

# Evidence based decision making and COVID-19: what *a posteriori* probability distributions speak.

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## Research Article

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# Abstract

**Background:** In the absence of a vaccine for coronavirus disease-19, the management of the current pandemic revolves around public health measures such as social distancing, lockdown, and contact tracing. A number of epidemiological models are used in decision making and for generating research intelligence. The models require information regarding the structures of social contact between different ages and genders. The present study fosters evidence-based decision making by estimating various *a posteriori* probability distributions from data of COVID-19 patients.

**Patients and Methods:** In this retrospective observational study, 987 real-time RT-PCR SARS CoV-2 positive patients from SMS Medical College, Jaipur, India were enrolled after approval of the institutional ethics committee. The data regarding age, gender, and outcome were collected from case sheets. The univariate and bivariate distributions of COVID-19 cases with respect to age, gender, and outcome were estimated. The age distribution of COVID-19 cases was compared with the age distribution of general population using goodness of fit  $\chi^2$  test. The independence of attributes in bivariate distributions was evaluated using the chi square test for independence.

**Results:** The age group '25-29' has shown highest probability of COVID-19 cases ( $P[25-29] = 0.14$ , 95% CI: 0.12- 0.16). The men ( $P[\text{Male}] = 0.62$ , 95%CI: 0.59-0.65) were dominant sufferers. The most common outcome was recovery ( $P[\text{Recovered}] = 0.79$ , 95%CI: 0.76-0.81) followed by admitted cases ( $P[\text{Active}] = 0.13$ , 95%CI: 0.11-0.15) and death ( $P[\text{Death}] = 0.08$ , 95%CI: 0.06-0.10).

The age distribution of COVID-19 cases differs significantly from the age distribution of the general population ( $\chi^2 = 399.04$ ,  $p < 0.001$ ). The bivariate distribution of COVID-19 across age and outcome was not independent ( $\chi^2 = 106.21$ ,  $df = 32$ ,  $p < 0.001$ ).

**Conclusion:** The age, gender, and outcome distributions helps in evaluating disease dynamics and the social structure of the community. The knowledge of patterns of disease frequency helps in optimum allocation of limited resources and manpower. The study provides information for various epidemiological models, to decide the duration of lockdown.

## Introduction

According to the World Health Organization report, 8,061,550 confirmed cases and 440,290 confirmed deaths due to coronavirus disease-19 (COVID-19) were recorded by 18 June, 2020 across 216 countries of the world (WHO, 2020). In the absence of a vaccine, the control of disease pandemic includes public health measures such as lockdown and social distancing. The effectiveness of social distancing and the duration of lockdown was investigated using various mathematical models. A number of epidemiological models including SIR used age structured data and social contact matrices to study the progress of the COVID-19 epidemic (Singh R, 2020). The patterns of disease frequency distributions in a community is a function of cultural habits and social contacts. The lesser frequency of occurrence of COVID-19 in children might be due to their having fewer outdoor activities and less international travel (Lee PI, 2020).

Furthermore, the effects of public health measures such as lockdown, social distancing, and personal protective measures are reflected in the probability distributions. The probability distributions of various predictors of mortality risk such as random blood sugar over ages reveals causes of mortality (Bhandari,2020). The objective of the present study is the estimation of probabilities for univariate and bivariate distributions of COVID–19 cases, over different ages and genders, as observed in patients in tertiary care hospitals in Rajasthan.

## Patients And Methods

In this hospital-based retrospective observational study, 987 real-time RT PCR, SARS CoV–2 positive cases from SMS Medical College and Hospital, Jaipur, Rajasthan, India were enrolled. Among the patients, 129 were admitted, 80 had died and, 778 had recovered from COVID–19.

## Data Collection

The age, gender, and outcome data were recorded from the case sheets of the patients. The age distribution of population and age-specific mortality rates were sourced from the government of India repository (Census of India, 2020). Observations were excluded if there were missing data of age, gender or mortality.

## Data analysis

The univariate discrete probability distributions of age, gender, and outcome were estimated. P[Death], expressed as a percent is also known as case fatality rate (Epidemiology Working Group for NCIP Epidemic Response, 2020)

The bivariate discrete probability distribution of age and gender, age and outcome, and gender and outcome were also estimated. The conditional probability distributions of P[Age | Outcome], P[Outcome | Age], P[Age | Gender], P[Gender | Age], P[Gender | Outcome] and P[Outcome | Gender] were obtained using the law of conditional probability:

$$P[C|D] = \frac{P[C \cap D]}{P[D]}$$

where P[C | D] is the conditional probability of occurrence of event C when event D has already occurred, P[C∩D] is the probability of occurrence of event C and D simultaneously and P[D] is the probability of occurrence of event D (Indrayan, 2020).

The age distribution of COVID–19 was compared with the general age distribution. Comparisons were also made for means of age between various levels of gender and outcome. Finally, we compared the outcome among various levels of gender and age groups.

## Statistical analysis

The quantitative variables were expressed as mean and standard deviation, estimates were expressed as 95% confidence intervals and comparison was performed using two tailed Student t-test. The qualitative variables were expressed as proportions and compared with chi-square test. The goodness of fit chi-square test was used to test distributions. The statistical level of significance was considered at 5%. The statistical analyses were done using JASP software (JASP Team) and MATLAB 2016a (MATLAB Team).

## Results

The univariate probability distribution of age (P[Age]) of coronavirus disease–19 cases has showed maximum probability in the '25–29' age group followed by the '30–34' age group and there was a minimum probability in the '75–79' age group. The occurrence of COVID–19 cases across age was significantly different ( $\chi^2=411.53$ ,  $df = 16$ ,  $p < 0.001$ ) (Figure 1 and Table S1). The age distribution of COVID–19 cases differed significantly with age distribution of the population ( $\chi^2=399.04$ ,  $p < 0.001$ ) (Figure 2). The probability of men (P[Male] = 0.62, 95% CI: 0.59–0.65) suffering from COVID–19 was higher than for women (P[Female] = 0.38, 95% CI: 0.35–0.41) (Figure 3 Panel A and Table S2). The probability of recovered cases (P[Recovered] = 0.79, 95%CI: 0.76–0.81) was higher than for death cases (P[Death] = 0.08, 95%CI: 0.06–0.10) or admitted cases (P[Active] = 0.13, 95% CI: 0.11–0.15) (Figure 3 Panel B and Table S3).

The bivariate probability distribution of age and gender showed males in the '25–29' age group constituted maximum cases of COVID–19 (Table S4). The conditional probability of age for both gender (P[Age | Male] and P[Age | Female]) were highest in the '25–29' age group (Figure 4 Panel A and Panel B). The distribution of COVID–19 cases across age and gender was independent ( $\chi^2=df = 16$ ,  $p = 0.17$ ).

The distribution of COVID–19 cases across age and outcome was not independent ( $\chi^2=df = 32$ ,  $p < 0.001$ ) (Figure 5 Panel A). The conditional probability distribution of age for given deaths (P[ Age | Death]) was highest in the '60–64' age group, but the conditional probability for death for a given age ( P[ Death | Age]) was highest in the '75–79' age group (Figure 5 Panel B and Table S5).

The bivariate probability distribution of gender and outcome showed the highest proportion of coronavirus cases were male and recovered (Table S6). The distribution of COVID–19 cases across gender and outcome was independent ( $\chi^2=df = 2$ ,  $p = 0.88$ ). The conditional probabilities for males for a given outcome were higher than for females (Figure 6 Panel A-C).The conditional probabilities of

outcome for a given gender were higher for recovered cases, followed by active cases and death. (Figure 7 Panel A-C).

## Discussion

Management of the COVID-19 pandemic with limited resources and manpower is a challenging task for public health authorities. The knowledge of disease patterns helps in decision making as well as for optimum allocation of resources. The observed disease patterns affected by biological susceptibility, social contact structure, and cultural habits. The rate of evolution of epidemic curve in Rajasthan is among the top eight states of India (Bhandari,2020). The mean age of COVID-19 cases was 37.08 years in Rajasthan, which was lower than the mean age-based on 65 research articles (Adhikari SP,2020; Gandhi PA, 2020; Kakkar, 2020). The age distribution of the general population of Rajasthan was right skewed. The mode of the general age distribution curve was the '10-14' age group. While the mode of the age distribution of COVID-19 cases occur at '25-29' age group. This could be explained by the decision of early closure of schools and colleges by the government (Times of India, 2020). The lower frequency of occurrence of COVID-19 in children might be the result of fewer outdoor activities and less international travel (Lee PI, 2020). A national study from China on 2135 pediatric patients showed no significant difference in susceptibility across age groups, although clinical manifestations in children were less severe (Dong Y, 2020). The study showed men constitute more cases of COVID-19, which might be due to higher independence as compared to females (Ram U, 2014; Adhikari SP). However, the sex ratio of Rajasthan is 926 females per 1000 males (Census of India, 2011). The case fatality rate was 8.1% which is more than reported for China, i.e., 7.2% (Dhar Chowdhury S, 2020). The higher rate may be due to fewer testing facilities and less contact tracing (Rajagopalan S, 2020). In an epidemiological study, COVID-19 cases in Maharashtra and New Delhi also showed the dominance of males and no association between gender and mortality. The age-specific mortality rate was also high among patients aged 61-70 years(19.2%), 71-80 years (15.8%) and above 80 years (13.9%) as in our study (Figure 5. Panel B, red line graph).

The  $P[\text{Death}|\text{Age}]$  suggests the probability of death in older age groups was higher, but  $P[\text{Age}|\text{Death}]$  suggests that the need for life saving equipment was equal in all age groups. Similarly, the  $P[\text{Active}|\text{Age}]$  suggests that the requirement for hospital beds was equal over age groups, but  $P[\text{Age}|\text{Active}]$  suggests that more hospital beds were occupied by younger age groups.

In the Indian context, we collated few recommendations based on estimated *a posteriori* probability distributions:

*Recommendation 1.* The probability of death in elderly group  $P[\text{Death} | > 60]$  is higher. The people above 60 years should stay at home.

*Recommendation 2.* Number of active cases helps in the estimation of requirements for hospital beds and medical equipment. The  $P[\text{Age}|\text{Active}]$  suggests most of the hospital beds are occupied by younger age groups. As suggested  $P[\text{Death}|\text{Age}]$  that younger age groups have a low mortality risk, management

strategies for mild cases might include home isolation. That would free up more hospital beds for the elderly population who are at higher risk of mortality.

*Recommendation 3.* The case fatality rate is quite high in our study, possibly due to low COVID–19 testing. Thus, there is a need to increase COVID–19 testing to improve the estimation of fatality rate.

Furthermore, we recommend the involvement of experts from multiple fields such as operations research, epidemiology, economics, management and sociology in policy making.

## Conclusion

The patterns of COVID–19 cases and hospital outcome across age and gender form the basis of evidence-based decision making in public health domain. Additional demographic, clinical and laboratory data permit us to determine the magnitude of medical resources and manpower required along with public health measures.

## Limitations Of The Study

The study estimates probability distributions from the early dataset of COVID–19 cases. As decisions on public health measures like lockdown, contact tracing, and testing guidelines are modified, those in turn affect the patterns of disease. Thus, real-time estimations are required and should be adjusted for the confounding effects.

## Abbreviations

CI: confidence interval

COVID–19: coronavirus disease–19

P[Age]: discrete probability distribution of age

P[Gender]: discrete probability distribution of gender

P[Outcome]: discrete probability distribution of outcome

P[Age | Gender]: conditional discrete probability distribution of age for a given gender

P[ Gender | Age]: conditional discrete probability distribution of gender for a given age

P[Age | Outcome]: conditional discrete probability distribution of age for a given outcome

P[ Outcome | Age]: conditional discrete probability distribution of outcome for a given age

P[Gender | Outcome]: conditional discrete probability distribution of gender for a given outcome

P[Outcome | Gender]: conditional discrete probability distribution of outcome for a given gender

SARS CoV-2: severe acute respiratory syndrome coronavirus 2

## Declarations

*Ethics approval and consent to participate* - The present study used de-identified data of patients and the ethical approval has been taken from Institutional Ethics Committee.

*Consent for publication*- Not applicable

*Availability of data and materials* - Data will available on reasonable request from corresponding author.

*Competing interests*- The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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*Authors' contributions*- All authors contributed equally.

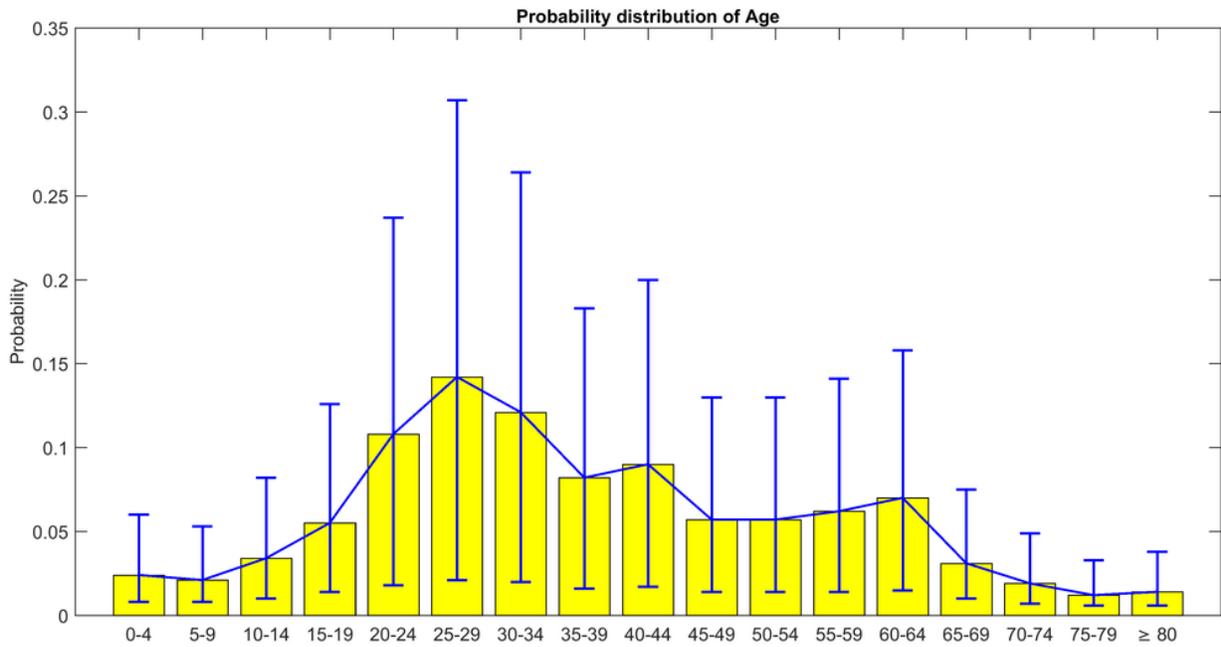
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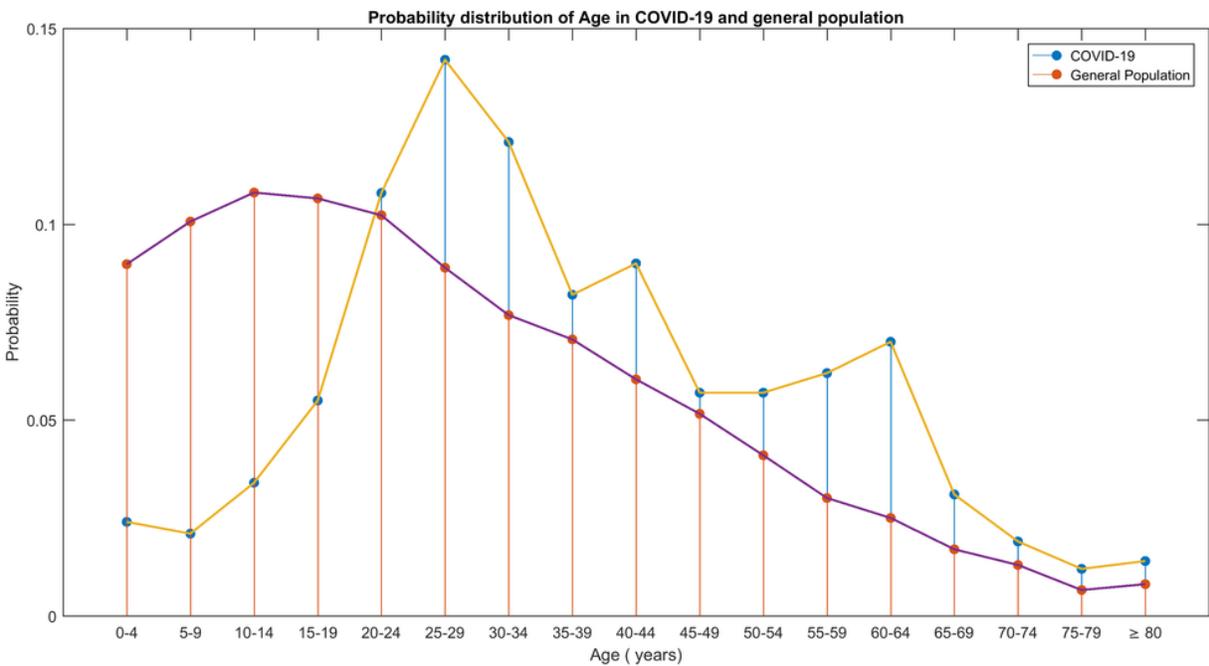
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## Figures



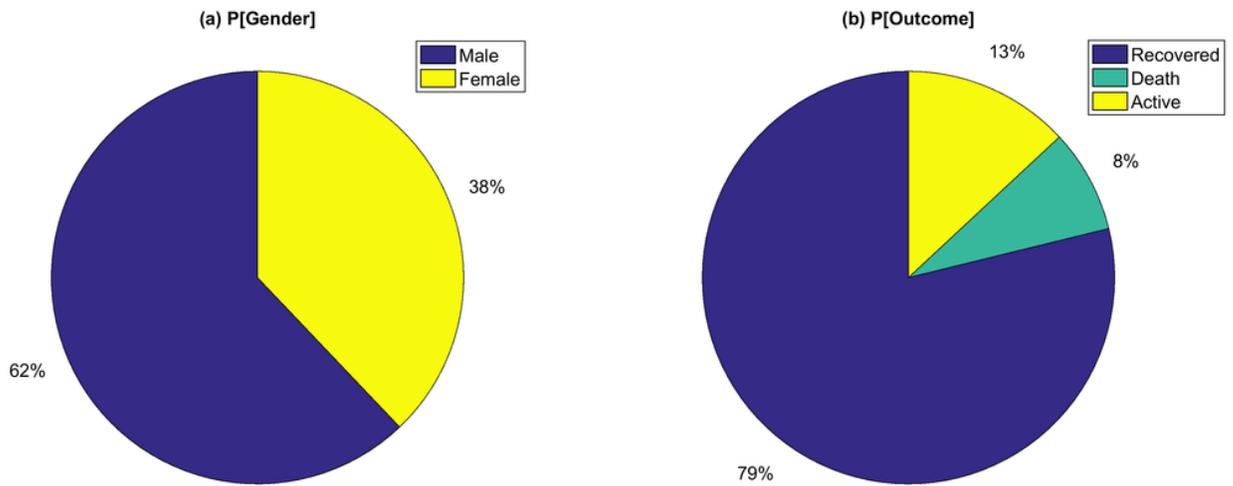
**Figure 1**

Box plot of univariate discrete age distribution of COVID-19 cases (N = 987) with error bars (blue) at 95% confidence intervals in the state of Rajasthan.



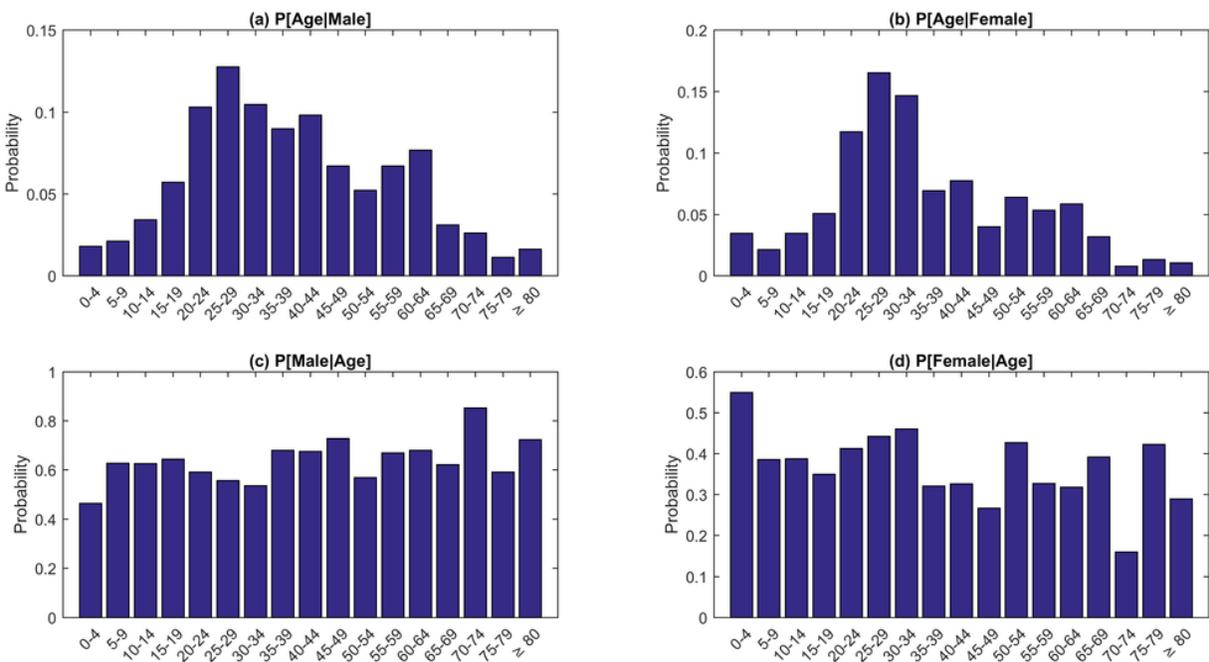
**Figure 2**

Stem plot of age distribution of observed (blue dots) cases of COVID-19 and expected cases (red dots) in the state of Rajasthan.



**Figure 3**

Pie charts of univariate discrete probability distribution of COVID-19 cases (N = 987) in the state of Rajasthan (a) P[Gender] (b) P[Outcome].



**Figure 4**

Histograms of conditional probability distributions of age and gender of COVID-19 cases (N = 987) in the state of Rajasthan. Panel A: P[Age|Male], Panel B: P[Age|Female], Panel C: P[Male|Age], and Panel D: P[

Female|Age].

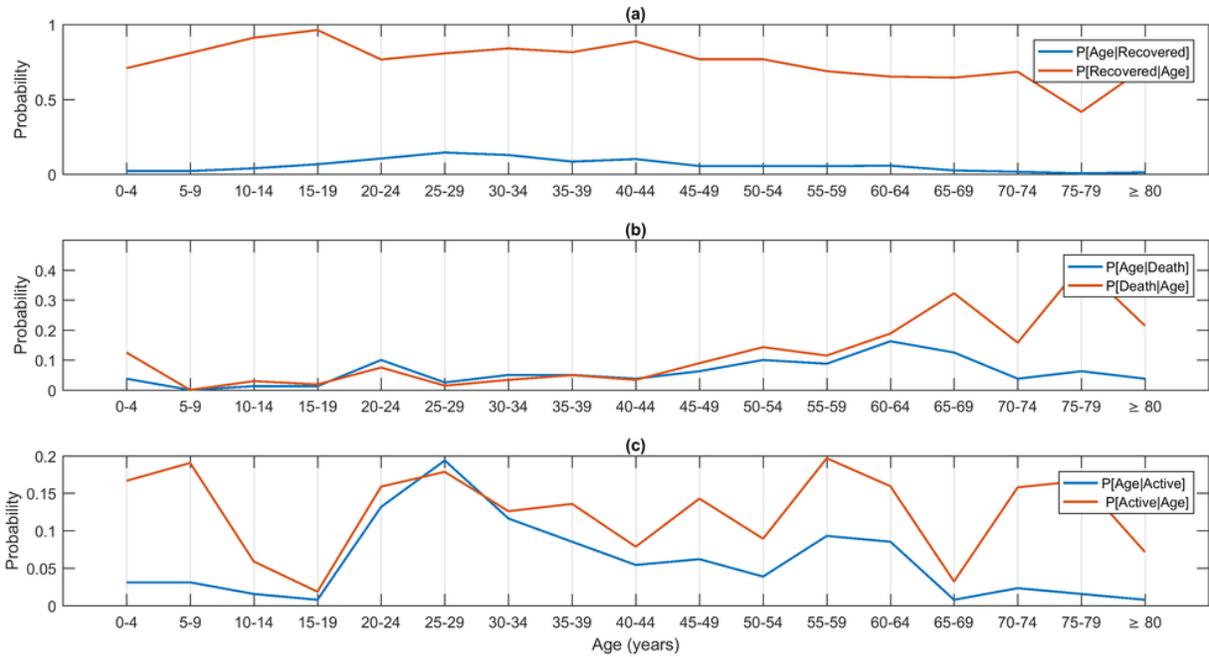


Figure 5

Line plots of conditional probability distributions of age and outcome of COVID-19 cases (N = 987) in the state of Rajasthan. Panel A:  $P[\text{Age}|\text{Recovered}]$  (blue line) and  $P[\text{Recovered}|\text{Age}]$  (red line), Panel B:  $P[\text{Age}|\text{Death}]$  (blue line) and  $P[\text{Death}|\text{Age}]$  (red line), and Panel C:  $P[\text{Age}|\text{Active}]$  (blue line) and  $P[\text{Active}|\text{Age}]$  (red line).

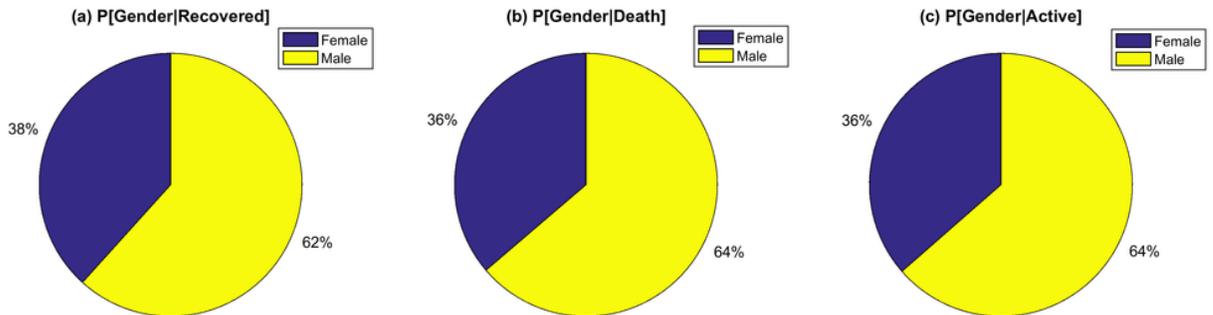
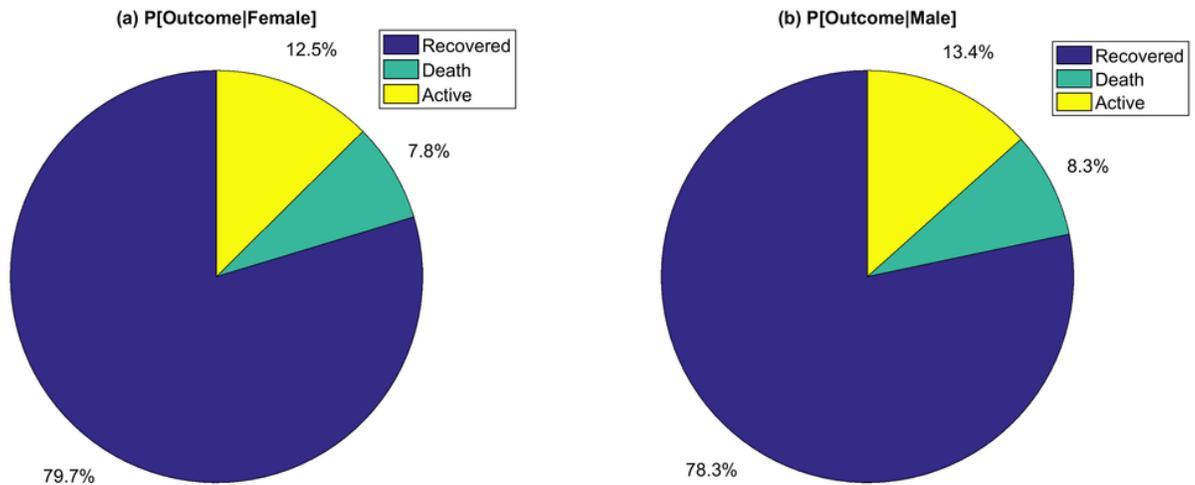


Figure 6

Pie charts of conditional probability distributions of gender for given outcome (N = 987) in the state of Rajasthan. Panel A:  $P[\text{Gender}|\text{Recovered}]$ , Panel B:  $P[\text{Gender}|\text{Death}]$  (c), and Panel C:  $P[\text{Gender}|\text{Active}]$ .



**Figure 7**

Pie charts of conditional probability distributions of outcome for given gender (N = 987) in the state of Rajasthan. Panel A:  $P[\text{Outcome}|\text{Female}]$ , and Panel B:  $P[\text{Outcome}|\text{Male}]$ .

## Supplementary Files

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- [SupplementaryInformationFile.docx](#)