Original Article

Evaluating the Economic Impact of Airborne Infectious Diseases on the Health System: A Cross-sectional Study Utilizing Disability-adjusted Life Years and Lost Productivity

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Abstract

Aim: Airborne infectious diseases have many adverse economic effects worldwide. However, evidence of these effects in low- and middle-income countries is still scarce. We, therefore, aimed to evaluate the socioeconomic burden of the COVID-19 pandemic as the most important infectious disease in the recent decade by estimating disability-adjusted life years (DALYs) and lost productivity. **Methods:** This cross-sectional study was based on 456 patients with COVID-19 diseases in Sabzevar, Iran, 2020–2021. We used Murray and Lopez's approach to calculate the burden of disease. The data on COVID-19 were collected from the Hospital Information System at Vaseie Hospital. Lost life after premature death (years of life lost [YLL]) and life with a disability (years lived with disability [YLD]) were used to measure DALY. The Human Capital Approach (HCA) was used to estimate Temporary Productivity Loss (TPL). **Results:** During the study period, 6456 patients with the COVID-19 disease were identified, of which 1028 cases resulted in death. The burden of disease caused by COVID-19 was 18,748 DALYs with a discount rate of 3%. The YLL was 4782 in men and 3597 in women. Moreover, YLD was 5283 and 5086 in males and females, respectively. The total costs of productivity loss due to absenteeism (TPL) and due to COVID-19 premature mortality were about $4 and $8 million purchasing power parity for all working-age classes, respectively. **Conclusion:** Overall, our study suggested that the main burden of COVID-19 was morbidity. YLD was responsible for about 55% of DALYs and males had a higher YLL and YLD than females.

Keywords: COVID-19, economic burden, productivity loss

Introduction

The COVID-19 pandemic is widely acknowledged as a major global economic and worldwide health issue[1] and is recognized as a global health concern.[2-5] The pandemic had several negative effects on the economy, beginning with dramatic declines in domestic production and revenue collection, followed by a significant and volatile rise in the cost of living.[6] Moreover, it triggered a global public health crisis that overwhelmed the healthcare systems of many countries, resulting in over 200 million reported cases and nearly 5 million deaths worldwide.[1] Household incomes and employment were severely affected. Survey data covering 51 countries reveal that 57% of firms reduced employment during the first two quarters of the pandemic, directly impacting household income.[7] Similarly, in 34 low- and middle-income countries (LMICs), 1.4 billion adults discontinued work due to the pandemic, leading to income reductions.[8]

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International studies have demonstrated that the medical costs of COVID-19 are significantly higher than those of other infectious diseases due to its elevated potential for hospitalization and mortality.[9] To gain a comprehensive understanding of the profound impact of this pandemic on public health, it is essential to investigate the burden of the disease.[10] The most well-known assessment of disease burden is the Global Burden of Disease (GBD) study conducted by the World Health Organization. Initiated in 1990, this study aims to quantify the health effects of more than one hundred diseases and injuries.[11] Disability-adjusted life years (DALYs) were used for the first time to calculate the GBD. This index is obtained by summing years lost due to premature death (years of life lost [YLL]) and years lived with a disability (years lived with disability [YLD]).[12] In addition, assessing the burden of productivity loss can provide valuable insights into the economic impact of the disease.[13] Lost productivity is critical in determining disease burden, considering clinical and epidemiological factors, and estimating the disease's economic and social impact. Short- and long-term absences due to disability and premature death can lead to productivity loss, incurring costs not only for the affected individuals and their families but also for the economy. The overall social cost includes a reduction in productivity.[10]

Decision-makers can facilitate accurate comparisons between different resource applications by disseminating information about the costs of diseases and their complications. Furthermore, the ultimate goal of disease burden estimation is to provide objective evidence needed for policy design, health program management, strategic research prioritization, resource allocation, and evaluation of the cost-effectiveness of interventions.[14] When comparing the economic effects of this disease to previous epidemics, it becomes evident that the current economic crisis is far more severe than the previous ones. Nevertheless, given the high cost of treating COVID-19 patients, the economic burden on the health system and the community, and the impending economic crisis, calculating the disease burden appears to be significant.[15] Understanding the economic consequences of diseases can aid policy-makers in devising plans to reduce out-of-pocket payments and develop funding strategies.[16] Economic burden studies have primarily been conducted in developed countries. For instance, in Brazil, only years of potential life lost and excess mortality due to COVID-19 were estimated.[17,18] In the Eastern Mediterranean Regional Office countries, studies have been conducted to estimate years of life lost following COVID-19, but limited research has been done to calculate productivity loss. Therefore, this study aimed to evaluate DALYs and productivity loss among COVID-19 patients admitted to a hospital in, Sabzevar, Iran.

Materials and Methods

Study area

This cross-sectional study was conducted in the northeast of Iran. Of six hospitals covered by Sabzevar University of Medical Sciences, Mohammad Vaseie Hospital with 260 beds was selected as the COVID-19 center, and all patients that need hospital curative services are referred to this Hospital.[19] This study was approved by the Ethical Committee of Sabzevar University of Medical Sciences (IR.MEDSAB.REC.1399.055). The data on 6456 cases of COVID-19 were obtained from the Hospital Information System in Vaseie Hospital from February 20, 2020 to April 30, 2021. After formal administrative coordination, the research team provided the data output in an Excel file. The obtained data were including occupation, education, gender, place of residence, date of infection, duration of hospitalization, receiving incentive respiratory care, and treatment result. All patients referred to the COVID-19 center were included in our study. Before analyzing the data, we exclude the patients whose main information, for example, gender, date of infection, or occupation was lost.

Murray and Lopez's approach was used to calculate the burden of disease.[12] DALYs for COVID-19 were calculated using a sex and age classification system. The calculation of DALY was based on the combination of YLL and YLD. Moreover, the Human Capital Approach (HCA) was used to estimate the two types of productivity loss: (i) temporary productivity loss (TPL) due to absenteeism and (ii) permanent productivity loss (PPL) due to premature death.

As the number of positive COVID-19 cases during the study was limited, YLL and YLD were calculated separately for each patient. To compute YLL per person, we required the patient's life expectancy, age, the duration of time off work due to illness, and the severity of disability caused by the disease. YLDs were estimated as the product of a prevalence estimate and a disability weight for the health status of each mutually exclusive sequel, adjusted for comorbidity.[20] Unfortunately, the disability weight specific to COVID-19 is currently unavailable. Therefore, given its clinical similarity to COVID-19, the YLD was calculated using the disability weight for lower respiratory tract infections (0.133).[10] Based on the recommendation of the WHO, in this study, for the age group <15 years, YLL, YLD, and DALY were calculated, and for the age of 15 years and above, productivity lost, YLL, YLD, and DALY were calculated.[21] The number of weeks of absenteeism, the average hourly wage for each age group, and weekly working hours were collected from the various sources to estimate the TPL. Monthly wages were calculated using the Iranian Ministry of Labor and Social Affairs' approved minimum wage for the first age group.[22] For subsequent age groups, wages were increased by 20% from the previous group, considering the annual salary increases in Iran,[23] typically ranging between 15% and 25%. Thus, the monthly salary was determined as follows: 15–24 years old group: 24,000,000 Rials; 25–34 years old group: 28,800,000 Rials; 35–44 years old group: 34,560,000 Rials; 45–54 years old group: 41,470,000 Rials; 55–64 years old group: 49,760,000 Rials. Consequently, the hourly wage was calculated.

According to the WHO guidelines, Productivity Lost was adjusted based on the number of infection cases, taking into account the number of deaths and individuals of nonworking age, with a standard absence of 2 weeks from work being considered.[24,25] No discount rate was applied since the absence period was less than a year. To calculate Permanent Productivity Lost, the following information was required: the number of deaths, age of death, unemployment rate, labor force participation rate, average hourly wage for each age group, weekly working hours, and retirement age. All the necessary data were extracted from the appropriate sources. The unemployment and labor force participation rates were found to be 11.38% and 27.51%, respectively. It should be noted that Iran's retirement age is 65 years.

Productivity years loss of life (PYLLj) for each individual belonging to a working group (Wj) was calculated as the difference between the retirement age and the mean age of death for the specific age group Wj. The following categories were considered as working age groups: W1 shows people between 15 and 24 years, W2 between 25 and 34 years, W3 between 35 and 44 years, W4 between 45 and 54 years, W5 between 55 and 64, Where j = 1. 5. PYLLj estimates for each working-age (Wj) [Table 1].

The yearly wage was calculated according to the labor force participation and unemployment rates. For each person in age group j, the adjusted annual wage j was defined. Specifically, AAW1 for people in W1 is equal to 23,758,000 Rials, and AAW2 for people in W2 is equal to 28,500,000 Rials. AAW3 for people in W3 was equal to 34,210,000 Rials, AAW4 for people in W4 was equal to 41,050,000 Rials, and for people in W5, AAW5 was equal to 49,260,000 Rials. A 3% discount rate was used for the annual wage.

Estimating years of life lost, years lived with disability, and disability-adjusted life year

Equation 1 was used to estimate YLL associated with acute COVID-19 respiratory infection:

$$YLLs[r.\ k.\beta] = \frac{KCe^{ra}}{(r+\beta)^2}\left[\begin{matrix} e^{-(r+\beta)(L+a)}\left[-(r+\beta)(L+\alpha)-1\right] \\ -e^{-(r+\beta)a}\left[-(r+\beta)\alpha-1\right]\end{matrix}\right]+\frac{1-K}{r}(1-e^{-rL}) \quad (1)$$

Moreover, estimating the YLD related to the acute respiratory infection COVID-19 was calculated using the YLD formula (Equation 2):

$$YLDs = DW\left\{\begin{matrix}\frac{KCe^{ra}}{(r+\beta)^2}\left[\begin{matrix} e^{-(r+\beta)(L+\alpha)}\left[-(r+\beta)(L+\alpha)-1\right] \\ -e^{-(r+\beta)\alpha}\left[-(r+\beta)\alpha-1\right]\end{matrix}\right] \\ +\frac{1-K}{r}(1-e^{-rL})\end{matrix}\right\} \quad (2)$$

where a is the age of death; r is the social discount rate; β is the age weighting constant; C is the adjustment constant for age-weights, K is the age weighting modulation constant, and L is the length of disability; and DW is the weight of disability. In this study, formulas are defined explicitly in the WHO model, that r value is 0.03, K-value is 1 because age weights are used, standard age weights use a Beta of 0.04 and a Constant of 0.1658. DALY was calculated as the sum of the YLLs and YLDs. The following metrics were reported in this study: Total YLL; total YLL for each age group and gender; total YLD; total YLD for each age group and gender; total DALY; and total DALY for each age group and gender.

Table 1: Productivity years lost of life for various working age groups

Age group	W1 (15–24)	W2 (25–34)	W3 (35–44)	W4 (45–54)	W5 (55–64)
PYLLj	44	34	25	15	5.5

PYLLj: Productivity years loss of life

Productivity loss estimation

The HCA was utilized to estimate productivity costs, considering the expected or potential earnings lost due to illness. In the case of an intervention that reduces the risk of mortality, the change in productivity costs is determined by the present value of additional days of paid work over the individual's lifetime, with these days valued using the gross wage rate.[26] Estimates of individual TPL were calculated as the weekly median wage for each age group multiplied by the number of weeks off or the length of absenteeism from work (Equation 3).

Personal TPL = weekly median wage × weeks off (3)

The total temporary productivity lost was calculated by multiplying the individual temporary productivity lost by the number of modified cases of COVID-19 disease.

The individual permanent productivity loss was calculated as the sum of annual reduced wages for the productive years of life lost for a specific age group. The unemployment rate and labor force participation rate in Iran were used to adjust it. The total permanent productivity loss of COVID-19 was then calculated by multiplying the individual permanent productivity losses by the number of deaths. Furthermore, all costs were computed using purchasing power parity (PPP) for 2020 and converted to an equivalent of 15,766 Rials per US dollar.[15]

Results

During the study period, 6456 patients with the COVID-19 disease were identified, of which 1028 cases resulted in death. Of the patients, 0.2% were under 15 years old, 22.9% were between 15 and 45 years old, 34.6% were between 45 and 65 years old, and 42.3% were 65≤ years old. The distribution by gender showed that 51.3% were male and 48.7% were female. Among them, 40.9% were homemakers and 20.6% were retired [Table 2]. In addition, 7% of the patients required ICU care due to a severe form of the disease. The average hospitalization duration was 5.3 ± 4 days.

The burden of the disease caused by COVID-19 was 18,748 DALYs and a discount rate of 3%. Out of these, 10,065 DALYs were attributed to men and 8683 DALYs were attributed to women. The average DALY was 2.9 years for each case, while for each COVID-19-related death, it was 18.2 years. Specifically, the YLL accounted for 4782 in men and 3597 in women, while the YLD was 5283 and 5086 for men and women, respectively. Overall, 44.7% of the disease burden was attributed to YLL [Table 3].

The distribution of DALY based on different age groups indicated that the highest DALYs were observed in the 55–64 years' age group [Figure 1].

The wage increase between different age groups was calculated at 20%, based on an annual increase of 15%–25% in salaries in Iran. The total cost of lost productivity due to absenteeism (TPL) was around $4 million PPP for all working-age classes, with $2,072,873 PPP being attributed to males (51.6%) [Table 4]. In addition, the average productivity loss per person was $1184 PPP. The total cost of lost productivity due to COVID-19 premature mortality (PPL) was around $8 million PPP for all working-age groups, with $4,872,245.6 PPP attributed to males (59.1%). Furthermore, on average, $25,757 PPP is lost in productivity per person [Table 5].

Discussion

To our knowledge, this is one of the first studies on the economic effects of the COVID-19 pandemic in a LMIC (i.e., Iran). The burden of disease caused by COVID-19 was 18,748 DALYs. The origin of 44.7% of the burden of the disease is YLL. Moreover, YLD was higher in males compared to females. The wage increase between different age groups was 20%, while the total cost of lost productivity due to absenteeism and COVID-19 premature mortality was approximately $12 million PPP, with males accounting for the majority of these losses.

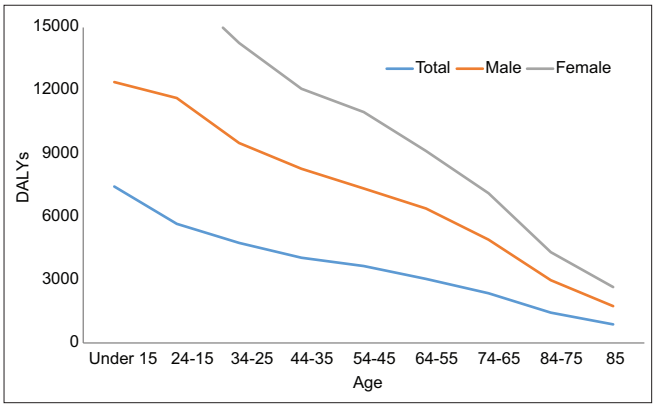

Figure 1: Distribution of disability-adjusted life years between different age groups per 1000 person

Interpretation of the results

The average DALY in our study was 18.2 years for each COVID-19-related death, which was higher than the findings of studies in Brazil and Australia. These studies estimated 13.1 and 8.7 DALY for each death, respectively.[27] However, it was lower than the results of studies in Ukraine, which calculated 19.3 DALY for each death.[28]

This study showed that the main burden of COVID-19 was morbidity. YLD was responsible for about 55% of DALYs. Males have a higher YLL and YLD compared to females. These findings are consistent with the results of De Castro's study in Brazil.[27] New evidence suggests that men die more often than women and 51.6% of TPL and 59.1% of PPL are attributed to men. This discrepancy could be due to sex-based immunological or gendered differences, such as smoking patterns and prevalence. According to the data from COVID-19 in Italy, men have a higher mortality rate than women across all age groups, as reported by Nurchis *et al.*[10] The economic perspective on the COVID-19 burden, provided by estimating productivity loss, adds to existing population health metrics, emphasizing the importance of considering the disease's impact on the labor force's productive capacity. The adopted methodology is a validated framework for calculating lost productivity for acute and chronic conditions based on the HCA. The importance of estimating lower respiratory tract infections (LRTIs) has been highlighted in previous studies.[29]

The findings showed that premature mortality was the primary cause of productivity loss. Indeed, the number of deaths in the 55–64 years' age group was ten times higher than in the 25–34 years' age group. As a result, the elderly age group has the most impact, although the number of productive years lost is lower than in the younger age groups. Even though lost productivity due to absenteeism was less than premature death, its impact on individuals and society is significant.

The health system must respond to a challenge posed by rapidly changing epidemiology. It is critical to prevent and treat the conditions that cause the most significant disease burden and demand for our healthcare services.[30] In an emergency, the healthcare metric used in this study can guide decision-makers in establishing research and policy priorities. In this light, data on the economic impact of illness and health problems are meant to supplement rather than replace epidemiological data on population health problems. This research was based

Table 2: The frequency (%) of the job of COVID-19 patients

	Self-employment	Housewife	Retried	Employee	Farmer	Unemployed	Student	Teacher	Medical doctor	Unknown	Total
Frequency (%)	1466 (22.7)	2632 (40.9)	1330 (20.6)	343 (5.5)	303 (4.7)	146 (2.3)	51 (0.7)	55 (0.8)	36 (0.5)	77 (1.2)	6455 (100)

on epidemiological and socioeconomic data gleaned from the Hospital Information System. Furthermore, because the pandemic is still ongoing, DALY estimates only refer to the acute phase of the disease, and the various sequelae and chronicity to which COVID-19 could be linked are still unknown. Indeed, the likelihood of developing a sequel or chronic condition is high, as documented in the scientific literature.[31] Because a specific value for COVID-19 is still not available, the disability weight was assumed to be an acute lower respiratory infection when calculating YLDs, as reported by Gaunt *et al.* for influenza and other coronaviruses.[32]

Nonetheless, the WHO has endorsed the adopted formulas. Our analysis focused on productivity loss and provided a quantitative characterization of the disease burden without considering other COVID-19-related factors (e.g., lockdown, quarantine of contacts, decrease in consumption, healthcare direct costs, etc.). When calculating TPL, the length of time away from work varies significantly from one person to another, as does the speed at which swabs are used to confirm clinical recovery.[33]

Table 3: Years of lost life, years lost due to disability, and disability-adjusted life years caused by COVID-19

Age group	Total YLL, YLD, and DALY for Female			Total YLL, YLD, and DALY for Male		
	YLL	YLD	DALY	YLL	YLD	DALY
Under 15	37.3	44.5	81.8	0	14.9	14.9
15–24	70.8	340.8	411.6	101.1	275.2	376.3
25–34	234.9	979.3	1214.2	229.4	863	1092.4
35–44	262.5	1098.2	1360.7	616.7	1491.5	2108.2
45–54	687.1	972.6	1659.7	787	1105	1892
55–64	816.8	887.1	1703.9	1286.5	854.3	2140.8
65–74	812.1	498.7	1310.8	924.6	421.8	1346.4
75–84	517.4	227.7	745.1	638.9	206.1	845
85+	158.6	37.3	195.9	198	51.2	249.2
Total	3597.5	5086.2	8683.7	4782.2	5283	10,065.2

YLL: Years of lost life, YLD: Years lived with disability, DALY: Disability-adjusted life years

Limitations

Our study had some limitations that should be considered in future studies. First, we did not perform a sensitivity analysis in this study, which could have increased our confidence in the impact of the variables. Another limitation of this study was the unavailability of disability weight specific to COVID-19, leading us to use the disability weight for LRTIs. However, it is evident that COVID-19 causes more symptoms and problems than LRTIs. In addition, the study population was limited to one province, so caution is necessary when generalizing the results to other provinces. Due to the unclear scenario of productivity loss in under-18 employment in Iran, the results of productivity loss for the age group of 15–24 years could be over/under-estimate which should be more considered in future studies. While the WHO suggests considering individuals between the ages of 15 and 64 as part of the productive

Table 4: Estimated temporary productivity loss per sex and age group by human capital approach

Age group	Number of adjusted cases		Individual cost of TPL (IR)	Total cost of TPL (IR)		Total cost of PPP ($)	
	Male	Female		Male	Female	Male	Female
15–24	60	74	11,200,000	672,000,000	828,800,000	42,623	52,569
25–34	222	247	13,440,000	2,983,680,000	3,319,680,000	189,248	210,559
35–44	472	347	16,128,000	7,612,416,000	5,596,416,000	482,837	354,967
45–54	468	418	19,353,600	9,057,484,800	8,089,804,800	574,495	513,117
55–64	532	552	23,224,320	12,355,338,240	12,819,824,640	783,670	813,132
Total	1754	1638		32,680,919,040	30,654,525,440	2,072,873	1,944,344

TPL: Temporary productivity loss, PPP: Purchasing power parity

Table 5: Estimated permanent productivity loss per sex and age group calculated with the human capital approach

Age group	Number of deaths		Individual cost of PPL (IR)	Total cost of PPL (IR)	Total cost of PPP ($)
15–24	Male	3	599,995,145.1	1,799,985,435.3	114,169 (60%)
	Female	2		1,199,990,290.2	76,112.6 (40%)
25–34	Male	8	630,974,128.2	5,047,793,025.6	320,169.5 (50%)
	Female	8		5,047,793,025.6	320,169.5 (50%)
35–44	Male	26	629,946,080.8	16,378,598,100.8	1,038,855.6 (70.3%)
	Female	11		6,929,406,888.8	439,516 (29.7%)
45–54	Male	45	531,155,344.3	23,901,990,493.5	1,516,047 (53.6%)
	Female	39		20,715,058,427.7	1,313,907 (46.4%)
55–64	Male	108	274,883,861	29,687,456,988	1,883,005 (60.7%)
	Female	70		19,241,870,270	1,220,466 (39.3%)
Total	Male	190		76,815,824,043.2	4,872,245.6 (59.1%)
	Female	130		53,134,118,902.3	3,370,171.2 (40.9%)

PPL: Permanent productivity loss, PPP: Purchasing power parity

population, special attention should be paid to younger age groups to ensure more accurate estimates. 15 and 64 years should be considered as productivity age.

Conclusion

Our study showed that the average DALY was 18.2 years per each COVID-19 death. The main burden of COVID-19 was morbidity and YLD was responsible for about 55% of DALYs. Males had higher YLL and YLD compared to females. Approximately $ 1184 PPP of productivity was lost per person due to absenteeism. Labor force participation and unemployment rates are not age dependent for temporary and permanent productivity loss. The new coronavirus outbreak is threatening societies from the inside out, affecting the lives and livelihoods of millions of people worldwide and having devastating social and economic consequences. Using DALYs and productivity loss metrics to characterize the burden of disease is critical in allowing the health system to be held accountable for the financing and allocation of resources needed to plan health policies to prevent emergency events.

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Ethics code

The study protocol and methods were approved by the Ethics Committee of Sabzevar University of Medical Sciences, Sabzevar, Iran (IR.MEDSAB.REC.1399.055). The informed consent was obtained from all subjects and/or their legal guardian(s). The research was performed in accordance with the Declaration of Helsinki.

Conflicts of interest

There are no conflicts of interest.

Authors' contributions

Alireza Ghorbani, Hadi Lotfi, and Ali Taj: Conceptualization, data collection, data analysis, manuscript writing, review, and editing, manuscript writing, review, and editing; Zahra Keyvanlo: Conceptualization, review, and editing; Mohammad Hosseinzadehhesari: Conceptualization, data collection, and manuscript writing. Mohammad Miri: Supervision, conceptualization, data analysis, manuscript writing, review, and editing.

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