A concise remark about the apparent growing lethality of Covid-19 and about the lockdown effects

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Luca Leuzzi (1,2), Enzo Marinari (1,2,3), Giorgio Parisi (1,2,3) and Federico Ricci-Tersenghi (1,2,3)

(1) Sapienza University of Rome, (2) CNR — Nanotec, Rome Unit, (3) INFN, Sezione di Roma 1

Data reported about the Covid-19 pandemics (for example by the John Hopkins University (a)) show that the time dependent, apparent lethality (defined as the cumulative number of deaths at a given day divided by the cumulative number of detected infected people at the same day) increases with time for many countries. For example our starting point could be the observation that in Italy the apparent lethality has increased by 20% in the last month.

A few preliminary, cautionary remarks are in order. First, we have no reasons to believe that what we call here the "apparent lethality" is in any way close to the real lethality of Covid-19. We do not know, indeed, at all, how many individuals have been really infected in the population (and this is, at the present point of the progress of the pandemics, one of the things that we would really like to learn soon). What we know is the number of positive answers that we get from tests daily made in a given number, according to a specific protocol. The real number of infected people is surely far larger than that and, as a consequence, the real lethality is probably smaller than the one we quote here. This is not a problem with our line of reasoning, since we do not care about an absolute normalization, as far as the protocols used for testing do not change during time in a substantial way (sometimes they did change in the past and, indeed, this is slightly visible at some points in the data; however the effect on the large time behavior we are looking at is not important and these variations can be ignored). Moreover, we can compare different countries as far as the protocols for testing in these countries and the number of tests performed are not too different (in practice they are different and this can, for sure, explain some of the differences we observe; we will comment about this further on). It has been recently discussed that also the number of deaths is surely underestimated but, probably, by a smaller factor with respect to infected people. Apart from some dramatic situations, the number of deaths is in average underestimated (b) by a factor close to two or smaller, while the number of infected is probably underestimated by a far larger amount (and we expect it to depend strongly on time).

It is clear that the increase of lethality over time does not match our expectations and, if real, it would mean very bad news. During the pandemic crisis new skills are developed, the appropriate use of medicaments is improved thanks to the clinical experience, and even the saturation and organization problems that some health systems have experienced in different countries cannot explain a persistent growth of lethality.

Figure 1: Effective, time dependent lethality as a function of time for different countries. On the horizontal axis, the day of year 2020, where 1 is for the first of January

We show in Figure 1 the effective, time dependent lethality, as a function of time (on the x axis we show the day of the year) for different countries. One can easily see that there is a clear, strong increase of this estimate of lethality, for all the countries we have analyzed. The overall lethality spans a broad range of values (and this can depend in part on the way different countries measure and report Covid-19 related deaths and infected people), but for all countries the increase is clear, and substantial. The data have interesting features. For example, in countries with a low effective lethality we observe much smaller intrinsic fluctuations, as opposed to the majority of high lethality (c) countries (compare for example data for Germany or Switzerland to data for Sweden or France).

In the period of 50 days shown in Figure 1 the estimated lethality grows by a huge factor, for example 3 for Spain and 4 for the UK. This does not make any sense at first view. In the following we give a very reasonable explanation of what we believe is really happening, and we will see that it makes indeed sense. We cannot be sure that it is the right answer, but we believe that it is a very appropriate educated guess. Exactly the same argument may be applied to the situation in Wuhan, at the start of the epidemic, when the lethality was estimated to be among 4 and 5 percent (as compared to 0.9 percent in the rest of China).

So, let us try to understand why the effective lethality depends so much on the date. We will give here a qualitative explanation, but formulas supporting our reasoning are not too complicated. Let us assume, to simplify our exposition, that deaths always arrive 12 days after the illness has been confirmed by a test (this is an oversimplification, since the actual delay varies a lot between patients, but results do not depend on this assumption). We also assume, for sake of simplicity (it is trivial to generalize the reasoning to different situations) that in the initial phase of the epidemics the number of infected people doubles every three days (exponential increase with a doubling time equal to 3 days). So if we have, for example, a true lethality of 1% we expect to see today a number of deaths equal to the number of people that got tested **twelve days ago** times 0.01. If we assume that we have perfect efficiency of our test system (an ideal situation very far from the real one), where every day we check the entire population, the number of detected infections is equal to the true number of infections. In this case the number of (detected and true) infections 12 days before was 16 times smaller than the number of infections we have today (doubling is every three days, and in 12 days we got the time to have 4 doubling periods, i.e. a factor 2 times 2 times 2 times 2 equal to 16). So in these conditions, under a steady exponential growth, the effective lethality that we measure under a complete detection of infections and deaths is 1/16 of the true 1%, i.e., 0.0625 percent.

Now, what happens when the exponential increase slows down, for example thanks to containment prescriptions and the end of the epidemics hopefully approaches? Clearly in this situation the lethality estimated by dividing the number of deaths by the number of infected in the same day approaches the true value. That is, the lethality becomes accurately estimated at large times. Let us repeat that in our case we have a constant factor between effective and real lethality that we cannot account for, since we do not really know the number of infected people. But what we can say is that when we are out from the regime of exponential growth the day by day estimates of the lethality tend to a constant, that we will be able to connect to the true Covid-19 lethality when we will have a fair estimate of the number of infections.

So, the regime of exponential growth causes an underestimate of the lethality and when the exponential growth stops, then the effective lethality increases and approaches a plateau. The flattening of the effective, time dependent lethality is thus a signal that the epidemic is in a steady state, that it has stopped growing. And this is the case for all the countries with a high effective lethality (those shown in the upper part of Figure 1). The evolution for countries with a very low effective lethality (e.g. Germany, Switzerland and USA) is smoother, so the distinction between the growing regime and the plateau is less clear. Nonetheless, we find the general result, and this is remarkable, that **the apparent increase of the effective lethality is connected with the decrease of the strength of the epidemics**. Again, the fact that the estimated value is high is not relevant till we measure with good accuracy the number of infections: probably when we will be able to get precise estimates it will turn out that the number of infections is underestimated by a factor of order ten.

Figure 2: Estimating the evolution of the effective lethality through the simple model of reference Orange curve: the new infections estimated in Italy via the model (scaled down by a million) have a peak at the day of the lockdown (March 11th). Blue curve: the effective, time dependent lethality grows a lot while the epidemic is becoming weaker.

We can substantiate our reasoning thanks to a very simple model that has been recently proposed (d) to describe the post lockdown slowing down of the epidemics. Such mathematical model, as applied to Italy, was useful to try to estimate the effects of lockdown (the complete nation-wide lockdown started in Italy on March 11th, 2020, and the model was used to qualify the situation on April 10th: at that day it gave a very accurate description of the situation and consistent results). In short, in this model one implements an exponential growth before lockdown with two different growth rates: a faster one before the so-called “red zones” were closed (February 26th) and a slower one after that date. The two growth rates were learned from the data. After the complete lockdown four different scenarios of the epidemics were proposed, decreasing with different rates, and the optimal scenario was determined by consistency with the actual data. On April 10th the answer to the question was that yes, the model was describing very accurately the available data, when using a time of 7 days for the halving of daily deaths (probably this number would be slightly higher if estimated today). We show with the orange curve in Figure 2 the evolution of the number of infected people in the model (scaled by a factor one million).

In order to check the ideas that we are presenting here we have computed the effective, time dependent lethality that such a model, trained on the real data, would imply. We divided the number of deaths predicted by the model times the number of detected positive cases. Again we do not know the global normalization of the number of infections, and we can only look at how they change in time: the global scale is, thus, arbitrary. We show the effective, time dependent lethality implied by the model in Figure 2 with a blue curve. Exactly how it happens in real data the day by day effective lethality estimated by the model grows with time after the lockdown when the epidemics is slowing down. We believe that this does, hopefully, completely clarify the situation.

Figure 3: Number of deaths as a function of days from the lockdown, normalized to the number of deaths on the day of the lockdown.

We also add a second remark, trying to quantify the effect of lockdown in different countries. Very interesting analysis about lockdown effects have been done by Serena Bradde and Benedetta Cerruti (e) and by Pedro Fonseca (f). They use a different normalization from us, and obtain results that look nicely complementary to ours. We base again our analysis on the data collected by John Hopkins University, while getting the lockdown dates from the Aura Vision's Lockdown Tracker (g). How did lockdown influence the progression of the number of deaths? In order to double check our results we normalize the total number of deaths both to the number of deaths at the moment of lockdown (if lockdown was implemented at zero deaths we normalize to one) and to the number of deaths at the tenth day after lockdown. We show the two sets of curves in Figures 3 and 4.

Figure 4: As in figure 3, but the number of deaths are normalized by those on the tenth day after lockdown.

Figures 3 and 4 are indeed very similar, showing that the choice of the moment we use to normalize our data is reasonably irrelevant. We see that **a group of countries** (Germany, Italy, Switzerland, UK and in some measure Spain) **seem to have**

reacted in a very similar way, while in other countries the growth of the number of deaths compared to the day of lockdown (or to ten days later) has been faster. Clearly there are large possible sources of errors and different ways to read such lockdown data, but we believe that the analysis of this behavior offers interesting perspectives.

Acknowledgments

This note has been written using data from May 3, 2020, from the github repository https://raw.githubusercontent.com/CSSEGISandData/COVID-19/master/csse_covid_19_data/csse_covid_19_time_series/

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References and footnotes

(a) https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6 These are the data that we will use in the present analysis.

(b) See for example E. Bucci, L. Leuzzi, E. Marinari, G. Parisi, and F. Ricci Tersenghi, "An estimate of direct and indirect deaths related to the COVID-19 epidemic in Italy", https://medium.com/@riccife/an-estimate-of-direct-and-indirect-deaths-related-to-the-covid-19-epidemic-in-italy-97a13c078df9 and references therein.

(c) Belgium systematically includes in deaths counting "suspected cases", i.e. people with Covid-19 clear symptoms but without certification. https://www.brusselstimes.com/all-news/belgium-all-news/106454/coronavirus-why-belgium-also-counts-suspected-deaths/ .

(d) Enzo Marinari, Giorgio Parisi e Federico Ricci Tersenghi, Il confinamento ci sta aiutando, e molto, su scienzainrete, 10/4/2020 (in Italian), https://www.scienzainrete.it/articolo/confinamento-ci-sta-aiutando-e-molto/enzo-marinari-giorgio-parisi-federico-ricci-tersenghi .

(e) https://medium.com/@benedetta.cerruti/the-lockdown-general-and-special-effects-57a74ee74888 and https://medium.com/@benedetta.cerruti/critical-response-time-e66cf1907cde .

(f) Private communication to Giorgio Parisi and https://www.facebook.com/groups/PhysicistsAgainstSARSCoV2/permalink/838298906662037/ https://www.facebook.com/groups/PhysicistsAgainstSARSCoV2/permalink/838716663286928/ .

(g) https://auravision.ai/covid19-lockdown-tracker/ . For Germany we use the lockdown date of March 23, since this is when a full lockout was really implemented in the majority of the Laender.