

Early-death weeks associated with COVID-19: a comparison among France, the UK and the USA

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ABSTRACT

Background Years of life lost (YLL) is recently used as a more insightful indicator to assess the mortality impact of COVID-19. However, this indicator still has methodological limits. This study aims to propose an alternative approach and new index, early-death weeks.

Methods The natural mortality and social mortality laws were employed to support two essential assumptions: the sequential and translational early-mortality patterns of COVID-19. This approach was then used with the data related to COVID-19 to calculate early-death weeks associated with COVID-19 in France, the UK and the USA.

Results As of week 20 of 2021, the rate of the total number of early-death weeks per the population of the USA is nearly two times compared to that of France and the UK, with 0.004% to 0.0021 and 0.0023%, respectively. The average numbers of early-death weeks after converting to units of years are 1.2, 1.0 and 1.3 years in France, the UK and the USA, respectively.

Conclusions The new approach is significantly different from death counts, excess deaths and YLL. The early-death week index provides more insights into COVID-19 and can be applied promptly at any time as well as anywhere once excess deaths have occurred.

Keywords COVID-19, early-death week, early-mortality model, sequential pattern, weeks of life lost

Introduction

Death counts associated with the new coronavirus SARS-CoV-2 (COVID-19) is at present still one of the key indicators to reflect the global catastrophic impacts of the ongoing pandemic.¹ Another indicator is the number of excess deaths which are indirectly measured by *excess mortality* method.^{2,3} This is defined as measuring the total number of deaths from all causes during a given time above the predicted number of deaths under normal conditions. This indicator has been urged for usage since the early months of the pandemic⁴ and was then officially guided by the WHO agency⁵ unfortunately most developing countries do not publish such statistics.⁶

Recently, several remarkable studies used the *years of life lost* (YLL)⁷ approach to overcome shortcomings of the excess mortality method, which treats all the COVID-19 related deaths as homogeneous instead of heterogeneous in ages and health conditions. Noticeably, a study has calculated YLL due to COVID-19 in 81 countries and reported that the average YLL per the COVID-19 death is 16 years.⁸ Due to YLL only being calculated from different life expectancies at each death, other studies modeled the mortality impacts of comorbidity to adjust the YLL of those who died from COVID-1,^{9,10}

especially took the advantage of the available individual-level data on comorbidities to calculate the adjusted YLL due to COVID-19, which is 1.3 years per death after adjusting for 11 comorbidities.¹¹

However, the YLL and adjusted YLL methods still have other methodological limitations beyond those as listed by the authors. First, these methods ignore the environmental changes (e.g., forest fires and air pollution) and medical/healthcare progress that affect life expectancy over time. For example, the potential YLL of a specific COVID-19 patient would vary between before and after the vaccine availability. Second, both methods have to set an upper reference age or life expectancy that is heterogeneous across the populations (e.g., commonly set at age 75) and is essentially arbitrary. Further, YLL does not take into account the case if a person is older than the reference age when they die since that person's YLL is set to zero. Third, YLL relies heavily on the historical statistical data of the mortality of severe diseases, which is often inconsistent over time and also heterogeneous

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across countries/geographies, Fourth, only a selected number of comorbidities (normally the top 11 severe diseases) is accounted for in calculating the adjusted YLL, while omitting others (e.g., in the top 20 diseases), especially for those deaths with multi-comorbidities. Fifth, COVID-19 also causes death to people whose death certificate indicates COVID-19 as the only cause mentioned, but these deaths were not properly taken into account in calculating YLL.

In this study, we introduce an alternative approach that considers the COVID-19 deaths as *early deaths* that occurred sooner than predicted and develop a new index to measure the mortality of COVID-19 in units of weeks rather than of years. Another goal is to provide a model that can be widely adopted to the different national contexts with its aggregate data so that a better comparison of the impact of COVID-19 globally can be facilitated.

Methods

We clarify all COVID-19 associated deaths from those belonging to two categories: unhealthy and healthy people. The unhealthy people are usually at the age of 64 or older and/or who have more than one pre-existing severe disease (e.g., hypertensive disease, diabetes), which are quite consistently clarified and reported across key health organizations, such as WHO,⁶ the US National Center for Health Statistics,¹² and the Public Health England.¹³ Meanwhile, the healthy people are those at the age below 64 and/or having no pre-existing health condition. We employ the *natural mortality* and *social mortality* laws to support the two essential assumptions: the sequential and translational early-mortality patterns of COVID-19. The sequential early-mortality patterns assumed COVID-19 only causes deaths weekly to all those who would have died in the nearest weeks and brought them forward sequentially at least one week (see Table 1). The translational early-mortality patterns assumed COVID-19 only kill people who would have died in the *deflationary period* of the pandemic while leaving others to die under the natural mortality law in the ongoing *inflationary period* (see Table 2). The additional details on this approach are available in Supplementary Material (SM). We then used the data related to COVID-19 from week 4 of 2020 to week 20 of 2021 to calculate early-death weeks associated with COVID-19 in France, the UK and the USA.

Data

To illustrating the above model, we employed data related to COVID-19 in France, the UK and the USA to measure the mortality burden of COVID-19 by two new indicators, the early-death week (eDW) index and its rate. Data for calculating

two other indicators, death counts and excess deaths, were also employed to enable comparison. Specifically, the main related data were retrieved from the same open-source, the Human Mortality Database (HMD),¹⁴ which includes detailed information on the total number of deaths, excess mortality and death rates. This supports calculation that is free of inconsistency in original input data or standardized format from various national sources, especially with available data of excess mortality. The data on death counts were retrieved from WHO at week 20 ending on 23 May 2021.¹⁵ The total number of excess deaths was selected through to week 20 of 2021 and compared to the period of 2015–2019 from the STMF visualization toolkit (see details in SM).¹⁶ The national life expectancies were retrieved from The Global Health Observatory.¹⁷

Results

As of week 20 of 2021, there were a total number of 5 959 044, 5 785 440 and 54 319 440 eDWs associated with COVID-19 in France, the UK and the USA, respectively. These numbers reflect the overall mortality burden of the COVID-19 pandemic in units of weeks or the cumulative eDW of the population. The three corresponding rates of eDW compared to that of the other conventional metrics were tabulated as in Table 3 for convenient comparison.

Table 3 shows a brief view of the evolution of the measurement of the mortality of COVID-19 and the difference of the most basic indicators in the three selected countries. Although calculating eDW is the main aim of this section, a comparison to the other two indicators in this table provides more outcomes that need further discussion. First, the total number of eDW in the USA is almost ten times higher than that in both France and the UK. This ratio is a particularly high level if compared to the corresponding ratios of excess deaths and death counts, around seven and five times, respectively. Meanwhile, the eDW rate of the USA is not so high, only two times compared to that of France and a bit lower than that of the UK. The value of the eDW rate of the USA implies that its population has lost 0.004% of the total *week-life expectancy*.

Second, although the comparison ratios of the eDW rate between the USA and the other two countries is quite different from that of the excess death rate, their rank in mortality level does not change. This seems to further prove that the varied length of the COVID-19 outbreak and its different number of waves occurring across countries do not affect the total number of eDW. Counting the number of weeks having excess deaths until week 20 of 2021, COVID-19 has

Table 1 Sequential early-mortality pattern of COVID-19

<i>Actual deaths</i>	<i>Pandemic time frame</i>											
Excess death counts associated with COVID-19	w3							<i>Observed week</i>				
	w3	w5	w6			w9						
	w2	w3	w5	w6	w8	w9	w10					
Predicted death counts of unhealthy people	1w	1w	1w	2w	2w	2w	3w	3w	3w			
		1w	1w	2w	2w	2w	2w	3w	3w			
		1w	1w	1w	2w	2w	2w	3w	3w			
		1w	1w	1w	2w	2w	2w	2w	3w			
Week	w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w(n-1)	wn

Notes: The area of ongoing excess deaths shows the details of weekly early deaths from later weeks, in which, each cell indicates the specific later week the early deaths come from. The area of predicted death counts shows a distribution sample of the early deaths by week, in which, each cell indicates how many weeks a specific early death was brought forward weekly, and included cells that are bold-italic formatted, implying contribution to the area of excess deaths.

Table 2 Translational early-mortality pattern of COVID-19

<i>Actual deaths</i>	<i>Pandemic time frame</i>															
Excess death counts associated with COVID-19	w9							<i>Observed week</i>								
	w9	w10	w11			w13										
	w8	w9	w10	w11	w12	w13	w14									
Predicted death counts by unhealthy people								7w	7w	7w	7w	7w	7w	7w		
								7w	7w	7w		7w				
								7w								
Week	w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12	w13	w14	w(n-1)	wn

Notes: The area of ongoing excess deaths shows the weekly early deaths, which are brought forward the same seven weeks from the future weekly period (in the bold shade area), respectively. Specifically, all early deaths at week w1 are those who would have died at week w8, early deaths at week w2 are those who would have died at week w9. Similarly, this continues through the early deaths at week w7 (are those who would have died at week w14) until ending the excess death period.

been in the USA, the UK and France for 70, 51 and 63 weeks, respectively (see details in SM).

Third, there is a significant difference in the number of death counts compared to the excess deaths between the USA and the other two countries. The confirmed cases in the former might lack in being recorded in a timely manner or may be overlooked so that its rate is lower than that of the latter. Meanwhile, the higher number of cases in the latter may suggest issues in over-recording or biased statistics of

COVID-19 as a cause of death to those who died from other diseases, which have similar symptoms. This once again proves that counting raw deaths is less reliable.

Table 3 only shows the total number of eDW associated with COVID-19 instead of each early death's eDW. However, due to 94 588, 113 440 and 775 992 excess deaths from the disease in France, the UK and the USA, respectively, then the average eDW of these deaths can be converted to early-death year by dividing by 52 (the standard number of weeks

Table 3 Total deaths, excess deaths and early-death weeks associated with COVID-19 in France, UK and the USA (through week 20 of 2021)^a

Country comparison	Death counts	Death count rate ^a (%)	Excess deaths ^b	Ex-deaths rate ^b (%)	Early-death weeks ^c	eDW rate ^c (%)
France	107 732	0.17	94 588	0.15	5 959 044	0.0021
UK ^d	127 716	0.21	113 440	0.19	5 785 440 ^e	0.0023
USA	583 696	0.18	775 992	0.24	54 319 440	0.0040

^aWeek 20 ends on 23 May 2021; the national populations were calculated based on data at week 1 of 2021 from the HMD (65 147 669, 59 647 563 and 329 523 336 people in France, the UK and the USA, respectively)¹³; the rates of death counts are per one million of people.

^bThe total number of excess deaths was selected through to week 20 of 2021 and compared to the period of 2015–2019 from the STMF visualization toolkit (see details in SM)¹⁵; the rates of death counts are per one million of people.

^cThese metrics were calculated by Exps (5) and (6); the national populations were calculated based on data at week 1 of 2021 from the HMD¹⁴; the national life expectancies are 82.48 years in France, 81.4 in the UK and 78.5 in the USA.¹⁷ Due to these metrics are calculated directly from the number of excess deaths, which is straightforward based on the source code available in the public repository;¹⁶ thus, there are not confidence intervals available.

^dInclude England and Wales.¹⁴

^eThe eDW of the UK in fact was intentionally only counted to week 9 of 2021 despite at week 19 recording a small number of excess deaths. The reason is from week 10 to 18 of 2021, the COVID-19 outbreak went into the deficit period.

in a year). So, the calculated results are 1.2, 1.0 and 1.3 years, respectively. These numbers are a bit lower than the estimation of the adjusted YLL method for a specific COVID-19 death after adjusting comorbidities, such as 1.3 years in Hungary,¹¹ but are much less than the estimation of the mere YLL in 81 countries as reported 16 years per the COVID-19 death.⁸

Discussion

The main findings of this study

The goal of this study is to introduce a new index, the early-death weeks and use this index to measure the mortality impact of COVID-19. The main findings were that from week 4 of 2020 to week 20 of 2021, COVID-19 has caused a total of 5 959 044, 5 785 440 and 54 319 440 eDWs in France, the UK and the USA, respectively. The average numbers of early-death weeks after converting to units of years are 1.2, 1.0 and 1.3 years, respectively. The rate of the total number of early-death weeks per the population of the USA is nearly two times compared to that of France and the UK, with 0.004% to 0.0021% and 0.0023%, respectively.

What is already known on this topic

Measuring the mortality effect of COVID-19 is a critical aspect of the ongoing pandemic. Due to a quick and accurate assessment of the disease's impact can assist the effective response of governments, scientists and health experts are calculating the excess deaths and YLL associated with COVID-19 besides counting the death toll. Although the excess death method can provide a rapid estimation of

COVID-19 mortality and the adjusted YLL method can provide a more accurate result, these methods have other limits.

The early-death week approach and index are the first time mentioned officially in this study to the best of our knowledge. Our index also measures mortality on a time scale but is totally different from the YLL method. Both the YLL and adjusted YLL methods require to set an upper reference age and rely on the historical statistical data of the mortality of diseases, while the eDW method does not. Further, the YLL methods have five significant limits as analyzed previously, especially in the case of the COVID-19 pandemic when the related data are often inadequate.

What this study adds

We developed a new index to assess the mortality effect of COVID-19 in a time scale of weeks and can overcome the limits of other methods. The eDW index was proved as a profound and rapid measure that can provide a more accurate and insightful assessment of the mortality impact of COVID-19, especially the index can be widely adopted to the different national contexts and the comparison of the impact of COVID-19 among the populations.

More specifically, we calculate the eDW of COVID-19 deaths in France, the UK and the USA and found that the eDW rate of the USA is significantly high, nearly two times compared to that of France and the UK. Meanwhile, the excess death rate of the USA is only a bit higher than that of France and the UK. Especially, the death count rate of the USA is even lower than that of the UK.

We also approved the varied length of the COVID-19 pandemic and its different number of waves occurring across three countries do not affect the total number of eDW, which does not present in the death counts, excess deaths and YLL methods. The average eDW of COVID-19 deaths in France, the UK and the USA after converting to early-death years are 1.2, 1.0 and 1.3 years, respectively. These numbers are much lower than the average result calculated by the YLL method in 81 countries, which reported 16 years per the COVID-19 death.⁸

By employing the eDW approach, our analyses provide critical insights into the mortality impact of the COVID-19 pandemic and the dead communication as well as a powerful index for assessing and comparing the pandemic's live damages among countries. Further, eDW will be vital to monitor the effect of COVID-19 and inform policy and clinical responses to the pandemic.

Another important aspect is that this method does not require complex calculations and formulas. This is probably the case fitted with the principle 'Ockham's razor' or 'the law of parsimony'¹⁸ as fewer assumptions coupled with simplified formulas for calculating eDW do better at reflecting the measurement of the mortality of COVID-19 in the time scale of weeks. Further, the most significant advantage is that the eDW index can be rapidly applied without waiting for the confirmed deaths like the excess deaths and YLL methods.

Limitations of this study

At the present form, the eDW approach and index also have temporary limits. First, in this study, the approach was not intentionally developed to support the calculation of the eDW of a specific COVID-19 death, which may be necessary for other purposes such as in pathology or clinical trials. Second, the approach also does not construct a model that supports estimating eDW in the coming months of the COVID-19 pandemic, which again is a feasible project but should be conducted in future research with further assumptions and procedures. Third, the eDW index can also be applied to more detailed components, such as calculating the eDW of men and women, unhealthy and healthy people and even of each age group, but the index again does not mention this aspect.

Otherwise, this study aims to introduce a novel methodology rather than a hypothetical model, the assumptions themselves are not calculations but rather means to create conditions for calculations. Thus, assessing the reliability and validity of the model may be a challenge. However, the results from applying the model and its index will ultimately be

evidence of their usefulness as George Box stated 'All models are wrong but some are useful.'¹⁹

Despite these limitations, the proposed eDW approach and index are not only a profound measure of COVID-19 mortality but can also be applied in other similar outbreaks or top diseases and can provide a strong basis for decisions about whether or not to impose a non-pharmaceutical intervention such as lockdown measures in a given place.

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This article has single author.

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Conflict of interest

The authors report no conflict of interest.

Data Availability Statements

The data underlying this article are available in the article and in its online supplementary material.

Ethical approval

Not applicable.

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