The strategy against COVID-19 spreading depends on mathematical modeling—but how?

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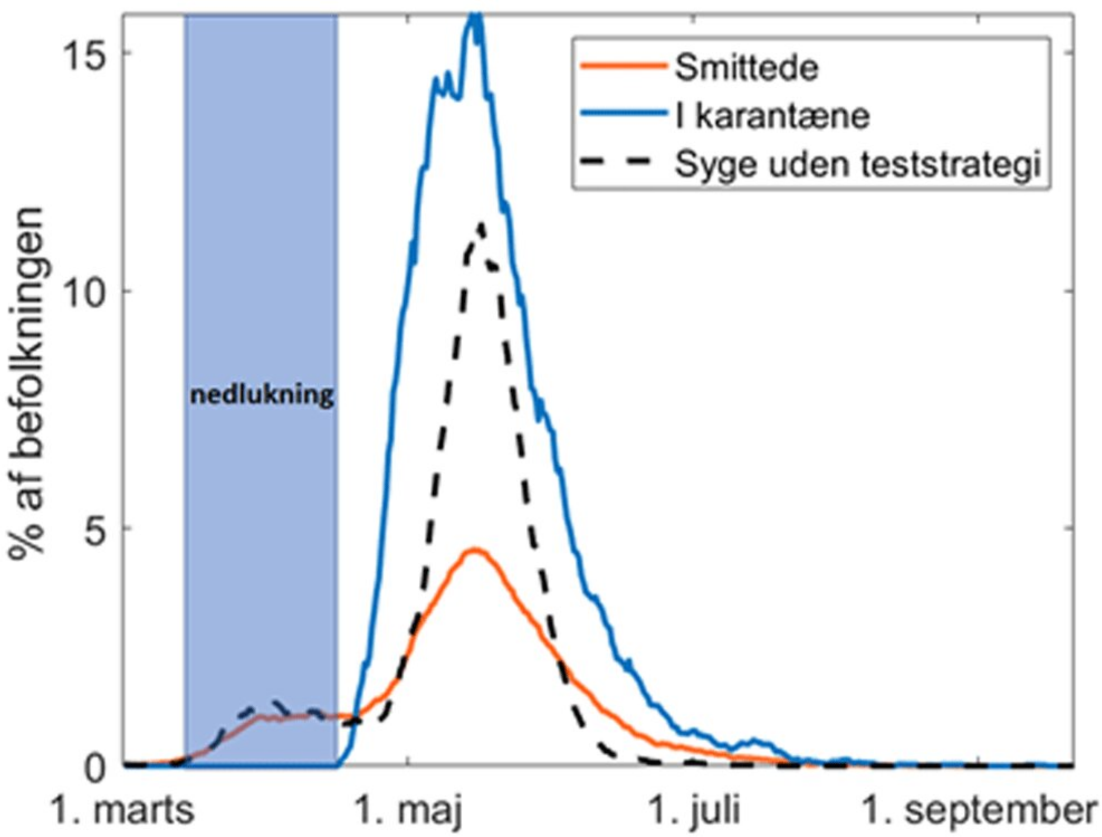

Figure 1: Comparison between two scenarios: With lock down, test and contact tracing and without test and contact tracing. The orange line shows the number of ill people in the scenario with contact tracing, and the blue line shows the number of people in quarantine. The dotted line shows the number of people ill

in the scenario without tracing infection. The X axis is % of the Danish population. Credit: Niels Bohr Institute

COVID-19 is presently impacting the entire world and different approaches to stopping the epidemic are tested around the globe. As weeks pass by, we learn more and more about this little virus, which affects our everyday lives and our world so much. In the biocomplexity section at the Niels Bohr Institute (NBI), University of Copenhagen, the researchers are busy applying methods from the physics of complex systems to examine how the epidemic is best handled. The, by now, well known and simplest manner is the "lock down," which we've been going through during the months of March and April. It is also the most expensive, it proved to be efficient, something we couldn't know before testing it. But there are many ways of calculating and forecasting the development of the epidemic, and the researchers in biocomplexity and complex systems explain one of them here, as well as some of the most prevalent concepts presented in the media.

Agent based mathematical models

At the Niels Bohr Institute, we work with many methods, one of them being the so-called agent-based models, in which individual persons are surveyed, as they meet other persons and possibly contract the disease. This is contrary to usual epidemic-models, in which only effects on population-level can be examined. These models allow, through data on individual person's networks, for the examination of a wider class of strategies. Especially the behavior of individual persons, like how many friends or family members they are around, their daily routines of movement and the like. The usual epidemic-models are far less detailed and won't allow us to catch the effect of all the individual changes in behavior we are all making these days.

We have worked closely with the effect of contact-tracking and quarantine. Preliminary calculations from the NBI group indicate that you can reduce the top of the epidemic with app. 50%, if using simple contact tracking and 5 day isolation of recent contacts to a confirmed sick person. As long as the infected person is in isolation at home, he/she doesn't contribute significantly to spreading COVID-19.

The effect of this "contact and quarantine" strategy is illustrated in Fig 1.

The figure compares the number of infected in a situation in which society is opened up completely to a situation where contact tracing is applied simultaneously with a complete opening. It is important to note that the number of infected can be kept further down still, if we maintain some of the infection reducing measures we know already, such as hand hygiene and limiting large assemblies. Contact tracing is not a measure to be applied alone.

Agent-based models are universal tools

Other strategies to limit the spreading of the disease can also be examined with agent-based models. Vulnerable groups of people can be isolated in order to protect them from the disease and to reduce the need for intensive care significantly. Preliminary simulations indicate that if all persons above the age of 60 reduce their social contacts with 75%, it reduces the maximum pressure on intensive care units to only a third. If grandparents on top of this choose to isolate themselves from their grandchildren, it most likely reduces the need for intensive care with another 50%.

The goal above all else for any strategy to limit the spreading of the disease is, of course, to ,reduce the pressure on health care systems, when the epidemic peaks. A telling fact for the importance of these calculations of the COVID-19 epidemic is that if nothing was done, the need for intensive care beds would be app. 10.000, - and our capacity is only app. 500.

The uncertain parameters for the disease

If you would like to understand the many uncertain predictions in the media these days, it is a great advantage to know the most important parameters for the COVID-19 epidemic. Below the three most important parameters are explained.

The growth rate of the disease

The growth rate is directly linked to the probability of infection when two people meet. The growth rate quite simply says with how many percent the epidemic grows per day. This parameter is estimated from the number of hospital admission in Denmark. Globally it is best estimated from the growth in the number of mortalities per day. Internationally the level in each country was 20% - 40% in the beginning of the epidemic, - highest in Italy and Spain. A percentage this size is characteristic for the exponential growth of an epidemic out of control. Physical distancing and lock down is all about limiting the amount of contacts, by which this rate should decline.

The infection pressure—the famous R

R describes the average number of persons infected by each infected individual. R is proportional to the probability of infection when two people meet. R is calculated from the growth rate and the time it takes from a person is infected until he/she infects again. This timeslot is still uncertain, but estimated to be between 3 and 7 days. The shorter the interval, the smaller will R be. A small R number is good, as it results in a lower maximum for the epidemic, and it becomes easier for a population to reach herd-immunity. With R = 2, in principle we "just" need to halve our social contacts to reach R = 1 where the epidemic starts to die out. With R = 4 we'd have to reduce our social contacts four times as much. Our general behavior would have to change significantly, if R is bigger. This is why different values of R mean so much for how models ar calibrated, and for how we should evaluate our lockdown in March. The best assessment right now is that the infection pressure R fell from app. 3 to app. 0.7 during our lockdown.

The dark figure

The dark figure is an indication of how many more infected individuals there are, than what we know of. It depends on how and how much we test, and will vary from country to country. Serum tests, showing if people have produced antibodies against the disease are very useful, because they will tell us how many have had the disease. The dark figure is not important for predictions in the beginning of an epidemic, but it is extremely important later, in order to assess where we are in the duration of the epidemic. A large dark figure will say that the disease is less dangerous and that we are closer to herd-immunity. The Norwegian authorities estimate that the dark figure is so high that only 3 in 1000 will die when infected.

These parameters are used in epidemic models of all types, so not only in agent-based models. When we wish to examine strategies depending on networks and social behavior, the agent-based models are particularly useful. As more precise data become available, we hope to be able to produce even better models, yielding more precise predictions of the development of the epidemic.

Provided by Niels Bohr Institute