted 2.51% and 97.49% of the DALYs, respectively. The contribution of the YLLs increased with age, and the relative contribution of YLLs and YLDs to DALYs varied by age. The total DALYs were highest in the 60–69 years age group (2212), followed by the 45-59 years (1645), 70–79 years (1529), and ≥ 80 years (1175) age groups (Table3) (Figure 4A). The DALYs per 1000 population were highest in ≥ 80 years age group (185.7), followed by 70–79 years (143.9), 60–69 years (134.5), and the 50–59 years (35.3) age groups (Table 3) (Figure 4B).

The 95% confidence interval for the total DALY is 8,206 (95% CI: 7,890–8,510). The difference between men and women in YLL is statistically significant ($p < 0.01$, Chi-square test). There is a significant difference among age groups ($p < 0.001$).

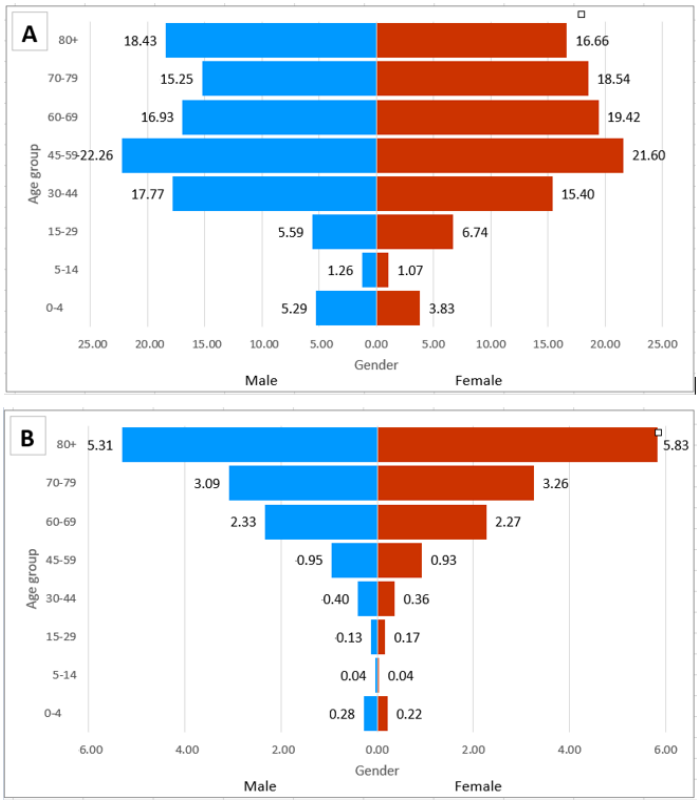

Figure 2. Years lived with disability (YLDs) for COVID-19 by age and sex group in Torbat Heydariyeh. (A) YLDs; (B) YLDs per 1000 population.

Table 1. Years of life lost (YLLs) for COVID-19 by age and sex groups

	Age subgroups	Population	Deaths	Deaths per 1,000	Average Age at death	YLLs	YLL per 1,000
Males							
	0-4	18,750	10	0.5	0.8	302	16.1
	5-14	29,501	1	0.0	11.0	29	1.0
	15-29	43,750	9	0.2	22.6	247	5.6
	30-44	44,038	28	0.6	37.7	674	15.3
	45-59	23,480	48	2.0	54.2	887	37.8
	60-69	7,255	79	10.9	64.0	1,116	153.8
	70-79	4,935	73	14.8	75.1	642	130.1
	80+	3,469	156	45.0	86.9	677	195.1
	Total	175,178	404	2.3	69.3	4,574	26.1
Females							
	0-4	17,751	4	0.2	0.3	122	6.9
	5-14	28,281	-	0.0		-	0.0
	15-29	39,914	2	0.1	23.5	55	1.4
	30-44	42,341	10	0.2	39.4	244	5.8
	45-59	23,164	36	1.6	54.0	714	30.8
	60-69	8,556	64	7.5	65.1	975	113.9
	70-79	5,689	82	14.4	74.8	853	149.9
	80+	2,856	89	31.2	86.7	463	162.1
	Total	168,552	287	1.7	71.1	3,426	20.3

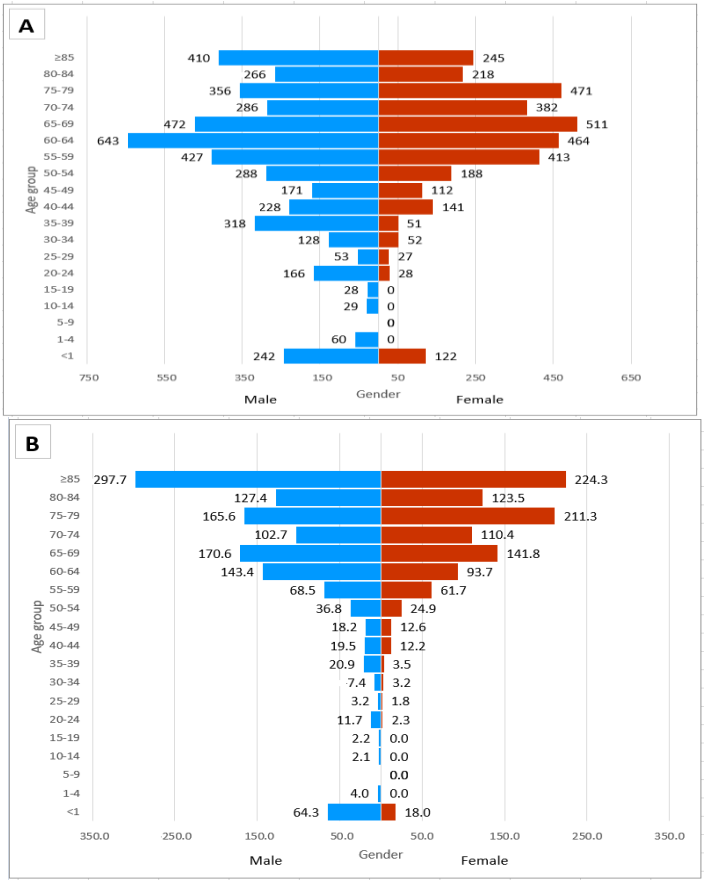

Figure 3. Years of life lost (YLLs) for COVID-19 by age and sex group in Torbat Heydariyeh. (A) YLLs; (B) YLLs per 1000 population.

Table 2. Years lived with disability (YLDs) for COVID-19 by age and sex groups

	Age subgroups	Population	Incidence	Incidence per 1,000	Age at onset	Duration (years)	Disability Weight	YLDs	YLD per 1,000
Males									
	0-4	18,750	138	7	1.1	0.0767	0.500	5	0.3
	5-14	29,501	33	1	8.6	0.0767	0.500	1	0.0
	15-29	43,750	146	3	23.2	0.0767	0.500	6	0.1
	30-44	44,038	464	11	37.4	0.0767	0.500	18	0.4
	45-59	23,480	581	25	52.4	0.0767	0.500	22	0.9
	60-69	7,255	442	61	64.2	0.0767	0.500	17	2.3
	70-79	4,935	398	81	75.0	0.0767	0.500	15	3.1
	80+	3,469	481	139	85.9	0.0767	0.500	18	5.3
	Total	175,178	2,683	15.3	56.3	0.0767	0.50	103	0.587
Females									
	0-4	17,751	100	6	0.8	0.0767	0.500	4	0.2
	5-14	28,281	28	1	8.0	0.0767	0.500	1	0.0
	15-29	39,914	176	4	23.3	0.0767	0.500	7	0.2

	30-44	42,341	402	9	37.9	0.0767	0.500	15	0.4
	45-59	23,164	564	24	52.7	0.0767	0.500	22	0.9
	60-69	8,556	507	59	64.4	0.0767	0.500	19	2.3
	70-79	5,689	484	85	74.6	0.0767	0.500	19	3.3
	80+	2,856	435	152	85.4	0.0767	0.500	17	5.8
	Total	168,552	2,696	16.0	57.6	0.0767	0.50	103	0.613

Table 3. Disability-adjusted life years (DALYs) for covid-19 by age and sex subgroups.

	Males			**Females**			**Persons**		
	Population	**DALYs**	**DALYs per 1,000**	**Population**	**DALYs**	**DALYs per 1,000**	**Population**	**DALYs**	**DALYs per 1,000**
Age subgroups									
0-4	18,750	308	16.4	17,751	126	7.1	36,501	434	11.9
5-14	29,501	30	1.0	28,281	1	0.0	57,782	32	0.5
15-29	43,750	253	5.8	39,914	62	1.6	83,664	315	3.8
30-44	44,038	692	15.7	42,341	259	6.1	86,379	951	11.0
45-59	23,480	909	38.7	23,164	736	31.8	46,644	1,645	35.3
60-69	7,255	1,133	156.1	8,556	994	116.2	15,811	2,127	134.5
70-79	4,935	657	133.2	5,689	871	153.2	10,624	1,529	143.9
80+	3,469	695	200.4	2,856	480	167.9	6,325	1,175	185.7
Total	175,178	4,677	26.7	168,552	3,529	20.9	343,730	8,206	23.9

Discussion and Conclusion

We measured the burden of COVID-19 from the first case on February 22, 2020, to August 18, 2021 in Northeast Iran using incidence-based DALYs. By August 18, 2021 there were a total of 8206 DALYs attributable to COVID-19, consisting of 206 YLDs and 8000 YLLs during the peak phase of the fifth wave of COVID-19 in Iran.

The DALYs were higher in females than in males and increased in both sexes with age. The study results showed that the number of DALYs for COVID-19 was highest in the 60–69 age group. However, when adjusted for population, the highest rate of DALYs were seen in the ≥ 80 age group. This indicates that the higher the age, the greater the risk of mortality and morbidity from COVID-19, which is consistent with the results of previous studies conducted in other countries (3, 9-12). The total burdens of COVID-19 in the northeast of Iran are expected to be greater than those reported in these results, as it is an ongoing epidemic. Also, there could be false negatives and undetected cases of COVID-19, leading to potentially more death. Particularly, if a sixth wave of COVID-19 were to occur, the burthen of DALYs would be even greater. We can reduce the DALYs of COVID-19 even if a sixth wave occurs. The most important strategy to reduce the burden of COVID-19 during the sixth wave will be to focus on reducing case-fatality rates, as over 95% of DALYs were due to YLL. it is important to focus on primary prevention in order to reduce the number of new cases through various preventive approaches. These include early detection of cases, extensive testing, contact tracing, wearing facemasks in public and practicing social distancing. If the number of new cases exceeds healthcare capacity, it will be extremely difficult to control the spread of the disease, leading to a rapid increase in cases (13). As a summary measure of population health, the

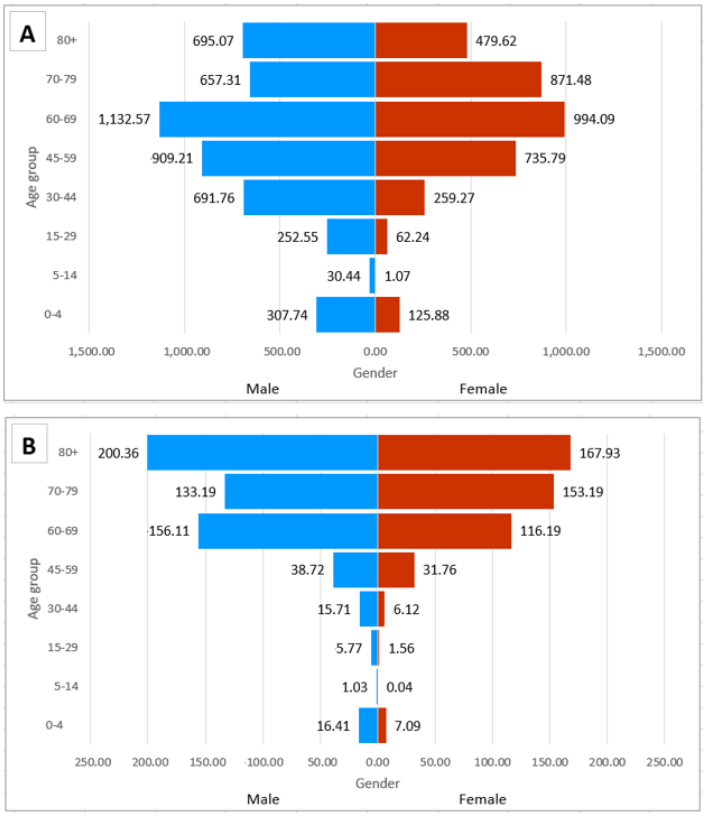

Figure 4. Disability-adjusted life years (DALYs) for COVID-19 by age and sex group. (A) DALYs; (B) DALYs per 1000 population.

DALY index is useful in identifying the impact of COVID-19 on public health.

Because Iran has been conducting screening for COVID-19 using real-time polymerase chain reaction, the incidence could be obtained and, in this study, used the incidence-based approach for estimation of DALYs instead of prevalence-based which was used recently by the Institute for Health Metrics and Evaluation for the Global Burden of Disease study (14, 15). The reason why this Institute used the prevalence-based approach was that it might be easier to obtain the prevalence than the incidence (16). Because most countries have reported this information for COVID-19, the methods used in this study could be used to estimate DALYs in other countries.

One of the strengths of this study was that the large sample size was followed over a long period. However, this study had some limitations.

However, several limitations must be acknowledged. First, the disability weights (DWs) for COVID-19 were not disease-specific, and we adopted a DW of 0.5 from similar respiratory infections. While we addressed this limitation through sensitivity analysis using a lower bound of 0.1 for mild cases, the actual DW may vary further, especially in the context of long COVID. Second, due to limited diagnostic testing and the likelihood of asymptomatic or undiagnosed cases, the incidence figures likely underestimate the true number of infections.

Consequently, YLDs and overall DALYs may be underreported. Incorporating seroprevalence data in future studies could mitigate this limitation.

Third, while we applied standard discounting (3%) and age-weighting (β=0.04), some scholars suggest alternative approaches in pandemic contexts, such as eliminating discounting to reflect urgent societal priorities. This could be considered in future iterations.

Lastly, the lack of confidence intervals in many previous local DALY studies made comparative assessment difficult. In this study, we introduced uncertainty intervals using 1,000 bootstrap iterations and applied statistical testing to assess differences across demographic groups, enhancing robustness.

In conclusion, this study provides valuable epidemiological insights for local health authorities. The dominance of YLLs in the COVID-19 burden emphasizes the urgency of mortality prevention, especially among older adults. The DALY approach offers a powerful framework for guiding resource allocation and pandemic preparedness strategies. In conclusion, this is the first study to calculate the disease burden caused by COVID-19 in Iran using DALYs. The methods used in our study can be applied to other countries. Calculation of the DALYs due to this emerging disease in other countries could provide the basis for international comparisons. Most of the disease burden from COVID-19 was derived from YLLs (97.49%); this indicates that decision-makers should focus on and make an effort to reduce mortality for the sixth wave of COVID-19.

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