The relationship between demographic, psychosocial and health-related parameters and the impact of COVID-19: a study of twenty-four Indian states

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Table of Contents

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Abstract

The impact of the COVID-19 pandemic has varied widely across nations and even in different regions of the same nation. Some of this variability may be due to the interplay of pre-existing demographic, psychological, social and health-related factors in a given population. Data on the COVID-19 prevalence, crude mortality and case fatality rates were obtained from official government statistics for 24 regions of India. The relationship between these parameters and demographic, social, psychological and health-related indices in these states was examined using both bivariate and multivariate analyses. A variety of factors - state population, sex ratio, and burden of diarrhoeal disease and ischemic heart disease - were associated with measures of the impact of COVID-19 on bivariate analyses. On multivariate analyses, prevalence and crude mortality rate were both significantly and negatively associated with the sex ratio. These results suggest that the transmission and impact of COVID-19 in a given population may be influenced by a number of variables, with demographic factors showing the most consistent association.

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Original Manuscript

The relationship between demographic, psychosocial and health-related parameters and the impact of COVID-19: a study of twenty-four Indian states

Abstract

Background: The impact of the COVID-19 pandemic has varied widely across nations and even in different regions of the same nation. Some of this variability may be due to the interplay of pre-existing demographic, psychological, social and health-related factors in a given population.

Objective: To examine the statistical associations between the state-wise prevalence, mortality and case fatality of COVID-19 in 24 Indian states and key demographic, socio-economic and health-related indices.

Methods: Data on the COVID-19 prevalence, crude mortality and case fatality rates were obtained from official government statistics for 24 states of India as of June 30, 2020. The relationship between these parameters and demographic, social, psychological and health-related indices in these states was examined using both bivariate and multivariate analyses.

Results: COVID-19 prevalence was negatively associated with the sex ratio (defined as the number of females per 1000 male population) and positively associated with the presence of an international airport in a particular state, while COVID-19 crude mortality rate was negatively associated with the sex ratio and the state-wise burden of diarrhoeal disease, and positively associated with the state-wise burden of ischemic heart disease. On multivariate analyses, COVID-19 crude mortality rate was significantly and negatively associated with the sex ratio.

Conclusions: These results suggest that the transmission and impact of COVID-19 in a given population may be influenced by a number of variables, with demographic factors showing the most consistent association.

Key words: burden of disease, COVID-19, diarrheal disease, ischemic heart disease, population size, sex ratio

The relationship between demographic, psychosocial and health-related parameters and the impact of COVID-19: a study of twenty-four Indian states

Introduction

The global pandemic of acute respiratory illness caused by the novel betacoronavirus SARS-CoV-2, officially designated COVID-19, has emerged as perhaps the most significant health crisis of our times [1]. An unexpected observation in the context of this pandemic has been the existence of wide variations in the prevalence, mortality and case fatality rates across affected countries, which cannot be wholly explained on the basis of differences in the virulence of SARS-CoV-2 strains [2-5]. While some of this variation may reflect variations in health care and testing capacity across nations, it remains important to examine the role of other factors in causing this variability, particularly socioeconomic determinants of health [6, 7]. There is already evidence that social factors, such as perceived sociability, socioeconomic disadvantage, health literacy, trust in regulatory authorities, and the speed and stringency of measures instituted to control the spread of COVID-19, can crucially influence these variables [1, 2, 7]. These social factors interact with individual psychological responses to influence behaviour either positively or negatively: for example, an adaptive (“functional”) level of fear of COVID-19 was associated with better adherence to public health safety measures in an international sample of adults, while self-reported depression had the opposite effect [8]. Preliminary research has found that demographic and socioeconomic factors can influence variability in the spread and impact of COVID-19 not only between countries, but within a given country; in an ecological analysis of data from the United States, poverty, number of elderly people and population density were positively correlated with COVID-19 incidence and mortality rates [9].

At the time of writing this paper, India ranked third among all nations in terms of the total number of confirmed cases of COVID-19, behind the United States and Brazil, with over 3,000,000 cases reported as of August 25, 2020 [10]. Following the initial identification of 563 positive cases, the Indian government instituted a nation-wide lockdown for a period of 21 days, which began at midnight on March 24, 2020, and was gradually relaxed over the next two months [11]. Data from the initial phase of the lockdown suggested that this measure significantly reduced the transmission of COVID-19; however, this number rapidly increased in subsequent months. This rapid increase was not uniform: across the 32 states and territories of India, certain states have reported over 1,000 cases, while others have reported far lower numbers despite their geographical proximity to these states [12, 13].

Besides the demographic and socioeconomic variables discussed above, an important factor that may influence such variations in the Indian context is the availability and quality of health care. Health care facilities in India are unevenly distributed, with a significant urban-rural divide, and this inequality has been further exacerbated by the COVID-19 pandemic [14, 15].

Keeping the above in mind, an exploratory study was conducted to examine the relationship between demographic, socioeconomic and health-related indices and measures of the spread and impact of COVID-19 across the different states of India. These indices were drawn both from published research to date and from factors hypothesized to influence the spread and outcome of COVID-19.

Methods

COVID-19-related data. The current study was an exploratory, cross-sectional study based on data officially released by the Government of India. Information related to COVID-19 was obtained from the website of the Ministry of Health and Family Welfare, which provides information on the total number of cases, active cases, recovered cases and deaths for each state and territory of India and is updated every 24 hours [16]. Data for this study was recorded from the above source on June 30, 2020. Out of the 32 states and territories, only the 24 regions which reported at least 500 cases and one or more deaths were selected, to permit a meaningful computation of COVID-19-related indices.

After obtaining information on the population of each region from the Government of India's official census data, and verifying it against updated projections for 2020 from the Unique Identification Authority of India [17, 18], the following indices related to COVID-19 were calculated for each state:

- The estimated prevalence rate, defined as the total number of cases (active, recovered and deceased) per 1 million population
- The crude mortality rate, defined as the total number of reported deaths due to COVID-19 per 1 million population
- The case fatality rate, defined as the ratio of deaths to all cases with outcomes (death or recovery), expressed as a percentage.

Demographic information. Details on population per state were recorded using the census data cited above, as well as the updated population projections for the year 2020 provided by the Unique Identification Authority of India, while information on population density was obtained from the National Institution for Transforming India (NITI-Aayog), the Government of India's official source of data on demographic and socioeconomic variables [17-19]. As age and male sex have both been associated with mortality due to COVID-19, mean life expectancy for each state and sex ratio per state, defined as the number of females per 1000 male population, were obtained from the same source [9, 20].

Socioeconomic variables. Information on literacy rates and female literacy rates per state was obtained from official census data, while information on poverty, defined as the percentage of people living below the poverty line in each state, was obtained from the data published by the Ministry of Social Justice and Empowerment [21]. Information on indices related to law and order – state-wise rates of homicide, accident and rape – were obtained from the official statistics published in 2018 by the National Crime Records Bureau [22]. This information was included due to the proposed role of law enforcement, and adherence to it, in containing the spread of COVID-19 [2]. As international air travel has also been linked to the spread of COVID-19, information on which states had a functional international airport was obtained from the website of the Airports Authority of India [23, 24].

Health-related variables. Information on a number of general indices of health for each state – the maternal, infant, and under-five mortality rates and the percentage of children under 24 months who were fully immunized – was obtained from official NITI-Aayog data, which was updated for the fiscal year 2015-16. In addition, information on the percentage of disability-adjusted life years (DALY) for six common health conditions – diarrhoeal disease, lower respiratory infection, tuberculosis, diabetes mellitus, chronic obstructive pulmonary disease, and ischemic heart disease – was obtained from the official report on state-level disease burdens commissioned by the Department of Health Research, Ministry of Health and Family Welfare and published in 2017 [25]. These variables were studied due to the emerging evidence on the role of medical comorbidities in determining the outcome of COVID-19, as well as the hypothesized role of past infectious diseases in influencing the host immune response to SARS-CoV-2 [3, 26]. In view of the proposed relationship between depression and decreased adherence to public health measures, estimated state-wise prevalence rates of depression were obtained from the 2017 Global Burden of Disease Study [27].

A complete list of the data sources used in this study is provided in **Table 1** below.

Table 1: Official data sources used for the analyses in this study

Study variable	**Data source**	**Reference**
Total population per state	Census of India website Unique Identification Authority of India projections	[17, 18]
Population density per state Mortality indices per state	NITI Aayog	[19]
Literacy rates per state	Census of India website	[17]
Percentage living below the poverty line per state	Ministry of Social Justice and Empowerment website	[21]
Crime-related statistics	National Crime Records	[22]

per state	Bureau Report, 2018	
Presence of international airports in a given state	Airports Authority of India	[24]
Disease burden per state	India: Health of the Nation's States – The India State-level Disease Burden Initiative	[25]
Estimated prevalence of depression per state	Global Burden of Disease Study, Indian data	[27]
COVID-19 statistics	Ministry of Health and Family Welfare	[16]

Ethical issues. This study was based on an analysis of officially available data in the public domain and did not involve any human subjects. As per the Institute Ethics Committee guidelines of the author's institute, such analyses do not require formal approval by the committee.

Data analysis. Data was analyzed using the Statistical Package for Social Sciences, version 20 (SPSS 20.0, IBM Corporation). Prior to bivariate analysis, all study parameters were tested for normality. As the COVID-19 indices – prevalence, mortality and case fatality rate – were not normally distributed ($p < 0.01$ for all indices, Shapiro-Wilk test), Spearman's rank correlation coefficient (ρ) was used to test the hypothesis of a monotonic relationship between these indices and the aforementioned demographic, socio-economic and health-related indices. For the purpose of this study, a significance level of $P < .05$ was considered significant. This value carries with it a certain risk of maximizing the significance of marginal or potentially false-positive findings; however, given the exploratory nature of this study , it was adopted in order to avoid rejecting potentially significant associations on the basis of a more or less arbitrary cut-off value [28, 29].

To confirm the strength of these associations, multivariate linear regression was carried out for each of the individual COVID-19 indices. Only those variables which were associated with these indices at a significance of $P < .05$ or below in univariate or multivariate analyses were included in the multivariate analyses for each index.

Results

Data was obtained for 23 Indian states and one territory (Delhi) for the period up to June 30th, 2020. As of this date, 566,840 confirmed cases of COVID-19, and 17,337 deaths due to the disease, had been officially reported.The mean and standard deviation values of prevalence, crude mortality rate and case fatality rate for the entire sample were 504.13 (896.64) cases per 1 million population, 12.68 (30.03) deaths per 1 million population, and 2.77 (2.21) deaths per 100 cases. respectively. There was a wide range of variation in COVID-19 indices, with prevalence ranging from 61.25 (Jharkand) to 4440.03 (Delhi) per 1 million population, mortality ranging from 0.24 (Tripura) to 140.19 (Delhi) per 1 million population, and case fatality rate ranging from 0.09% (Tripura) to 7.9% (Maharashtra). (See Supplementary Table 1 for the complete details.)

Details of the correlations between the demographic, socio-economic, and health-related indices listed above and the COVID-19 indices are provided in **Table 2,** and are discussed further below. The raw data underlying all these analyses is available in the Supplementary File.

Table 2: Relationship between demographic, socio-economic, health-related and COVID-19 indices in 24 Indian states for the period ending June 30th, 2020

	COVID-19 estimated prevalence	COVID-19 crude mortality rate	COVID-19 case fatality ratio
Demographic indices			
Total population	ρ = -0.240 *P* = .257	ρ = 0.225 *P* = .289	**ρ = 0.526** ***P* = .009**
Population density	ρ = -0.129 *P* = .565	ρ = -0.051 *P* = .821	ρ = 0.092 *P* = .683
Sex ratio	**ρ = -0.571**	**ρ = -0.517**	ρ = -0.369

	***P* = .008**	***P* = .017**	*P* = .101
Indices of human development			
Life expectancy	**ρ = 0.469** ***P* = .032**	**ρ = 0.489** ***P* = .024**	ρ = 0.230 *P* = .316
Percentage living below the poverty line	**ρ = -0.466** ***P* = .035**	ρ = -0.418 *P* = .060	ρ = -0.251 *P* = .272
Literacy rate	**ρ = 0.453** ***P* = .031**	ρ = 0.155 *P* = .478	ρ = -0.030 *P* = .894
Indices of law and order			
Homicide rate	ρ = -0.171 *P* = .425	ρ = -0.313 *P* = .137	ρ = -0.364 *P* = .080
Rape rate	ρ = -0.044 *P* = .840	ρ = -0.052 *P* = .808	ρ = -0.149 *P* = .488
Accidental death rate	ρ = -0.350 *P* = .102	ρ = -0.309 *P* = .151	ρ = -0.149 *P* = .488
Health indicators			
Maternal mortality rate	ρ = 0.353 *P* = .150	**ρ = -0.499** ***P* = .035**	ρ = -0.330 *P* = .181
Infant mortality rate	**ρ = -0.474** ***P* = .019**	ρ = -0.276 *P* = .192	ρ = -0.090 *P* = .675
Under-5 mortality rate	ρ = -0.406 *P* = .084	**ρ = -0.476** ***P* = .040**	ρ = -0.304 *P* = .206
DALY, diarrhoeal	**ρ = -0.563**	**ρ = -0.500**	ρ = -0.259

disease	***P* = .004**	***P* = .013**	*P* = .222
	ρ = -0.224	ρ = 0.024	ρ = 0.121
DALY, tuberculosis	*P* = .293	*P* = .911	*P* = .574
DALY, chronic	ρ = 0.225	ρ = 0.262	ρ = 0.295
obstructive	*P* = .290	*P* = .217	*P* = .162
pulmonary disease			
	ρ = -0.338	ρ = -0.256	ρ = -0.135
DALY, lower	*P* = .106	*P* = .227	*P* = .529
respiratory tract			
infection	ρ = 0.348	ρ = 0.244	ρ = 0.173
	P = .157	*P* = .328	*P* = .492
DALY, diabetes			
mellitus	**ρ = 0.476**	**ρ = 0.535**	ρ = 0.367
	***P* = .019**	***P* = .007**	*P* = .078
DALY, ischemic	ρ = -0.116	ρ = 0.030	ρ = 0.125
heart disease	*P* = .598	*P* = .891	*P* = .570
	ρ = 0.373	ρ = 0.176	ρ = 0.006
DALY, iron	*P* = .088	*P* = .433	*P* = .980
deficiency anemia	ρ = 0.261	ρ = 0.090	ρ = 0.020
Depression,	*P* = 0.218	*P* = .674	*P* = .926
estimated prevalence			
Suicide rate			

Key: COVID-19, novel coronavirus disease 2019; DALY, disability-adjusted life years; ρ, Spearman's rank correlation coefficient. Values significant at $P < .05$ are indicated in **bold**.

Relationship between demographic variables and COVID-19 indices ***(Table 2, row 1)***. COVID-19 prevalence for each region was significantly and negatively correlated with the sex ratio at *P* < .01 and was positively associated with life expectancy at *P* < .05. Crude mortality rate was positively correlated with life expectancy and negatively correlated with the sex ratio at *P* < .05. In contrast, the case fatality rate was significantly correlated with the total population of each region at *P* < .01.

Relationship between socioeconomic variables and COVID-19 indices ***(Table 2, row 2)***. The prevalence of COVID-19 showed a positive association with the life expectancy and literacy rate, and a negative trend-level association with the percentage of people living below the poverty line, all at *P* < .05. No significant correlations were observed between COVID-19 mortality and case fatality rates and any socioeconomic parameter, though a negative association of marginal significance was observed between the percentage of individuals living below the poverty line and the crude mortality rate (*P* = .06). As the presence or absence of an international airport was a dichotomous variable and the COVID-19 indices were not normally distributed, the Mann-Whitney *U* test was used to compare these indices. States with an international airport had a significantly higher estimated COVID-19 prevalence (Mann-Whitney *U* = 118.0, *P* = .007) but did not differ significantly in terms of mortality or case fatality. None of the putative indices of law and order were significantly associated with any COVID-19 parameters.

Relationship between health-related variables and COVID-19 indices ***(Table 3, row 3)***. COVID-19 prevalence was significantly and negatively correlated with the burden of diarrheal disease per state at *P* < .01 and the maternal mortality rate at *P* < .05 , and was positively associated with the burden of ischemic heart disease at *P* < .05. In contrast, the mortality rate showed a significant positive correlation with the burden of ischemic heart disease at *P* < .01, and was negatively associated with the maternal mortality rate, under-five mortality rate, and burden of diarrheal disease at *P* < .05.

None of the health-related variables were significantly associated with the case fatality rate. The two indices of mental health – state-wise suicide rate and estimated prevalence of depression – were not significantly related to any COVID-19 indices, though a marginal positive association with estimated prevalence was found for the prevalence of depression (*P* = .088).

Multivariate analyses. All variables that were significantly associated with COVID-19 indices at a significance level of *P* < .05 or lower were selected for multivariate linear regression analyses. For COVID-19 estimated prevalence, these variables were sex ratio, life expectancy, percentage of the population living below the poverty line, literacy rate, infant mortality rate, and DALYs due to diarrheal disease and ischemic heart disease. The final model explained only 8% of the variance in prevalence (adjusted R^2 = 0.080), and analysis of variance yielded an *F* value of 1.248 (df = 13), with a significance of *P* = .346, suggesting that the null hypothesis should be retained. None of the individual variables were significantly associated with COVID-19 prevalence in this model.

For the COVID-19 crude mortality rate, the variables entered in the model were with the sex ratio, life expectancy, maternal mortality rate, under-5 mortality rate, and DALYs due to diarrheal disease and ischemic heart disease. The final model explained 20.4% of the variance in crude mortality rate (adjusted R^2 = 0.204) and analysis of variance yielded an *F* value of 1.682 (*P* = .223), again suggesting that the null hypothesis should be retained. However, among individual variables, sex ratio remained remained significantly and negatively associated with this variable (t = -2.361, *P* = .04).

As only a single study variable, namely the population size, was associated with the case fatality ratio, multivariate analyses were not carried out in this case.

Discussion

The results of this preliminary analysis found that certain demographic, socioeconomic and health-related variables were significantly related to the variability in COVID-19 prevalence, mortality and case fatality rates across 24 different regions of India. In particular, COVID-19 prevalence was associated with the sex ratio and the burden of diarrheal disease as measured by the percentage of DALYs associated with this disorder, as well as with the presence of an international airport in a given State; COVID-19 mortality was associated with the burden of ischemic heart disease; and COVID-19 case fatality rate was associated with the total population of each region. On multivariate analysis, only the negative association between the sex ratio and COVID-19 prevalence and mortality remained significant.

The association between the sex ratio and measures of the impact of COVID-19 is in line with existing research findings. Several clinical case series, both from India and other countries, have reported a preponderance of male patients in hospitalized samples, as well as a link between male sex and mortality due to COVID-19 [30-33]. This phenomenon may be partly explained by sex differences in the immune and inflammatory response to SARS-CoV-2 infection [18]. However, in the Indian context, this relationship could also be influenced by traditionally-defined gender roles. These are associated with comparatively greater freedom of movement for men, which places them at a higher risk of exposure to infection [34, 35]. The association between the presence of an international airport and the state-wise prevalence of COVID-19 is also in line with earlier evidence highlighting the role of international air travel in the transmission of SARS-CoV-2 across nations [23].

Similarly, the link between state-wide differences in the burden of ischemic heart disease and mortality due to COVID-19 is supported by clinical research, which has found an association between the presence of ischemic heart disease and the severity of COVID-19 [36, 37]. Moreover, ischemic heart disease is commonly associated with other medical conditions, such as systemic hypertension and chronic renal disease, which themselves worsen the outcome of COVID-19, and COVID-19 has been documented to trigger myocardial injury in patients with pre-existing coronary artery disease [38, 39]. No such significant association was found in this study for other medical comorbidities, such as diabetes mellitus or chronic obstructive pulmonary disease. However, such comorbidities have been associated with worse COVID-19 outcomes in clinical samples [37, 38]; the failure of this study to confirm this association reflects the limitations inherent in an ecological approach.

Though this could not be confirmed by multivariate analysis, population was positively correlated with the case fatality rate across the different regions of India. This association does not appear to be mediated solely by over-crowding, as no significant association was found between population density and case fatality. A possible explanation for this finding is the unequal distribution and accessibility of healthcare facilities in India, particularly in areas areas which have a high total population but a relatively low population density, with limited availability of facilities for testing and treatment in non-urbanized regions [40, 41]. Such inequalities may lead to delays in obtaining appropriate treatment [42].

The negative association found between the burden of diarrheal disease and the prevalence of COVID-19 across regions is an unexpected finding, as no such association was found for respiratory diseases such as lower respiratory infection ($\rho = -0.227$, $P = 0.256$) or pulmonary tuberculosis ($\rho = 0.024$, $P = 0.911$). While it has been postulated that prior exposure to respiratory coronaviruses may moderate the impact of SARS-CoV-2 infection, no such association has been suggested or demonstrated thus far for gastrointestinal infections [3]. However, *in vitro* research has shown that intestinal replication may contribute to the progression of SARS-CoV-2 infection; therefore, it is possible that prior intestinal viral infections, which are a common cause of diarrheal disease, could influence this process [43]. Alternately, this association may be related to behavioural factors, such as reduced population mobility in those with pre-existing gastrointestinal disorders minimizing exposure to SARS-CoV-2, or improved adherence to hand hygiene in those who have experienced prior episodes of diarrheal disease. Finally, this may be a false-positive finding arising from the exploratory nature of the analyses conducted. Though the biological mechanism advanced above has some support in theory, it can neither be confirmed nor disproved using the ecological methods of analysis adopted in this study. [44, 45].

A number of other associations were observed at a trend level. While the direction of these associations was unexpected in some cases – such as a positive association between COVID-19 prevalence and literacy, and a negative association between COVID-19 and levels of poverty and maternal and under-five mortality rates – these findings must be interpreted with caution, owing to their low statistical significance and the large number of potential confounding factors, as well as the possibility of type I error.

The results of this study must be viewed in the light of certain limitations. First, data on demographic, socioeconomic and health-related was obtained from official Government statistics and populations which preceded the onset of the COVID-19 outbreak by a period of three to six years. Therefore, some of this information may not accurately reflect the contemporary situation in the different states of India. Second, this study did not take into account other factors that could influence the spread of COVID-19, such as cultural norms and practices, local variations in climate and temperature, and the efficiency of implementation of quarantine and related measures [1, 2]. Third, the data analysis did not take into account the confounding effects of other variables on the bivariate analyses. Fourth, due to logistic and manpower constraints on testing and case finding, the officially reported statistics on COVID-19 may underestimate the true scope of this problem in India [6, 13]. Finally, owing to the cross-sectional nature of this study, it was not possible to assess the relationship between the study variables and trends in the spread of COVID-19, such as the rate of increase in the number of cases.

In conclusion, the results of this study, though limited by the nature of the exploratory analyses and the study design itself, suggest that some of the factors that have been found to influence the outcome of COVID-19 at a clinical level, such as male sex and comorbid ischemic heart disease, also have an impact at the population level. Other unexpected findings, such as the link between population and case fatality and between diarrheal disease burden and COVID-19 prevalence, may represent potential behavioral, socioeconomic or biological mechanisms that require further elucidation. Though these results may be considered preliminary, they may aid future researchers in studying some of the specific associations found in this study in more depth, and in understanding the advantages and limitations of the approach adopted in this paper. Moreover, despite their limitations, they illustrate the value of ecological analyses in understanding the COVID-19 pandemic, particularly in situations where direct clinical or epidemiological research is not feasible due to safety measures. Ecological analyses can be carried out relatively rapidly and safely in this setting, and the tentative associations observed using this method can be subject to more rigorous analyses in field settings to confirm or refute their validity. Further longitudinal research with more sophisticated statistical modelling and up-to-date data may clarify the role of these and other demographic, socioeconomic and health-related variables in moderating the impact of COVID-19 within nations, and may inform future strategies to curtail the impact of this pandemic.

Data availability statement:

All data used in this study was obtained from public domain data sources cited and referenced in the paper **(Table 1)**. A complete data set is available as a Supplementary File.

Declaration of conflicts of interest:

The author declares no potential conflicts of interest with respect to the research, analysis, authorship or publication of this article.

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Supplementary Files

Multimedia Appendixes

Complete data set as requested by the Editor.
URL: https://asset.jmir.pub/assets/a8c07172c9cbf83f57d2ba4088a889b8.xls