

# Statistics associated with the lethality of COVID-19 by age group and gender in Mexico

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## Abstract

We analyzed outcomes of 102,985 SARS-CoV-2 confirmed cases of patients attending the IMSS (Mexican Institute for National Insurance) from January 2 to August 3, 2020. We calculated relative IFR by age group and gender and introduced the concept of *adjusted lethalties*, that can be used to project the burden of the disease for a population with different demographic characteristics.

*Keywords:* COVID-19, SARS-CoV-2, IFR, Lethality, Age, Gender, Adjusted lethality

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## 1. Introduction

Since it was first identified in pneumonia patients in Wuhan, China, the coronavirus disease 2019 (COVID-19) by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been characterized by its fast-spreading and high related disease burden [1]. The spectrum of symptoms is wide and ranges from asymptomatic infection to severe respiratory illness [2]. By August 4, 2020, almost 20 million confirmed cases of COVID-19 had been reported globally and a fatal outcome was registered in nearly a half million of them [3]. Gender and age-related differences in disease severity and risk of death have been documented [4].

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The lethality of a disease, also known as Infection Fatality Rate (IFR) is the fraction of infected individuals that die from the disease. It's estimation is of the utmost importance for the design of and application of containment measures and to decide if lockdowns are implemented as when these should be reinforced  
15 or lifted. Unfortunately, our data does not come from a random sample and we cannot estimate the IFR, instead, we estimate the relative share of the IFR by age group and gender and introduce the concept of *adjusted lethalties* that can be used to project the burden of the disease for a population whose demographic characteristics is known.

## 20 Methodology

We used the database of the Instituto Mexicano de Seguro Social (IMSS, acronym for Mexican Institute for National Insurance) with confirmed SARS-CoV-2 cases. The IMSS provides health services to about 10% of the population in Mexico, over 12 million persons. The database on SARS-CoV-2 we used  
25 contains confirmed cases from January 2 to June 23, 2020. We included only cases with disease outcome as dead or recovered, leaving a database with 102,985 cases, from which 55 % were males and 45% females.

When a patient is diagnosed with COVID-19, it follows one of the paths depicted in Figure 1. With this data we constructed Table 1 after dividing the  
30 population in seven age categories and two genders.

Table 2 shows a processing of the information in Table 1. Vectors  $\mathbf{h}$ ,  $\mathbf{c}$ ,  $\mathbf{d}$  and  $\mathbf{d}_c$  in Table 2 are described as follows:

$\mathbf{h}$  = relative frequency of hospitalized patients.

35  $\mathbf{c}$  = fraction requiring ICU among those that went into hospitalization.

$\mathbf{d}$  = fraction dying among those that went into hospitalization.

$\mathbf{d}_c$  = fraction dying among those that went into ICU.

As mentioned before, it is not possible to estimate the IFR from the data

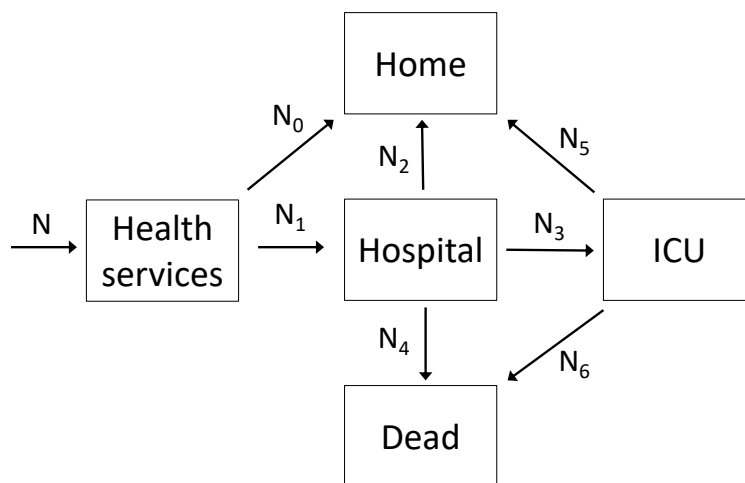


Figure 1: Transitions in our model:  $N_0 + N_1 = N$ ,  $N_2 + N_3 + N_4 = N_1$ ,  $N_5 + N_6 = N_3$

40 available (Table 1) since the death rates are conditional on patients mostly symptomatic and thus they are not a representative sample of the response to an infection. Nevertheless, there is a couple of things that we can obtain from Table 2. The first one is the *relative lethality* and the second *adjusted lethality*.

## 2. Relative lethality

45 Table 2 tells us, for instance, that the probability that a female person in age group 40-49 that is hospitalized from infection with SARS-CoV-2 dies is 0.3548, but this does not provide information on the probability that a female infected person in age group 40-49 dies from the disease. Nevertheless, observe that if  $f_{ij}$  is the fraction in the population of individuals of gender  $i$ ,  $i = 1, 2$   
 50 and group age  $j$ ,  $j = 1, 2, \dots, 7$ , and we assume that everyone is equally likely to become infected but there is a differential response to the disease, then, if  $p$  is the fraction of individuals in the population that is infected and  $\beta_{ij}$  is the fraction of infected individuals of gender  $i$  and age group  $j$  that become hospitalized, then:

$$f_{ij} p \beta_{ij} \propto h_{ij} \quad (1)$$

55 Where  $h_{ij}$  is the fraction of hospitalized that belong to age group  $i$  and gender  $j$ .  
Now, if  $\alpha_{ij}$  is the fraction of individuals hospitalized that die from COVID-19,  
then

$$f_{ij} p \beta_{ij} \alpha_{ij} \propto h_{ij} d_{ij} \quad (2)$$

where  $d_{ij}$  is the fraction of individuals of these hospitalized that dies.

Let  $\theta_{ij}$  be the *lethality* or infection fatality rate of gender  $i$  and age group  $j$ ,  
60 then, the lethality of gender  $i$  and age group  $j$  can be written as:

$$\theta_{ij} = \beta_{ij} \alpha_{ij}. \quad (3)$$

Thus, the IFR by gender and group age follows this relationship:

$$\theta_{ij} \propto h_{ij} d_{ij} / f_{ij}. \quad (4)$$

The reason why we only establish that  $\theta_{ij}$  is proportional to some value is  
because we ignore the value of  $p$ , the true proportion of infected individuals in  
the population. Thus, we define  $\theta_{ij}^*$  as the *relative lethality*:

$$\theta_{ij}^* = h_{ij} d_{ij} / f_{ij} \quad (5)$$

Even although the value of  $p$  is not known, the ratio of any two relative  
lethalities  $\theta_{ij}^* / \theta_{kl}^*$  reflects the ratio of the true lethalities, that is:

$$\theta_{ij}^* / \theta_{kl}^* = \theta_{ij} / \theta_{kl},$$

65 therefore this quotient can be used to compare the lethality of any two groups.  
Table 3 shows in the last column the relative infection fatality rates in (5), after  
normalization. In this table  $\mathbf{f}_M$  and  $\mathbf{f}_F$  are the relative frequencies by age group  
and gender in the Mexican population. In this table we can see, for instance,  
that the lethality of COVID-19 in age group 60+ is  $0.37511/0.19795 = 1.9$   
70 times higher in males than in females, and that the lethality in the 60+ group  
compared to the group with less than 20 years age is:

$$\frac{0.37511 + 0.19705}{0.00068 + 0.00024 + 0.00041 + 0.00048} = 317.7$$

times larger. Table 3 also shows that the lethality among people 50 years or older is about 6 times larger than among people less than 50 years old.

### 3. Adjusted lethality

75 It is possible to estimate the true values of  $\theta_M$  and  $\theta_F$ . The lethality of the disease is the probability that a person at random that has been infected with SARS-CoV-2 dies, which is:

$$\text{IFR} = \mathbf{f}'_M \boldsymbol{\theta}_M + \mathbf{f}'_F \boldsymbol{\theta}_F \quad (6)$$

which assumes all individuals are equally likely to become infected. If we have an estimate of the lethality of the disease,  $\theta$ , then we can rescale  $\boldsymbol{\theta}_M^*$  and  $\boldsymbol{\theta}_F^*$  80 multiplying by a constant  $c$  so that

$$\theta = c \mathbf{f}'_M \boldsymbol{\theta}_M^* + c \mathbf{f}'_F \boldsymbol{\theta}_F^* \quad (7)$$

Some estimates of the IFR are in the range 0.05% – 0.25% [5, 6, 7]. Here we will use the lethality reported by [5] of 86 in 100, 000 (about 0.1%) because it is a more recent study with a large sample size, thus, we use  $\theta = 0.001$ . The adjusted lethality by age group and gender are shown in Table 4.

85 One immediate application of Table 4 is the possibility of projecting the IFR for another population whose demographics by age and gender are known. Consider for instance the demographics of the Za'atari refugee camp, in Jordan<sup>1</sup>, which is shown in Table 5. We use  $\boldsymbol{\theta}_M$  and  $\boldsymbol{\theta}_F$  from Table 4 and the  $\mathbf{f}_M$  and  $\mathbf{f}_F$  from the camp's demographic and thus the IFR projected for this camp is:

$$\text{IFR} = \mathbf{f}'_M \boldsymbol{\theta}_M + \mathbf{f}'_F \boldsymbol{\theta}_F = 0.00037$$

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<sup>1</sup><https://data2.unhcr.org/en/situations/syria/location/53>

90 Observe this adjusted lethality is about 2.7 times smaller than the overall IFR, which is due to the fact that Za’atari refugee camp is a young population with 3/4 of the refugees being less than 30 years old. Although this comparison used  $\theta = 0.001$  as the overall IFR of SARS-CoV-2, the observed ratio of 2.7 is independent of this value because the adjusting constant  $c$  in 7 cancels out.

95 Clearly, this projection includes only demographic factors and not other health and socioeconomic factors or availability of health services. Figure 2 shows a comparison between the demographics of the Za’atari camp and the *Adjusted lethalties* from Table 4 by age group and gender.

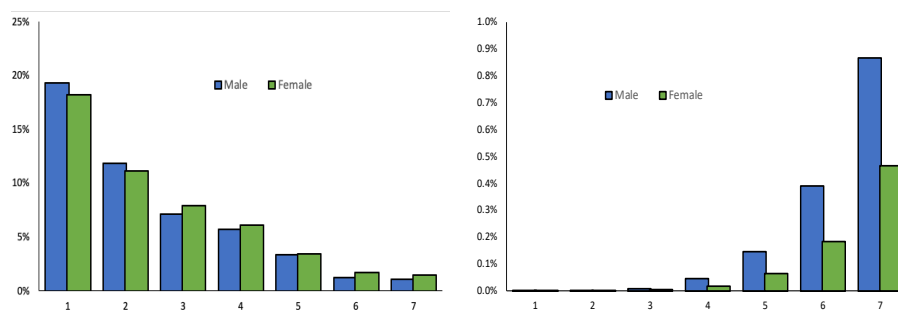


Figure 2: Population frequency in Za’atari camp (left) and Adjusted lethalties from Table 4 (right) by age and gender. For this particular camp, the lethality affects a group of individuals that are found at a very low frequency in the camp.

*The distribution of deaths across age groups and gender.*

100 Another use of the *adjusted lethalties* in Table 4 is the estimation of the distribution of deaths across group ages and genders. The question we want to answer is: what is the probability that a dead individual belongs to a particular gender and age group? This is clearly given by  $\mathbf{f}_M \circ \boldsymbol{\theta}_M$  and  $\mathbf{f}_F \circ \boldsymbol{\theta}_F$  after normalization. For the Mexican population, a plot of this distribution is given

105 in Figure 3.

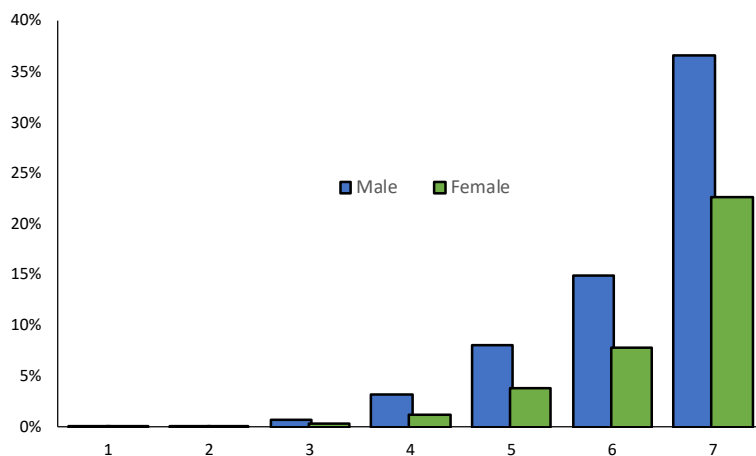


Figure 3: The projected distribution of deaths across age groups and gender for Mexico's population.

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### Conflicts of interest

Authors declare no conflict of interest.

### Funding and study approval

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the views of DFID, the WBG or UNHCR. This study had approval R-2020-601-07 by the Health Research Ethics Committee (601) of the IMSS.

Table 1: Number of transitions between compartments in Figure 1 by age group and gender.

| <b>Males</b> |                       |                         |                         |                         |                         |                         |                         |                         |
|--------------|-----------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| <b>Age</b>   | <b><math>N</math></b> | <b><math>N_0</math></b> | <b><math>N_1</math></b> | <b><math>N_2</math></b> | <b><math>N_3</math></b> | <b><math>N_4</math></b> | <b><math>N_5</math></b> | <b><math>N_6</math></b> |
| 0-9          | 256                   | 97                      | 159                     | 116                     | 20                      | 23                      | 14                      | 6                       |
| 10-19        | 367                   | 261                     | 106                     | 83                      | 6                       | 17                      | 3                       | 3                       |
| 20-29        | 5,627                 | 4,585                   | 1,042                   | 852                     | 8                       | 182                     | 6                       | 2                       |
| 30-39        | 10,829                | 7,706                   | 3,123                   | 2,289                   | 29                      | 805                     | 14                      | 15                      |
| 40-49        | 11,788                | 6,153                   | 5,635                   | 3,539                   | 65                      | 2,031                   | 32                      | 33                      |
| 50-59        | 11,566                | 3,799                   | 7,767                   | 3,914                   | 65                      | 3,788                   | 24                      | 41                      |
| 60 +         | 16,392                | 2,599                   | 13,793                  | 4,407                   | 111                     | 9,275                   | 27                      | 84                      |
| Total        | 56,825                | 25,200                  | 31,625                  | 15,200                  | 304                     | 16,121                  | 120                     | 184                     |

| <b>Females</b> |                       |                         |                         |                         |                         |                         |                         |                         |
|----------------|-----------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| <b>Age</b>     | <b><math>N</math></b> | <b><math>N_0</math></b> | <b><math>N_1</math></b> | <b><math>N_2</math></b> | <b><math>N_3</math></b> | <b><math>N_4</math></b> | <b><math>N_5</math></b> | <b><math>N_6</math></b> |
| 0-9            | 205                   | 90                      | 115                     | 81                      | 17                      | 17                      | 14                      | 3                       |
| 10-19          | 423                   | 316                     | 107                     | 80                      | 3                       | 24                      | 2                       | 1                       |
| 20-29          | 5,778                 | 4,972                   | 806                     | 684                     | 15                      | 107                     | 13                      | 2                       |
| 30-39          | 9,894                 | 8,211                   | 1,683                   | 1,330                   | 29                      | 324                     | 23                      | 6                       |
| 40-49          | 10,128                | 6,868                   | 3,260                   | 2,260                   | 22                      | 978                     | 8                       | 14                      |
| 50-59          | 8,274                 | 3,515                   | 4,759                   | 2,755                   | 33                      | 1,971                   | 13                      | 20                      |
| 60 +           | 11,458                | 2,068                   | 9,390                   | 3,600                   | 54                      | 5,736                   | 12                      | 42                      |
| Total          | 46,160                | 26,040                  | 20,120                  | 10,790                  | 173                     | 9,157                   | 85                      | 88                      |

Table 2: Statistics associated with the transition of COVID-19 patients between compartments in Figure 1. **h** = distribution of patients arriving to hospitals. **c** = probability of requiring ICU among those that went into hospitalization; **d** = probability of dying among those that went into hospitalization; **d<sub>c</sub>** = probability of dying among those that went into ICU.

| <b>Males</b> |          |          |          |                      |
|--------------|----------|----------|----------|----------------------|
| <b>Age</b>   | <b>h</b> | <b>c</b> | <b>d</b> | <b>d<sub>c</sub></b> |
| 0-9          | 0.0031   | 0.1258   | 0.1824   | 0.3000               |
| 10-19        | 0.0020   | 0.0566   | 0.1887   | 0.5000               |
| 20-29        | 0.0201   | 0.0077   | 0.1766   | 0.2500               |
| 30-39        | 0.0604   | 0.0093   | 0.2626   | 0.5172               |
| 40-49        | 0.1089   | 0.0115   | 0.3663   | 0.5077               |
| 50-59        | 0.1501   | 0.0084   | 0.4930   | 0.6308               |
| 60 +         | 0.2666   | 0.0080   | 0.6785   | 0.7568               |

| <b>Females</b> |          |          |          |                      |
|----------------|----------|----------|----------|----------------------|
| <b>Age</b>     | <b>h</b> | <b>c</b> | <b>d</b> | <b>d<sub>c</sub></b> |
| 0-9            | 0.0022   | 0.1478   | 0.1739   | 0.1765               |
| 10-19          | 0.0021   | 0.0280   | 0.2336   | 0.3333               |
| 20-29          | 0.0156   | 0.0186   | 0.1352   | 0.1333               |
| 30-39          | 0.0325   | 0.0172   | 0.1961   | 0.2069               |
| 40-49          | 0.0630   | 0.0067   | 0.3043   | 0.6364               |
| 50-59          | 0.0920   | 0.0069   | 0.4184   | 0.6061               |
| 60 +           | 0.1815   | 0.0058   | 0.6153   | 0.7778               |

Table 3: Normalized relative lethalties. “ $\circ$ ” and “ $\oslash$ ” are the Hadamard element-by-element multiplication and division respectively.

| <b>Males</b> |                         |                       |                       |   |
|--------------|-------------------------|-----------------------|-----------------------|---|
| <b>Age</b>   | <b><math>f_M</math></b> | <b><math>h</math></b> | <b><math>d</math></b> | <b><math>\theta_M^*</math></b>            |
|              |                         |                       |                       | <b><math>h \circ d \oslash f_M</math></b> |
| 0-9          | 0.09871                 | 0.00307               | 0.18239               | 0.00052                                   |
| 10-19        | 0.09976                 | 0.00205               | 0.18868               | 0.00036                                   |
| 20-29        | 0.08130                 | 0.02014               | 0.17658               | 0.00403                                   |
| 30-39        | 0.07203                 | 0.06035               | 0.26257               | 0.02029                                   |
| 40-49        | 0.05566                 | 0.10890               | 0.36628               | 0.06609                                   |
| 50-59        | 0.03851                 | 0.15010               | 0.49298               | 0.17722                                   |
| 60 +         | 0.04218                 | 0.26656               | 0.67853               | 0.39548                                   |

| <b>Females</b> |                         |                       |                       |   |
|----------------|-------------------------|-----------------------|-----------------------|---|
| <b>Age</b>     | <b><math>f_F</math></b> | <b><math>h</math></b> | <b><math>d</math></b> | <b><math>\theta_F^*</math></b>            |
|                |                         |                       |                       | <b><math>h \circ d \oslash f_F</math></b> |
| 0-9            | 0.09577                 | 0.0022                | 0.1739                | 0.00037                                   |
| 10-19          | 0.09824                 | 0.0021                | 0.2336                | 0.00045                                   |
| 20-29          | 0.08709                 | 0.0156                | 0.1352                | 0.00223                                   |
| 30-39          | 0.07908                 | 0.0325                | 0.1961                | 0.00744                                   |
| 40-49          | 0.06096                 | 0.0630                | 0.3043                | 0.02900                                   |
| 50-59          | 0.04225                 | 0.0920                | 0.4184                | 0.08399                                   |
| 60 +           | 0.04846                 | 0.1815                | 0.6153                | 0.21252                                   |

Table 4: Adjusted lethalties by age group and gender for the Mexican population ( $M$ =male,  $F$ =female). The *adjusted lethalties* are obtained from rescaling the *unadjusted lethalties* in Table 3, so that  $\mathbf{f}'_M \boldsymbol{\theta}_M + \mathbf{f}'_F \boldsymbol{\theta}_F = 0.001$ .

| Age   | $\boldsymbol{\theta}_M$ | $\boldsymbol{\theta}_F$ |
|-------|-------------------------|-------------------------|
| 0-9   | 0.00001                 | 0.00001                 |
| 10-19 | 0.00001                 | 0.00001                 |
| 20-29 | 0.00009                 | 0.00005                 |
| 30-39 | 0.00045                 | 0.00016                 |
| 40-49 | 0.00145                 | 0.00064                 |
| 50-59 | 0.00389                 | 0.00184                 |
| 60 +  | 0.00868                 | 0.00467                 |

Table 5: Population structure of Syrian refugees in Jordan.

| Age   | $f_M$  | $f_F$  |
|-------|--------|--------|
| 0-9   | 0.1934 | 0.1823 |
| 10-19 | 0.1190 | 0.1116 |
| 20-29 | 0.0714 | 0.0794 |
| 30-39 | 0.0574 | 0.0611 |
| 40-49 | 0.0337 | 0.0348 |
| 50-59 | 0.0127 | 0.0171 |
| 60 +  | 0.0110 | 0.0150 |
| Total | 0.4987 | 0.5013 |