RESEARCH BRIEFS

Timing and Toll: Europe's Excess Mortality in the First Three Years of COVID-19

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Abstract

This study examines excess mortality patterns in 32 European countries during the first three years of the pandemic, offering insights into the pandemic's toll on each country. Using data from national statistical offices, we calculated monthly excess mortality for 2020–2022. Time series decomposition was employed for trend analysis, followed by clustering countries based on their mortality trends. Then we compared total excess mortality among different clusters. We found that neighboring countries with similar characteristics experienced comparable levels of excess mortality, regardless of the differences in their pandemic trajectories identified by cluster analysis. Other factors, such as healthcare infrastructure and pre-existing health risks, appear to have had a more significant impact on total excess mortality, with various pre-existing regional factors playing significant roles in shaping the pandemic's final toll. While the timing of peak excess mortality may have been a factor, it was not the primary driver of the overall toll. This study highlights the critical need for comprehensive public health strategies that focus on reinforcing healthcare infrastructure and mitigating pre-existing health risks, essential for effective pandemic preparedness and response. These findings suggest the need for reevaluating current approaches and exploring alternative strategies for managing future health emergencies.

Keywords SARS-CoV-2 · Excess mortality · Europe · Public health · Pandemic response · Health strategy

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Introduction

During the first three years of the COVID-19 pandemic (2020–2022), European countries tried various health measures to control the spread of the virus and thereby mitigate the negative consequences of the pandemic. The World Health Organization (WHO) called the end of the COVID-19 global health emergency on May 5th, 2023 (Rigby & Satija, 2023). Nevertheless, some measures were lifted long before this date, with people wanting to return to life as normal. The question arises as to what the total mortality consequences of the pandemic were and how different countries fared through the first three years of the pandemic. Detailed, cause-specific mortality data is not reliable and is not readily available across all countries of Europe (Marinković et al., 2023), which leaves excess mortality as the most reliable way to gauge how deadly the pandemic was during these three years.

By integrating monthly data from national vital statistics records from 2020 to 2022 and contrasting it with pre-pandemic trends (2016–2019), this study provides a detailed analysis of excess mortality trends, offering a comparative perspective across different European countries during the pandemic. We raise questions about the differences in these trends and the total relative excess mortality during the pandemic. This comparative analysis can help assess the effectiveness of various public health interventions and policies, offering insights into what worked and what did not in managing the pandemic's impact. Our research brief adds to the body of knowledge on the direct and indirect impacts of pandemics on mortality, serving as a foundation for further research on mortality during this period. This unique bird's eye view is important for understanding the full scope of the pandemic's impact, placing national-level studies of excess mortality into a broader context, and helping strategies for future global health emergencies.

Methodology

Data

The dataset for this study was compiled from national statistical offices. Average mortality values during the four pre-pandemic years (2016–2019) were used as expected mortality values to calculate excess mortality. Instead of the usual three-year or five-year intervals, four years were chosen because 2015, and to a lesser extent 2017, were burdened with above-average mortality during the winter months in Europe, most likely due to intensified influenza activity during those two seasons (Paget et al., 2019; Pebody et al., 2018). Therefore, the four-year period provides a more accurate baseline for excess mortality calculation. Excess mortality was calculated monthly for the years 2020, 2021, and 2022, as well as over the cumulative period from 2020 to 2022. This excess mortality was expressed as a relative measure, indicating the percentage increase over the expected mortality rates. We have opted for a percentage-based approach instead of more standard measures, such as excess mortality rates per 100,000 inhabitants because it does not rely on additional data (such as population estimates). However, in the Supplementary Information, we provided a

map and a table with excess mortality per 100.000 inhabitants (Online Resource 1), with underlying data available in spreadsheet format (Online Resource 2).

Statistical Analysis

Time series decomposition was performed on the monthly excess mortality data by country to separate trend and seasonal components, which was important to understand the underlying pattern. This decomposition was performed using the decompose function from the *stats* R package, which applies classical decomposition methods to a time series object with a specified frequency, in this case, 12, to denote monthly data. Following decomposition, the trend component was clustered to identify patterns across different countries using a dynamic time-warping algorithm. This method is particularly effective for clustering time series because it can find alignments between sequences that may vary in speed. Each time series was normalized before clustering to ensure that the magnitude of the data did not bias the clustering process but instead focused on the shape of the trend. Three clusters were specified a priori, based on preliminary data exploration (elbow method).

The Kruskal-Wallis test, a non-parametric method, was employed to assess statistical differences in excess mortality rates among different clusters of European countries. Following significant results from the Kruskal-Wallis test, a post-hoc Dunn test was conducted for cluster pairwise comparisons. The Dunn test was used to identify which specific pairs of groups differ in relative excess mortality, adjusting for multiple comparisons.

Reproducibility

All R code and data used in this study necessary for replication are available in an open online repository https://osf.io/mc428 .

Results

The analysis of COVID-19's impact across 32 European countries reveals three distinct clusters based on relative excess mortality rates (Fig. 1). These excess mortality trends can be viewed as translating to infection rates and reflect the efforts of the countries to control the spread of the virus. While it is important to recognize that each country had its unique journey through the pandemic, with a unique combination of demographic, socioeconomic, political, and other contextual factors, a distinct pattern emerges when looking at the trends of excess mortality during the pandemic. Countries in the first cluster had a distinct bell shape with an excess mortality trend starting low and then rising, only to decrease in the final year of the pandemic. This cluster was characteristic of the countries of Eastern Europe. The second cluster groups the countries with an upward trend starting from a lower point and with peak excess mortality in 2022. The third cluster groups countries that had a reversed trend, peaking in the first year of the pandemic and maintaining the downward trend.
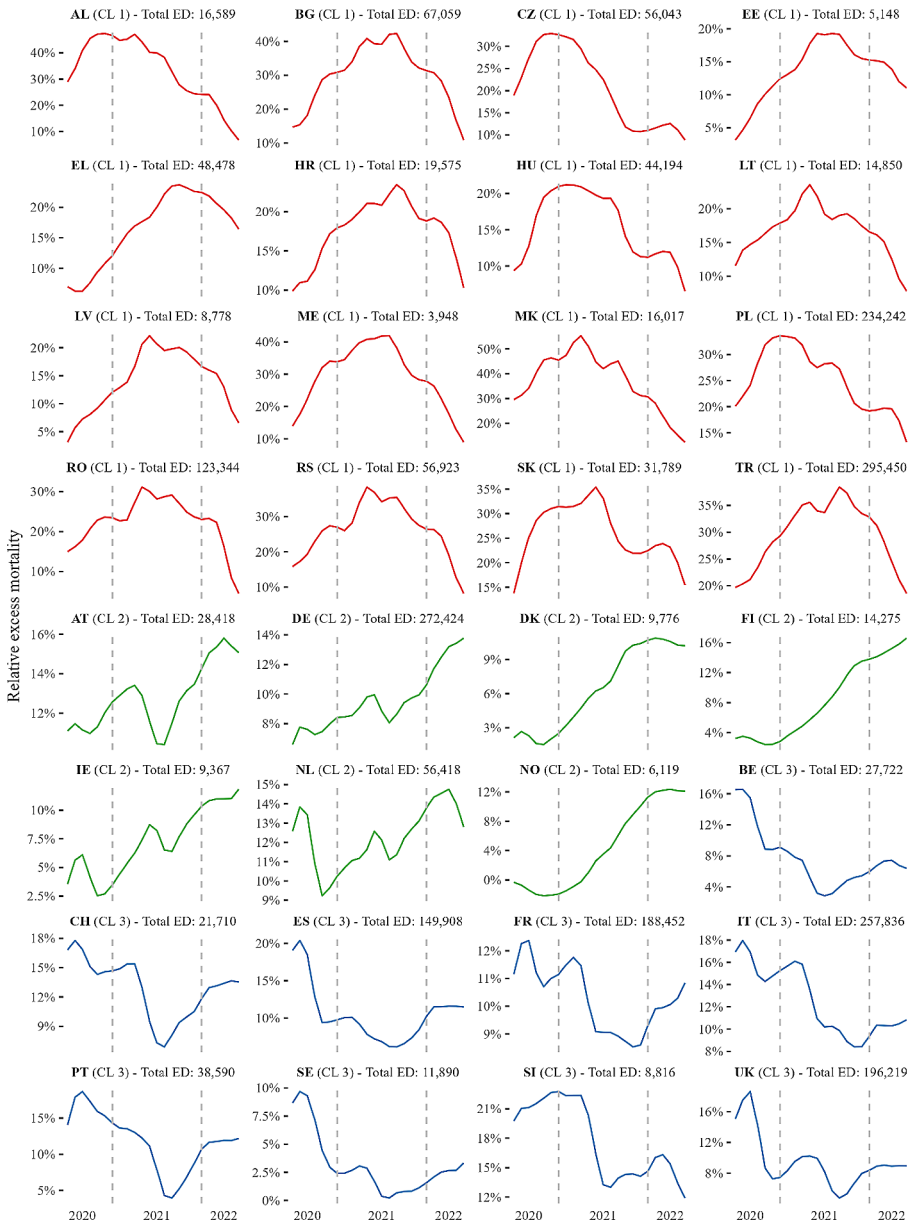
Fig. 1 Trend components of monthly relative excess mortality for 32 countries of Europe (2020–2022) by cluster. Note: CL – cluster; ED – excess deaths. The years are separated by the dashed lines. The initial and final years are truncated because the method used for time series decomposition relies on surrounding months to establish patterns

The Total Magnitude of Excess Mortality

There were statistically significant differences in total excess mortality between the three clusters (χ^2 (2) = 13.466, $p < 0.002$) (Fig. 2). Examined countries of Europe in which excess mortality peaked in 2021 (i.e., those that belong to cluster 1), on average, had much higher total excess mortality rates than those where mortality peaked in the first year ($p < 0.005$) and those where mortality peaked in the third year ($p < 0.001$). Differences in total excess mortality between clusters 2 and 3 were not statistically significant ($p < 0.212$).

Comparative Analysis

Given that countries belonging to the first cluster are similar to each other in many other ways than just having similar excess mortality trends and that there is no difference between the second and third clusters, a closer look and comparing like-with-like was merited. To further examine the timing of excessive mortality, we will compare several pairs of neighboring countries with different excess mortality trends during the pandemic but with a similar level of total excess mortality during the three years.

Sweden and Norway

Sweden chose not to restrict movement and economic activities, which resulted in increased mortality during the first year of the pandemic. However, later, the figures showed a steady decline. Norway implemented measures to contain the spread of the virus among its population. However, the excess mortality was high in 2022, thus bringing these two Scandinavian countries to almost equivalent relative excess mortality by the end of the third year of the pandemic.
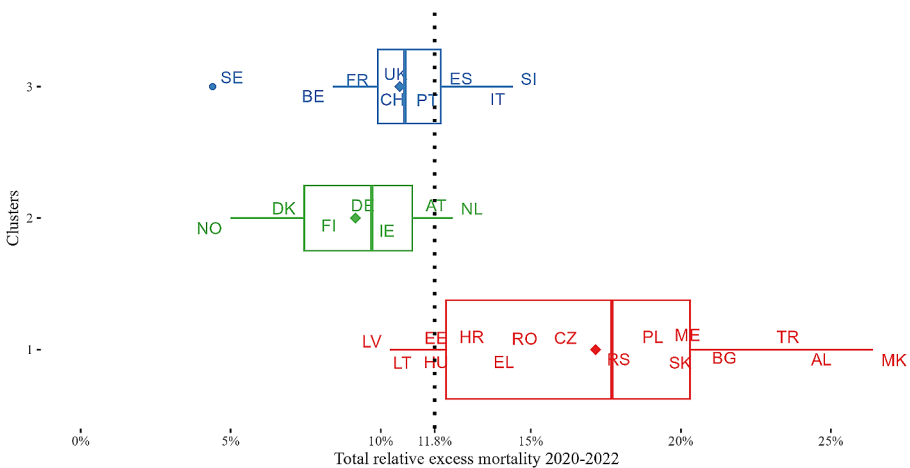

Fig. 2 Total relative excess mortality during the three pandemic years (2020–2022) by trend clusters

France and Germany

The two most populous countries of the European Union, France being the first exposed to the pandemic and Germany rigorously controlling the virus's spread. Both ended up with almost the same relative excess mortality.

The United Kingdom and Ireland

These two neighboring island countries had completely different excess mortality trends yet ended up with similar levels of relative excess mortality.

Italy and Greece, as Well as Austria and Hungary

Countries from the first and third, and first and second clusters, respectively. The populations in these countries were exposed to different virus strains at varying times, yet the final results are very similar.

Discussion

While our results indicate that the timing of the peak seems to matter at first glance, we need to reexamine our initial suppositions when we look closer at the countries that belong to the different clusters denoting the timing. Countries that experienced peak excess mortality in 2021 have fared much worse, as measured by the total excess mortality during these three years. This does not mean that they fared worse just because of the timing. These countries could have fared worse because of many different reasons. The same countries generally have lower life expectancy, less equipped healthcare infrastructure, and, in many cases, more vulnerable populations with a higher prevalence of smoking and diabetes, two key risk factors for COVID-19 (Morshed & Sarkar, 2021; Young-Wolff et al., 2023). These are also the countries where vaccine refusal and hesitancy were higher (Toshkov, 2023).

The differences between the second and third clusters that show opposite trends in excess mortality bring us to the question – Why have the countries that have managed to control the spread early on and countries that have not ended up with similar levels of excess mortality?

The restrictive measures not evident in Sweden did not make much difference in excess mortality compared to other countries in the North. Sweden had a comparatively lower death rate per capita than many other affluent countries that enforced more rigorous lockdown protocols (Björkman et al., 2023), especially at the start of the pandemic. The countries with peak excess mortality in the last year (2022) experienced similar excess mortality while having the benefit of both natural and vaccine immunity, similar health infrastructure capacities, and comparable levels of population vulnerability. In other words, why were these countries unable to escape the exacting death toll of the pandemic? It appears that the infection of the entire population was inevitable and that measures only succeeded in delaying the impact

of the pandemic. This also raises the question of whether lockdown was successful during the COVID-19 pandemic.

The combined toll of 2,340,366 excess deaths over the three years in the 32 countries studied highlights the severe impact of the pandemic. Our results show that timing was not the primary driver of different total excess mortality. A broader range of factors beyond immediate response strategies may influence the long-term impact of the pandemic. The total excess mortality toll might depend more on healthcare capacities and health risks in the population regionally established well before the pandemic rather than on the success of the countries in containing the virus.

The timing was shown to be irrelevant to total excess mortality when looking at the upward and downward trends of the second and third clusters, but it may still have played a role when it comes to countries of the first cluster. The excess mortality in the countries of the first cluster peaked during the deadliest SARS-CoV-2 variant, the delta variant (Liu et al., 2023). Compared to those countries that were exposed early on to the less deadly pre-delta variants or later to the post-delta omicron variants, which were the least deadly. Additionally, the level of population compliance with anti-COVID-19 measures and the extent of pandemic fatigue, particularly during the deadliest waves, undoubtedly played a role (Spira, 2022).

Limitations

The primary limitation of this research brief is its limited geographical scope, encompassing only European countries. While this provides valuable insights, it must be noted that the pandemic's impact is a global issue, and conclusions drawn from the European context may not be universally applicable. Monthly excess mortality data is challenging to come by, even for the countries of Europe, where an overarching institution (Eurostat) exists; this kind of data can be collected only by manually searching the national statistical offices.

The indicator of excess mortality requires previous mortality levels to be known, accurate, and representative. If one country had very high mortality in 2016–2019, the relative increase due to the pandemic would be smaller. This is particularly relevant for measuring total excess mortality and comparing its levels between countries.

Furthermore, the research brief primarily utilizes a univariate approach, focusing on excess mortality as the sole metric. While this is a robust measure amidst controversies regarding underreporting or overreporting of COVID-19 deaths, it is important to acknowledge that the complex nature of the pandemic might necessitate a more multifaceted analytical approach. Excess mortality remains an essential indicator despite these constraints, providing a consistent basis for cross-country comparisons during the pandemic, but it is important to acknowledge that other factors, such as local epidemics or climate events (such as heatwaves) can also affect excess mortality measures.

Conclusion

Our research into excess mortality trends across 32 European countries underscores the complexity and variability of COVID-19's consequences. Notably, the timing of peak excess mortality does not singularly dictate the overall impact; other factors, including healthcare infrastructure, pre-existing health risks, and public health responses, likely play deciding roles.

The similarities in total excess mortality among countries with divergent pandemic trajectories highlight the inevitable nature of COVID-19's spread and question the long-term effectiveness of restrictive measures. Despite varied approaches to managing the pandemic across different European countries, similar levels of excess mortality were observed, particularly among countries with different pandemic trajectories. This indicates the need for a reevaluation of current health emergency response strategies, focusing on what can be universally applied and what needs to be adapted to specific national or regional contexts. We highlight that other pre-existing factors, such as healthcare infrastructure, the population's vulnerability, and health behaviors, were more determinant of the pandemic's final toll than immediate response strategies. Future policies should prioritize strengthening healthcare systems, addressing non-communicable diseases, and promoting healthier lifestyles to mitigate the effects of future health crises.

Declarations

Ethics Approval The study did not require ethics approval.

Competing Interests The authors have no relevant financial or non-financial interests to disclose.

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