COMP90083 Assignment 1: An investigation of how immunity levels impact the propagation of COVID-19

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1 Background

Since the first outbreak in Wuhan, a relatively mysterious and under-reported aspect of the COVID-19 pandemic has been whether or not people can become infected by the virus more than once. In theory, if humans were unable to develop immunity to the virus after having been infected, the virus could continue to spread and remain present in society indefinitely. Whether humans develop immunity or not should be central to the long-term outlook of the COVID-19 pandemic.

To understand immunity to COVID-19, researchers have looked at a range of phenomena such as the level of SARS-CoV-2-specific T cells or virus antibodies present in those who have recovered from the virus. While some sources suggest that immunity levels are high amongst those who have recovered from COVID-19 [1], there are equally many sources that suggest immunity will wane with time or is much lower than we currently expect [2]. The current uncertainty regarding immunity is what motivated this study. It is important to forecast the effect that different immunity levels may have on virus propagation so as to best prepare for uncertain times ahead.

Question: What are the effects of different immunity levels on the propagation of the COVID-19 virus throughout a high density population?

2 Experimental Design

A high density population (average 50 interactions per day) was chosen to simulate the pandemic because it illustrated the propagation of the virus more realistically; due to model simplicity it was found that in a low density scenario (less than ten interactions per person per day) the infection count quickly converged to zero, and there were no insights gained about the immunity level. Indian slums are very high density, and have been well documented through their course of the pandemic. Parameters have been chosen to emulate the dynamics of the Dharavi slum in Mumbai (see ODD document).

The model is used to simulate a range of scenarios: (a) no one is immune; (b) 50% of recovered are immune; (d) 70% of recovered are immune; (e) 90% of recovered are immune; (f) 100% of recovered are immune. Each scenario is repeated twenty times, and the average and standard deviation are reported for (i) the death toll; (ii) the lifetime of the virus; (iii) the percentage of the population that contract the virus.

When referring to immunity, this is specifically the chance that one becomes immune if they recover from an infection.

3 Results and Discussion

Figure 1 shows that the immunity rate impacts the death toll. When the population had zero immunity to the virus, on average 114 people (2.9% of the population) died, whereas when the population became immune after infection with 100% probability, only 64 people (1.6% of population) died. This illustrates how, when extrapolated to the real world, the immunity rate may be a significant factor in the eventual virus death toll.

Interestingly, there was no apparent correlation between immunity level and virus lifetime. In theory one would expect that if there is less immunity to the virus, people would continue to become reinfected into the future, and so the virus would remain present in the population for longer. This was not the case in the simulations, illustrating the simplicity of the model.

The percentage of the population that contracted the virus at least once decreased surprisingly little as immunity increased; 60% of the population contracted the virus at least once when the population had zero immunity versus 48% when the population had full immunity after infection. This implies that a large proportion of deaths must be from people becoming reinfected. Figure 2 shows the high correlation between the number of deaths and the average number of infections per person. In summary, sustaining multiple infections increases the probability of dying from COVID-19.

If COVID-19 continues to infect people across the world and no vaccine becomes available, the immunity level may be responsible for many lives. In the worst case, where immunity wanes and people become susceptible again after a period of

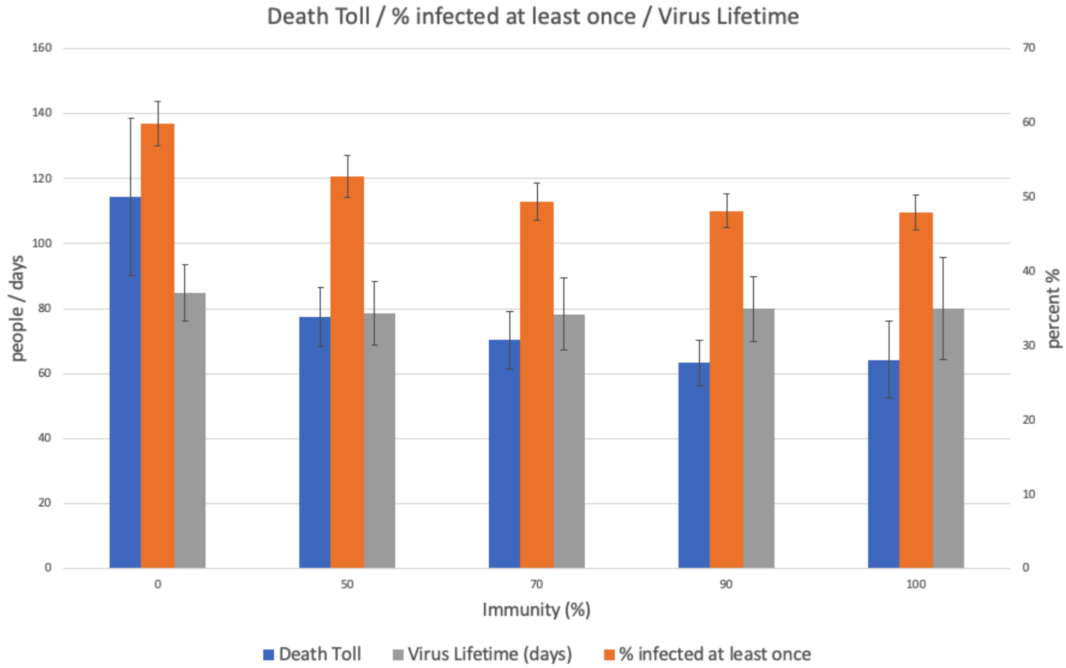

Figure 1: As immunity increases, a downward trend can be seen in death toll and percentage of population infected. Standard deviation bars are also shown.

time, the death toll of the virus could be much higher than anticipated. If an immunity level of 70% or greater is sustained, the findings in this study suggest that the overall death toll would not be increased to a great extent.

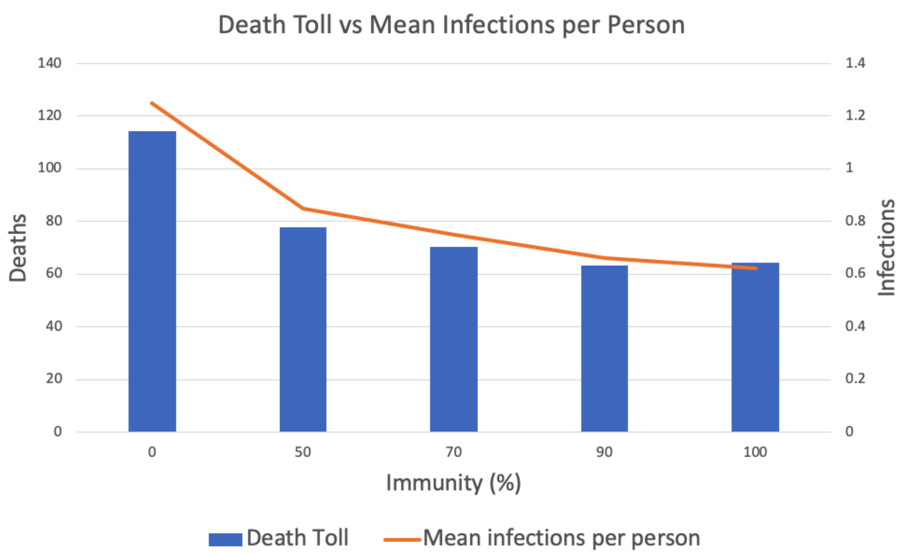

Figure 2: A strong correlation between the number of infections per person and the death toll is shown

References

[1] Takuya Sekine, André Perez-Potti. (2020). *Robust T cell immunity in convalescent individuals with asymptomatic or mild COVID-19*. bioRxiv 2020.06.29.174888; doi: https://doi.org/10.1101/2020.06.29.174888

[2] Jeffrey Seow, Carl Graham. (2020) *Longitudinal evaluation and decline of antibody responses in SARS-CoV-2 infection*. medRxiv 2020.07.09.20148429; doi: https://doi.org/10.1101/2020.07.09.20148429