ABSTRACT

Background: Early reports on coronavirus disease 2019 (COVID-19) case fatalities in India suggest that males are at a greater disadvantage than females, but it is unclear whether males experience a higher risk of mortality throughout the age-spectrum or there are sex-differentials in survival risk. We adopt a gender lens and present a disaggregated view of age-sex specific COVID-19 infection and mortality risk in India.

Methods: We use crowdsourced data (https://www.covid19india.org/) to provide preliminary estimates for age-sex specific COVID-19 case fatality rate (CFR) for India. We analyse the burden of the cases and deaths for age-sex categories. CFR is estimated as the ratio of confirmed deaths in total confirmed cases. We report binomial confidence interval for the CFR estimates. Also, an adjusted-CFR is developed to capture the potential mortality among the currently active infections.

Results: As of May 20, 2020, males share a higher burden (66%) of COVID-19 infections than females (34%) but the infection is more or less evenly distributed in under-five as well as elderly age groups. The CFR among males and females is 2.9% and 3.3%, respectively. The age-specific COVID-19 CFR assumes ‘Nike-swoosh’ pattern with elevated risks among the elderly. The World Health Organization world standard population structure standardized CFR for India is 3.34%. The adjusted-CFR is estimated to be 4.8%.

Conclusion: Early evidence indicates that males have higher overall burden, but females have a higher relative-risk of COVID-19 mortality in India. Elderly males and females both display high mortality risk and require special care when infected. Greater focus on data collection and sharing of age-sex specific COVID-19 cases and mortality data is necessary to develop robust estimates of COVID-19 case fatality to support policy decisions.

Keywords: COVID-19; Case fatality rate; Gender difference; Elderly; India
INTRODUCTION

In India, the first case of coronavirus disease 2019 (COVID-19) was detected on Jan 30, 2020. Until Mar 1, 2020, India had only three confirmed cases but ever since the contagious infection has grown exponentially. As of May 21, 2020, with over 112,000 cases India accounts for 11th highest share of 2.24% in global burden of COVID-19. India also reports over 3400 COVID-19 deaths and accounts for 1.05% of the COVID-19 deaths worldwide. Meanwhile, the policy response to COVID-19 has revolved around an all-encompassing nationwide lockdown that helped curb the COVID-19 outbreak in the initial phases. But, sooner rather than later, lockdown would be relaxed leading to greater exposure to the virus. In fact, with no vaccine or (validated) cure in sight, the fate of all individuals remains as good as their immune systems. Clearly, further evidence and insights on infection risks and survival chances of this novel infection assumes salience for all individual and policy decisions.

In this regard, the concept of case fatality rate (CFR) has considerable relevance and can provide much needed inferences regarding survival patterns. With an ongoing epidemic, the CFR is best described as a dynamic rate and is defined as the percentage of confirmed deaths in total confirmed cases. For instance, during mid-April the Ministry of Health and Family Welfare reports a CFR of 3.3% for India. Nevertheless, there is increasing evidence that the COVID-19 survival chances are sensitive to age-pattern and other co-morbidity conditions of the infected population. In particular, early evidence from China and Italy reveal a steep age gradient in risk of death and can vary across contexts. For instance, based on the cases observed till April 20, 2020, a recent study estimates an overall COVID-19 CFR of 3.2% for India. The study finds CFR of 14.3% for those aged 60 and above whereas the mortality risk is found to be much lower (below 1%) among the younger population (aged below 25 years). Although, the age-group classifications are too broad, but these provide insights regarding variations in survival experience of children (or the older elderly), the young adult and the elderly (60+ years). Besides, with evolving nature of the pandemic and increasing number of cases it is critical to track the CFR with all available information and add to our understanding on COVID-19 mortality risk among infected children and elderly population in India.

An important concern here is to examine the overall as well as age-specific COVID-19 infection and mortality risk from a gender lens. Preliminary evidence from various countries suggests that men are at greater risk of both infections and deaths, but these inferences should be carefully interpreted. The early reports of COVID-19 cases and deaths in India suggests that males are at a greater disadvantage than females with CFR of 3.3% and 2.9%, respectively. However, it is unclear whether males experience a higher risk of mortality throughout the age-spectrum or there is sex-differentials in survival risk. It is argued that pre-existing conditions, behavioural risk factors (smoking) and biological factors all elevate the risk of mortality among males but these patterns need to be verified with new and emerging information on COVID-19 outbreak in India.

A related concern is regarding the distinction between sex-specific burden and risk of COVID-19 deaths in India. Overall, it is noted that more men than women are infected with COVID-19 and are also more likely to die from the infection. Some of the early estimates from the Ministry of Health and Family Welfare indicated that three-fourth of all confirmed cases are males. But it is important to disaggregate the burden to understand whether the inference is valid for children as well as the elderly age group. In fact, bulk of the evidence on age-sex patterns in COVID-19 mortality has focused on adults and the elderly but very little is known...
about the age-sex specific relative risks and patterns of COVID-19 mortality, particularly for populous and resource-poor settings such as India. Understanding the risks for children and women is also critical because of widespread poverty and undernourishment which is likely to weaken immunity against infectious diseases. The issue assumes relevance for India because of large young population and also because of health system deficiencies and ongoing economic slowdown. Against this backdrop, the main objective of the paper is to present an age-sex disaggregated assessment of COVID-19 cases and COVID-19 deaths in India. The analysis specifically aims to draw attention toward analysis and interpretation of the two distinct concepts of burden and risk of COVID-19 cases and deaths in India. The analysis is expected to provide a first set of estimates for age-sex specific CFR and emphasises on presenting an accurate interpretation of the differentials in sex-specific risk and burden of COVID-19 infections and fatalities in India.

**METHODS**

The analysis is based on the crowdsourced data on COVID-19 cases in India publicly available for download at [https://www.covid19india.org/](https://www.covid19india.org/). The website provides information on time-series of cumulative and daily numbers of COVID-19 cases, recoveries and deaths. The information on these indicators is consistent with the official estimates provided by the Ministry of Health and Family Welfare as well as other international online databases on COVID-19 such as [https://coronavirus.jhu.edu/map.html](https://coronavirus.jhu.edu/map.html) from the Johns Hopkins University and Medicine or the [https://ourworldindata.org/coronavirus](https://ourworldindata.org/coronavirus). Unit level information of cases by age and sex is also provided. The main analysis is based on the COVID-19 infections and deaths data available till May 20, 2020. However, given the exponential growth in cases and the need to confirm robustness of estimates, we also conduct sensitivity analysis and track COVID-19 infections and deaths at 4 different time points: April 10, May 1, May 9, and May 20, 2020. These time points reflect 4 different phases of nationwide lockdown as follows: Phase 1 (Mar 24 to Apr 14, 2020), Phase 2 (April 15 to May 3, 2020), Phase 3 (May 4 to May 17, 2020), and ongoing Phase 4 (May 18 to May 31, 2020). This helps verify the consistency in the distribution of reported cases of COVID-19 infections and deaths by age-sex specifics. Also, it helps understand the dynamics of CFR estimates up to the most recent data point and base the inferences on cumulative observations. Specifically, for April 10, May 1, May 9, and May 20, 2020 we have reports on 1,160, 3,384, 6,914, and 15,341 number of COVID-19 cases and 127, 316, 507, and 569 number of COVID-19 deaths, respectively. During these dates the total (including those with missing age-sex information) cumulative number of confirmed cases were 7,618, 37,257, 67,161, and 112,027 whereas the cumulative number of confirmed deaths were 249, 1,223, 2,212, and 3,433, respectively. The distribution of missing and reported cases is presented as [Supplementary Table 1](https://doi.org/10.35500/jghs.2020.2.e17). Since the individual-level age-sex information is not available for all the confirmed cases, therefore, for analytical purposes we apply the standard assumption that the age-sex distribution of the cases with missing information is similar to the age-sex distribution of the reported cases. We use the data to describe the growth in COVID-19 infections using a curve-fitting exercise using the curvefit module of Stata (StataCorp LLC, College Station, TX, USA).

The CFR is estimated as the ratio of confirmed deaths in total confirmed cases and denotes the risk of mortality from COVID-19 infection. The CFR is estimated for males and females for overall and for 9 age-groups as follows: 0–4 years, 5–19 years, 20–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, 70–79 years, and 80+ years. We report the Binomial 95%
confidence interval (CI) for the CFR estimates. Further, we analyse the burden of the cases and deaths. The burden of cases or death is defined as the number of cases or deaths of a particular sex (male or female) in total deaths (both sexes). This can also be defined as share of a particular age-group in total number of cases or deaths. The burden of cases or death for males and females is defined as total share of a particular age-group of given sex in total number of cases or deaths for that particular sex. Moreover, a further standardization is necessary to improve the interpretation of the CFR if these were applicable to the entire country. For this purpose, we develop the population standardized CFR estimate for India. The standardization is based on the World Health Organization (WHO) world standard population distribution.21

The CFR, nevertheless, encounters two specific concerns: first, if the epidemic is still ongoing, then the estimate of CFR may vary because the probability of death among currently active cases is likely to be non-zero, and; second, it is critical that the CFR accounts for the risk of mortality among the currently active cases. Although, there are methods22 to adjust CFR for this censored period but there are considerable data gaps in India to understand the duration since onset of infection and final status (deceased or recovered). Accordingly, we propose an alternative definition of adjusted CFR as follows: CFR* = θ(1 + α); where, θ denotes conventional CFR i.e., the ratio of total deaths to total cases (Dt/Ct) and α denotes the ratio of active cases to total cases (At/Ct). The CFR inflation factor assumes that the active cases will also experience similar relative probabilities of death and recoveries.22 As the epidemic ends, the active cases would gradually reduce to zero (α=0) and accordingly CFR* would approach the true CFR. Taken together, CFR and CFR* provides a reasonable estimate and the trends in CFR and CFR* converge at the end of the epidemic to reveal the final CFR.

RESULTS

COVID-19 cases and growth
As of May 20, 2020, India reports more than 112,000 confirmed COVID-19 infections. Since March 24, 2020, India is under lockdown (in four different phases) with varying intensity and restrictions across regions depending on the COVID-19 outbreak situation. A curve-fitting exercise reveals that since March 1, 2020, COVID-19 outbreak has witnessed an exponential growth of 6.4% per day. The exponential growth was the highest at 12.9% during the first phase of lockdown (March 24 to April 14, 2020) but has declined to 6.5% and 5.4% during the second (April 15 to May 3, 2020), and third (May 4 to May 17, 2020) phase, respectively. The reduced growth rate, nevertheless, gets translated into large and ever-increasing number of infections per day. The geo-spatial dispersion of COVID-19 is also an emerging concern. Two important aspects of the spread are: i) heavy concentration in western India (major urban centres) and ii) increasing transmission to Eastern India. It is noted that more than 60% of the COVID-19 cases are concentrated in five cities namely Ahmedabad, Chennai, Delhi, Mumbai, and Thane. In India the progress of the epidemic is also monitored through concepts such as doubling time. It is worth noting that the COVID-19 cases in India doubled from 1,019 to 2,059 in 4 days (March 29 to April 1, 2020) whereas it took 11 days (April 23 to May 3, 2020) for a 2-fold increase in cases from 21,373 to 42,546 and 13 days (May 5 to May 18, 2020) to increase from 49,405 to 100,327.

Burden of COVID-19 infections and deaths
Table 1 presents the absolute burden of male and female in total COVID-19 infections and deaths for overall cases as well as for specific age-groups. Overall, females have 34.3% share
in total burden of COVID-19 infections. The burden is more or less similar among under-five boys (51.5%) and girls (48.5%). The burden increases among males in middle age group and reaches a maximum of 70.4% for the age group 30–39 years (Fig. 1). Thereafter, the share of females in total burden increases with age. The burden among females is over 40% for the age groups 70–79 years and 80+ years.

The burden of females in total COVID-19 deaths is 36.9%. It may be noted that the absolute burden of deaths among females is higher than males than the absolute burden among females in total number of infections. The difference in female burden in infections and deaths is 2.6% and is statistically significant ($P$-value = 0.001). Females in the age group 30–39 years have lowest burden of death (21.3%) whereas elderly females in the age group 80+ years have more or similar burden (48.5%) in total death for this particular age group. Although, females share a lower mortality burden than males in general but there is no reported case of male mortality in the age group 5–19 years hence the entire burden is borne by females.

### Table 1. Sex-specific absolute burden of COVID-19 infections and deaths by age groups, India, May 20, 2020

<table>
<thead>
<tr>
<th>Age group</th>
<th>Cases (% Share)</th>
<th></th>
<th>Deaths (% Share)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 4 years</td>
<td>Male 51.5</td>
<td>Female 48.5</td>
<td>Total 100.0</td>
<td>Male 64.9</td>
</tr>
<tr>
<td>5 to 19 years</td>
<td>Male 60.3</td>
<td>Female 39.7</td>
<td>Total 100.0</td>
<td>Male 0.0</td>
</tr>
<tr>
<td>20 to 29 years</td>
<td>Male 65.1</td>
<td>Female 34.9</td>
<td>Total 100.0</td>
<td>Male 64.9</td>
</tr>
<tr>
<td>30 to 39 years</td>
<td>Male 70.4</td>
<td>Female 29.6</td>
<td>Total 100.0</td>
<td>Male 78.7</td>
</tr>
<tr>
<td>40 to 49 years</td>
<td>Male 68.3</td>
<td>Female 31.7</td>
<td>Total 100.0</td>
<td>Male 58.4</td>
</tr>
<tr>
<td>50 to 59 years</td>
<td>Male 66.5</td>
<td>Female 33.5</td>
<td>Total 100.0</td>
<td>Male 68.4</td>
</tr>
<tr>
<td>60 to 69 years</td>
<td>Male 63.3</td>
<td>Female 36.7</td>
<td>Total 100.0</td>
<td>Male 64.7</td>
</tr>
<tr>
<td>70 to 79 years</td>
<td>Male 54.5</td>
<td>Female 45.5</td>
<td>Total 100.0</td>
<td>Male 57.6</td>
</tr>
<tr>
<td>80+ years</td>
<td>Male 56.6</td>
<td>Female 43.4</td>
<td>Total 100.0</td>
<td>Male 51.4</td>
</tr>
<tr>
<td>All</td>
<td>Male 65.7</td>
<td>Female 34.3</td>
<td>Total 100.0</td>
<td>Male 63.1</td>
</tr>
</tbody>
</table>

Source: Authors based on https://www.covid19india.org/ (accessed on May 20, 2020).

*Note:* Denotes cumulative number of confirmed cases and deaths as on May 20, 2020. The age-sex distribution is based on the assumption that the cases with missing information have similar age-sex distribution as of the reported cases.

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**Fig. 1.** Male and female share in total burden of COVID-19 cases and deaths in India, May 20, 2020. Estimated burden is based on the assumption that the age-sex distribution of the cases with missing information is similar to the age-sex distribution of the reported cases. Source: Authors based on https://www.covid19india.org/ (accessed on May 20, 2020).

Table 2 presents the age-specific relative burden in infections and deaths among males and females as well as for the combined cases. As per the data till May 20, 2020, Children and adolescents (below age 20 years) account for 13.8% share in total COVID-19 infections but have relatively lower burden of 2.1% in total COVID-19 deaths (Fig. 2). Elderly aged (60 and above) although account for 9.7% share in total infection but they account for 51.6% share in total deaths. Table 2 further shows that the age-specific relative burden in deaths among males aged 60 years is 50.7% whereas the same is 54.5% among females. The population in the age group 20–59 years have a higher relative burden of 76.4% in total cases but...
account for 46.4% share in total deaths. The relative burden of total cases is higher among the middle-aged population but the relative burden in deaths is mostly borne by the elderly population. Sensitivity analysis based on the sex-specific burden in total infections and deaths in India at four different time points shows that the share of females in total infections and deaths has been increasing since April onwards (Supplementary Table 2).

**CFR and relative risk of COVID-19 deaths**

As of May 20, 2020, the CFR for India is estimated to be 3.1% (95% CI, 3.0%–3.2%) (Table 3). With an ongoing epidemic, the CFR becomes a dynamic statistic and has to be closely monitored to understand its evolution along with the increasing number of COVID-19 infections and deaths. Therefore, as a sensitivity analysis, we also estimated CFR at four different points in time: April 10, May 1, May 9, and May 20, 2020. During these four time points, the CFR has declined from 3.3% to 3.1% (Supplementary Table 3).

The age-specific CFR for India presumes a ‘Nike-Swoosh’ pattern with high risk of mortality for under-five children, lower risks among adolescents and young adults and then increasing risks for older adults and elderly (Fig. 3). The CFR is much higher for all infected elderly but with particularly elevated mortality risk of over 20% for those aged 70 and above. An important observation from age-specific temporal comparison is that COVID-19 among elderly is more fatal than what was revealed through some of the early estimates. For instance, April 10, 2020 data reveals an adjusted CFR of 8.9%, 12.1%, and 22.4% among those aged 60–69 years, 70–79 years and 80+ years. Whereas, the May 20, 2020 data shows CFR of 14.3%, 20.1%, and 22.2% for these age groups, respectively (Supplementary Table 3).

As of May 20, 2020, the CFR for males and females is estimated to be 2.9% (95% CI, 2.8%–3.1%) and 3.3% (95% CI, 3.1%–3.5%), respectively, indicating a relatively higher risk of death among females. The difference in overall male and female CFR is also found to be significant ($P$-value = 0.001). Fig. 3 displays age-specific CFR pattern for males and females. The CFR among males is usually higher than females for most of the age groups. Male and female CFR also have distinct patterns with greater disadvantage for male survival in under-five as well as in older age groups (Supplementary Figs. 1-4). Females have higher risk of mortality in the age group 40–49 years ($P$-value = 0.000) and this leads to a marginally higher overall risk of COVID-19 mortality for females. The difference is found to be statistically significant (at 5% level) only for three age groups (5–19 years, 30–39 years, and 40–49 years). Further

<table>
<thead>
<tr>
<th>Age group</th>
<th>Males</th>
<th>Females</th>
<th>Both sexes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 4 years</td>
<td>1.9 (1.2–2.8)</td>
<td>1.1 (1.6–3.4)</td>
<td>1.7 (1.2–2.3)</td>
</tr>
<tr>
<td>5 to 19 years</td>
<td>-</td>
<td>0.6 (0.4–0.8)</td>
<td>0.2 (0.1–0.3)</td>
</tr>
<tr>
<td>20 to 29 years</td>
<td>0.3 (0.2–0.4)</td>
<td>0.3 (0.2–0.4)</td>
<td>0.3 (0.2–0.3)</td>
</tr>
<tr>
<td>30 to 39 years</td>
<td>0.6 (0.5–0.8)</td>
<td>0.4 (0.3–0.6)</td>
<td>0.6 (0.5–0.7)</td>
</tr>
<tr>
<td>40 to 49 years</td>
<td>2.1 (1.8–2.3)</td>
<td>3.2 (2.8–3.7)</td>
<td>2.4 (2.2–2.6)</td>
</tr>
<tr>
<td>50 to 59 years</td>
<td>6.7 (6.2–7.3)</td>
<td>6.2 (5.5–6.9)</td>
<td>6.6 (6.2–7.0)</td>
</tr>
<tr>
<td>60 to 69 years</td>
<td>14.5 (13.5–15.5)</td>
<td>13.6 (12.4–14.9)</td>
<td>14.3 (13.5–15.1)</td>
</tr>
<tr>
<td>70 to 79 years</td>
<td>21.1 (18.9–23.3)</td>
<td>18.6 (16.4–20.1)</td>
<td>20.1 (18.6–21.7)</td>
</tr>
<tr>
<td>80+ years</td>
<td>20.5 (16.9–24.5)</td>
<td>25.3 (20.8–30.2)</td>
<td>22.2 (19.3–25.3)</td>
</tr>
<tr>
<td>All</td>
<td>2.9 (2.8–3.1)</td>
<td>3.3 (3.1–3.5)</td>
<td>3.1 (3.0–3.2)</td>
</tr>
</tbody>
</table>

The WHO world standard population age-sex structure based standardized CFR estimated for May 20, 2020 is 3.34%. The estimated burden is based on the assumption that the age-sex distribution of the cases with missing information is similar to the age-sex distribution of the reported cases. Values are presented as CFR with 95% confidence interval. Source: Authors based on https://www.covid19india.org/ (accessed on May 21, 2020). COVID-19 = coronavirus disease 2019; CFR = case fatality rate.
standardization as per the population age-structure is necessary to interpret the CFR. For this purpose, we use the WHO world standard population structure and find a standardized CFR of 3.34% for all-India.

**Adjusting the CFR for active infections (CFR*)**

When an epidemic is underway, the CFR presents an incomplete assessment of the currently active infections as it is only after a certain number of days that these censored cases will be ultimately categorized into recoveries or deaths. **Figure 4** presents the trends in CFR as well as the adjusted-CFR estimate (CFR*) that accounts for the potential risk of death among the
currently active cases. The adjustment is done by inflating the CFR by a factor that assumes that the active cases of COVID-19 will also experience the same risk of death as the current known level of CFR. As of May 20, 2020, the CFR for India is 3.1% but in comparison, the CFR* for India is estimated to be 4.8%. Unless there is a dramatic fluctuation in the number of infections and deaths, the CFR and CFR* reflect a reasonable range for estimate COVID-19 mortality in India.

DISCUSSION

The analysis puts forth four salient inferences as follows. First, while males have a higher overall burden (66%) of COVID-19 infections than females, but the infection is evenly distributed in the under-five age group and, to some extent, even among the elderly age groups (particularly 70+ years). Second, the COVID-19 CFR assumes a ‘Nike-swoosh’ type age-specific mortality pattern in India with particularly elevated risk of mortality among the elderly population. The pattern is evident so far but may further evolve as more and new data is accumulated. Third, although males share a higher burden of death but at the same time it is important to note that females have relatively high risk of COVID-19 death. The data reveals that the overall CFR among males is 2.9% but the same is significantly ($P$-value = 0.001) higher among females (3.3%). In particular, the difference in male and female CFR in the middle age groups is statistically significant ($P$-value = 0.000) indicating greater caution for females in the age group 40–49 years. Finally, the CFR for India is likely to increase because of a large number of active infections. In fact, the adjusted CFR* as of May 20, 2020 that accounts for potential mortality among the currently active cases is estimated to be 4.8%

The WHO world standard population based adjusted estimate of CFR for India is estimated to be 3.3%. It is important that for international comparisons the WHO world standard population is used because countries vary substantially in their population age-structure. Countries with aging population, in particular, are likely to have high CFR whereas those with higher share of young population may have low CFR but both set of estimates should be standardized to facilitate comparisons.

The study has 2 key limitations. First, the analysis is based on crowdsourced data with considerable gaps in reporting of age-sex specific information of all the COVID-19 infections and deaths. To overcome this, we assume that the distribution of missing cases follows the same distribution as of the reported cases. Our estimate of age-sex specific CFR is sensitive to this assumption. However, as sensitivity check we have conducted this analysis at various time points and have noted consistent findings regarding the age-sex CFR patterns indicating that the assumption is reasonable. Second, the number of confirmed cases in India depends upon the testing facility and capture of the data. Although, testing frequencies, data capture and sharing on age-sex specificities of the COVID-19 cases has been inadequate but data cumulation has allowed much needed robustness for CFR estimations. However, it is likely that the estimates may further evolve with greater availability of data.

The gendered impacts of COVID-19 outbreak need to be effectively analysed for potential public health and policy inferences. The analysis reveals that while the overall burden of COVID-19 is higher among men but it is important to note that females are at an overall higher relative risk of mortality. This finding calls for equal, if not greater, attention toward females for COVID-19 care. In the under-five age group as well as elderly age group particularly, those aged 70+ years the risk of COVID-19 death is more or less similar for
both males and females. Evidence from China also indicates that there is no significant sex difference in risk of COVID-19 infection among children.\textsuperscript{25} Also, further data and insights are necessary to understand whether the excess risk for males and females are associated with socioeconomic circumstances, gender bias in care-seeking or specific biological characteristics. For instance, it is argued that female hormones, specifically estrogen, has a beneficial effect on upper and lower airways and is associated with stimulation of the immune response to upper airway infections.\textsuperscript{26} The reduction in estrogen in menopausal and elderly age group may also be responsible for increase in the relative risk of death among females in the age group 40+ years onwards.\textsuperscript{28} However, evidence from developed countries such as Italy and United States confirms a higher CFR among males.\textsuperscript{24,26} A higher risk among females can also be associated with reporting gaps in India. For instance, there are more than 1,100 cases of COVID-19 infection among male aged 5–19 years is reported but there is no report of any single COVID-19 deaths in this age-sex groups.

In the Indian context, it is evident that bulk of infections and deaths are among males and part of the explanation may be found in the gendered nature of work and society in India.\textsuperscript{27,29} Men are relatively more likely to undertake visits for household chores or for socializing but at the same time the gendered nature of occupations and employment also pose greater risk of infection among men. In fact, bulk of the infection in India is concentrated across 4 to 5 major urban centres in Western India that has considerable share of young male migrants who are also more likely to acquire and transmit infection.\textsuperscript{30,31} Given increasing reports of reverse urban-to-rural migration, if such COVID-19 transmissions are left unchecked than it would lead to increase in number of COVID-19 clusters across rural areas. This can also have a direct impact on rural population where every household has higher proportion of children, women and elderly. Clearly, the ever-increasing numbers of daily new cases of COVID-19 infections is a major concern for India.

With greater details on age-sex specifics, the aggregate statistic of CFR can be more useful for policy action. Nevertheless, the CFR strongly relies on the confirmation of cases which; however, can be underestimated during epidemics. Particularly, the underestimation can be higher in resource-poor settings because of limited testing and health care facilities. The CFR is also sensitive to age-sex specifics, co-morbidity conditions, and health care condition.\textsuperscript{14} A high burden of deaths among the older adults and elderly can be associated with certain pre-existing conditions including diabetes and cardiovascular diseases.\textsuperscript{32,33} Lifestyle risk factors are also an important aspect and also leading to early onset of non-communicable diseases in India.\textsuperscript{34} Men are also more likely to have multimorbidity conditions with early onset of such diseases.\textsuperscript{9} Also, resource-poor settings with inadequate facilities for clinical care and intervention can further elevate the risks of infection and mortality.\textsuperscript{35}

Since CFR does not capture the risk of mortality among currently active infections therefore, we also suggest the indicator CFR* that aims to mirror the actual CFR that is known only when the epidemic ends. In fact, it would be useful to briefly compare the CFR* estimate with countries where the COVID-19 epidemic has more or less subsided or the curve has flattened. We use CFR* of India and compare this with CFR of China, South Korea and Thailand mainly because these countries now witness very small number of daily cases.\textsuperscript{36} Under such situation, CFR* converges with CFR because the share of active infection to total cases is very low. China, South Korea and Thailand display CFR of 5.5\%, 2.4\%, and 1.9\%, respectively. Whereas, it is worth noting that India’s CFR* is higher than South Korea and Thailand and it is, more or less, likely to settle near the Chinese experience.
Alternative approaches for CFR estimation are also available. For instance, 2 alternative CFRs can be defined as follows: \( \text{CFR}_1 = \frac{D_t}{C_{t-15}} \) and \( \text{CFR}_2 = \frac{D_t}{D_t + R_t} \); where \( t, C, D \) and \( R \) refer to time point (days), cases, deaths and recoveries, respectively. Based on these methods, an all-India CFR of about 13%–15% is estimated during first half of April 2020. But both methods may not provide reasonable estimates because the numerator \( D_t \) does not capture all potential future deaths (leading to underestimation) whereas the denominators are restricted to cases with 2–3 weeks lag (leading to overestimation). Besides, the estimated \( \text{CFR}_1 \) and \( \text{CFR}_2 \) appear to be much higher than the CFR noted for countries that have flattened the curve or are in penultimate stages of the epidemic. In contrast, the CFR* suggested here is effective in capturing the mortality risk based on twin parameters that combines both the proportion of active cases as well as prevailing CFR levels.

Nevertheless, since the CFR does not include all possible infections this limitation is overcome by estimating the infection fatality rate (IFR) which is defined as the total number of infection-related deaths divided by the total number of infected cases. But IFR estimation is also fraught with difficulties because true count of cases is seldom known due to inadequate testing and presence of asymptomatic infections. The infectivity potential of such asymptomatic cases is also an unknown parameter. Besides, within event period, the IFR will also encounter similar problems of accounting for deaths and recoveries among currently active cases. This would also need a robust surveillance system to keep track of infection spread for estimating such parameters.

To a large extent, the response to COVID-19 infections depends on the immune system of the individuals. It is widely acknowledged that individuals with poor nutritional status are likely to have weak immune system. In fact, among children under-five with widespread undernutrition there will be further compromising of the immune system and this can elevate the risk of mortality if such children are exposed to COVID-19. A significant proportion of women in the age group 15–49 years are undernourished and this also leaves them vulnerable to an elevated risk of COVID-19 infection and severe outcomes. The COVID-19 pandemic has also severely disrupted food and health systems worldwide. Recently released Global Nutrition Report (2020) takes cognizance of these adversities and is particularly concerned about its disproportionate impact on the poor and the vulnerable populations. India is no exception whereby the COVID-19 outbreak and the ensuing policy response has a devastating effect on millions. Amidst elevated risks to lives and livelihood, there is also a surge in reports of hunger and food deprivation in both rural and urban areas of India. Restrictions and declines in economic activity also imply that children from subsisting households may have to compromise with both the quantity as well as quality of the dietary intake. The disruption of the health care services is also inimical to nutritional health and well-being of the children and women.

The analysis reveals that the risk of COVID-19 case fatality in India is relatively higher among females than males. The burden of infections and death is shared equally among under-five boys and girls and to some extent among the oldest old men and women. Besides, women in age group 40–49 years have relatively higher risk of mortality. With increasing trend of active cases, and increasing urgency to roll back lockdown measures, this analysis offers two important policy insights. First, the healthcare system should strictly reduce exposure of elderly and children. In fact, with such high CFR it is critical that all elderly COVID-19 patients should be treated at tertiary care facilities with adequate life-saving support system. Also, special care should be ensured at institutional facility for elderly as well as nursing
homes. Second, it is important to improve data capture and reporting as there are huge gaps in age-sex specific reporting of information. Also, testing information by age-sex groups should be available to understand the specific trends and patterns in COVID-19 infections.

So far, testing for COVID-19 is mainly being done among at-risk individuals (e.g., those with influenza-like symptoms, people who have had contact with an individual testing positive for COVID-19, healthcare professionals, or those with a travel history to an affected region). As a consequence, an accurate value for how many individuals are truly infected is not known. Since at-risk individuals are not representative of the general population, it is impossible to ascertain the true prevalence of COVID-19 in the population. Establishing this value is vital to understand the COVID-19 related morbidity and mortality age-sex specific risk in the population, particularly in India, which cannot absorb the economic and public health fallout of a national lockdown. India has increased its testing intensity, and, to a large extent, this has led to increased detection of COVID-19 infections. At the same time, while COVID-19 deaths have gone up, the CFR appears to be considerably low given the size and density of India. In fact, given the low CFR among the younger population, it is also proposed that they may be gradually allowed to return to work or education subject to certain medical conditions and rules. But even when we assume the death data to be more or less accurate, this implies that the infection fatality risk (i.e., the risk of dying) is also lower but, due to the sheer population size, even lower prevalence translates to large absolute numbers.

Clearly, a full comprehension of the risk profile is very critical to decide upon lockdown relaxation approach and flexibilities in resumption of economic activities for different population age-sex groups. India is yet to witness the peak of the COVID-19 curve. Given a lengthy recovery period, social distancing or lockdown essentially delays the intensity of the epidemic outbreak. But an extended lockdown phase can disrupt the food system and other economic activities to significantly elevate the risks of mortality among the vulnerable population groups of children, women and elderly. Evidence to understand the equity aspect of COVID-19 infection burden and mortality risk is an important area for further research.

SUPPLEMENTARY MATERIALS

**Supplementary Table 1**
Number of reported COVID-19 cases and deaths with age-sex information, India

[Click here to view]

**Supplementary Table 2**
Sex-specific absolute burden of COVID-19 infections and deaths in India

[Click here to view]

**Supplementary Table 3**
COVID-19 CFR (in %) for India by age-group, April 10, May 1, May 9, and May 20, 2020

[Click here to view]
Supplementary Fig. 1
Click here to view

Supplementary Fig. 2
Click here to view

Supplementary Fig. 3
Click here to view

Supplementary Fig. 4
Click here to view

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