Early-Career Researcher Prize 2022

Ainhoa-Elena Leger and Silvia Rizzi

Estimating Excess Deaths in French and Spanish Regions During the First COVID-19 Wave with the Later/Earlier Method

A Word from the Jury President

Since 2015, the *Population* Early-Career Researcher Prize has been awarded to eligible researchers for their work. For the 2022 edition, the journal received nine manuscripts addressing a wide range of topics, including health and mortality, fertility, education, occupational trajectories, and the effects of the COVID-19 pandemic. Submissions covered different geographical contexts, including Africa, North America, Asia, and Europe. The number of submissions was lower this year, probably due to the particular health context since 2020.

After an initial screening, five manuscripts were shortlisted, each sent to two external reviewers. The whole review process was double blind. The jury met on 10 February 2022.

I am pleased to announce that the 2022 prize goes to Ainhoa-Elena Leger and Silvia Rizzi for their paper entitled 'Estimating Excess Deaths in French and Spanish Regions During the First COVID-19 Wave with the Later/Earlier Method'.

Following a detailed review of the methods for estimating excess mortality in the short term, Leger and Rizzi describe the 'later/earlier' method for estimating excess deaths in France and Spain during the COVID-19 pandemic. They meticulously analyse all-cause-of-death data during the first wave in both countries, producing informative results not only on pandemic-related excess mortality but also on differences in COVID-19 vulnerability for population subgroups and for specific regions. One key demonstration is that the later/earlier method is simple and requires fewer assumptions than other forecasting methods. It is also less biased and more accurate than the intuitive 5-year-average method.

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Authors of some of the shortlisted manuscripts have been invited to submit a revised version of their manuscript to the journal's editorial board.

I hope that you enjoy reading this article and that it will encourage many early-career researchers to compete for the 2023 award.

Jean-François KOBIANÉ

International Jury of the 2022 Competition

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Ainhoa-Elena Leger* and Silvia Rizzi*

Estimating Excess Deaths in French and Spanish Regions During the First COVID-19 Wave with the Later/Earlier Method

The 2019 coronavirus disease (COVID-19) spread across Europe in early 2020 and reached France and Spain in February 2020, posing serious challenges for the two countries, which have struggled to contain its spread and protect their health systems from collapsing. A mandatory national lockdown started in France and Spain in mid-March, and restrictions were gradually lifted from May onwards.

Since the onset of the pandemic, many online dashboards, such as those published by the World Health Organization, Johns Hopkins University, and Worldometer, have reported daily numbers of COVID-19 deaths. These measurements have mostly relied on summary data supplied by national governments and are not well suited for country comparability due to variations and changes over time in the definition of *COVID-19 death* and in the coverage of the data (Karanikolos and McKee, 2020; Garcia et al., 2021). Indeed, some countries such as Spain initially counted only confirmed COVID-19 deaths, while others such as France included suspected COVID-19 deaths. Furthermore, limited testing capacity led to reporting mainly hospital deaths, despite a significant number of COVID-19 deaths occurring in other settings, notably in care homes. At first, Spain included only hospital deaths in the death count (Jordan, 2020; Linde, 2020). France started to publish official death estimates for people in care homes on 31 March (Comas-Herrera et al., 2020). The estimates in care homes were added to the number of COVID-19-related deaths from 1 April, resulting in a spike in the number of reported deaths (Morgan et al., 2020).

A more comprehensive assessment of the impact of COVID-19 can be performed by estimating excess mortality, obtained as the difference between the observed number of deaths and the number of deaths that would be ex-

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pected had the COVID-19 pandemic not occurred. Excess mortality encompasses deaths from all causes, those directly due to COVID-19 but also those from other causes attributable to the overall crisis condition and thus indirectly to COVID-19 (Beaney et al., 2020). Therefore, excess mortality captures not only the confirmed deaths but also the COVID-19 deaths incorrectly diagnosed and reported. The literature suggests that although a similar number of confirmed COVID-19 deaths was reported in Spain and France, the excess deaths were quite different in these two countries during the first wave (Kontis et al., 2020; Morgan et al., 2020). Our study focuses on France and Spain and estimates the excess mortality between February and June 2020. The comparison of the excess deaths with the reported COVID-19 deaths might indicate the extent of the under-reporting and indirect effects of COVID-19.

Excess mortality has long been analysed to quantify the death toll of various health shocks, from the impact of seasonal influenza (Mazick et al., 2012; Mølbak et al., 2015; Nielsen et al., 2018) to the effects of heatwaves (Fouillet et al., 2006; Toulemon and Barbieri, 2008) and previous pandemics such as the Spanish flu of 1918 (Ansart et al., 2009). Estimates of excess mortality have been used to assess the impact of COVID-19 in different countries, both by major media outlets, such as the *Financial Times* (*FT* Visual and Data Journalism Team, 2020) and *The Economist* (2021), and academic literature (Félix-Cardoso et al., 2020; Kontis et al., 2020; Islam et al., 2021), using different methods to estimate the baseline mortality expected in the absence of the shock. Most of the literature on COVID-19 focuses on nationwide estimates of excess death, with little attention to the subnational level, despite the importance of the geographical component of the spread of the virus within countries (Rodríguez-Pose and Burlina, 2021). Concentrations of excess deaths in specific regions, during the first wave especially, were reported extensively for Italy (Alicandro et al., 2020; Blangiardo et al., 2020; Michelozzi et al., 2020; Scortichini et al., 2020). Evidence of regional differences in excess deaths has also been analysed for England (Sinnathamby et al., 2020), Sweden (Modig et al., 2021), and the United States (Weinberger et al., 2020). For France and Spain, estimates of excess deaths at the subnational level are more limited: results for French regions have been published by EuroMOMO (European Mortality Monitoring) for the first pandemic months (Fouillet et al., 2020), whereas for Spain there are no studies (to our knowledge) of excess death at the regional level. We provide empirical evidence about the burden of mortality potentially related to the first wave of COVID-19, focusing on French and Spanish regions by sex and age groups to analyse the differences in COVID-19 vulnerability for population subgroups and spatial areas.

I. Methods for forecasting expected deaths in the absence of health shocks

Excess mortality refers to the number of deaths above what one would expect to see under 'normal' conditions and is calculated by subtracting the expected number of deaths (or baseline deaths) from the observed number of deaths. As the number of expected deaths is not directly measurable, excess mortality relies on its estimation. Assuming that the incidence of other diseases remains steady over time, excess mortality can be viewed as those deaths caused both directly and indirectly by COVID-19 and gives a summary measure of the 'whole-system' impact. Excess mortality can then be standardized for age or population size to aid comparability between countries.

One approach to estimating expected deaths relies on the definition of epidemic and non-epidemic periods so that the difference in the observed mortality between the two periods represents an estimate of excess mortality. One uses the levels of weekly or monthly mortality registered in the same periods (to take into account the seasonality of the mortality) over some previous years. The most common method during the COVID-19 pandemic has been to use the average number of deaths over previous years—for example, the 5 most recent years—for the corresponding week or month when making the comparison (e.g. Morgan et al., 2020). The main advantage of this approach is that it is simple and requires few assumptions.

Other approaches replace the simple arithmetic mean with a model. Modelling brings some additional advantages, such as the possibility of directly including seasonal variation or of controlling for time-varying population size and age structure. If no shocks occur, mortality in temperate zones tends to follow a seasonal pattern over corresponding weeks each year, with the highest number of deaths occurring in the winter. Many factors contribute to seasonality, but influenza is recognized as a main contributing factor in winter excess mortality. Early research on the modelling of deaths, accounting for seasonal patterns of pneumonia and influenza deaths, was based on the Serfling (1963) method, usually fitted with a cyclic variation over the year. State-of-the-art approaches for quantifying the health burden of seasonal influenza are the autoregressive integrated moving-average method (Reichert et al., 2004; Nunes et al., 2011a, 2011b) and the Poisson regression method (Nielsen et al., 2011, 2018).

From the beginning of the pandemic, the 5-year-average method has been extensively used to compute baseline mortality in media outlets and in the scientific literature (Alicandro et al., 2020; Félix-Cardoso et al., 2020; Michelozzi et al., 2020; Morgan et al., 2020). *The Economist* has used projections based on a linear model with a seasonal term. In scientific publications, some authors have used linear models adjusting for seasonal variation and recent yearly trends (Karlinsky and Kobak, 2021); others have used a Poisson regression model accounting for seasonal variability (Weinberger et al., 2020), with different model specifications, e.g. allowing for smooth long-term and seasonal effects (Scortichini et al., 2020), using overdispersed Poisson regression (Islam et al., 2021), or accounting for temperature effects, autoregressive residuals, adjustments for bank holidays, and Bayesian inference (Kontis et al., 2020). The EuroMOMO network, which monitors excess deaths related to seasonal influenza and pandemics at the European level, uses a model based on a Poisson regression adjusted for a linear or non-linear trend and seasonal variation. Their model has been used in many studies during the COVID-19 pandemic (Fouillet et al., 2020; Michelozzi et al., 2020; Sinnathamby et al., 2020; Vestergaard et al., 2020).

We use the 'later/earlier method' introduced by Rizzi and Vaupel (2021), who applied it to estimate the excess mortality during the first COVID-19 wave in Denmark and Sweden. This method is comparable to the 5-year-average method in its simplicity, but it produced more accurate and less biased estimates. In this article, we estimate excess mortality in France and Spain during the first COVID-19 wave and investigate the validity of the later/earlier forecasting method. The method serves to produce short-term forecasts, from a few weeks to several months, after a major shock. In the application shown here, the forecasting period corresponds to the first COVID-19 wave. As the forecasts are made based on the past, the observed deaths are available for the same period, and excess deaths can be calculated by subtracting the expected deaths from the observed deaths.

II. The later/earlier method applied to the first COVID-19 wave in France and Spain

1. Short-Term Mortality Fluctuations and Eurostat mortality data

The Short-Term Mortality Fluctuations (STMF) data series (STMF, 2021) of the Human Mortality Database was created in May 2020 in cooperation with national statistics offices and provides weekly mortality estimates at the national level for 38 countries. In April 2020, Eurostat launched a collection of weekly death counts covering many European countries and their regions (Eurostat, 2021).

We retrieved data for France and Spain at the national level from the STMF data series, which cover the whole population of metropolitan France (excluding deaths in overseas territories) and all the deaths that occurred in Spain. The data consist of weekly all-cause death counts disaggregated by sex and five age groups (< 15, 15–64, 65–74, 75–84, and 85+). We extracted data from 2009 to 2020 and kept STMF age groups to have the most detailed classification. To compare our national estimates of excess mortality with official COVID-19 death counts, we used the daily reported data on COVID-19 by country provided by the European Centre for Disease Prevention and Control (ECDC, 2020).

For the regional analyses, we used the 'Deaths by Week – Special Data Collection (demomwk)' from Eurostat (Eurostat, 2021), reporting the deaths of the resident population. Data are released by sex, 10-year age group, and region according to the classification of the Nomenclature of Territorial Units for Statistics (NUTS), with various levels of granularity. We aggregated the age groups from 0 to 60 due to few deaths in the younger groups in some regions, and kept Eurostat categories after age 60 (60–69, 70–79, 80–89, 90+). We selected the NUTS Level-1 regions, ending up with seven regions for Spain (Noroeste, Noreste, Comunidad de Madrid, Centro, Este, Sur, and Canarias) and 14 regions for France (Île-de-France [Paris region], Centre-Val de Loire, Bourgogne-Franche-Comté, Normandie [Normandy], Hauts-de-France, Grand Est, Pays de la Loire, Bretagne [Brittany], Nouvelle-Aquitaine, Occitanie [Occitania], Auvergne-Rhône-Alpes, Provence-Alpes-Côte d'Azur, Corse [Corsica], and Régions ultrapériphériques [overseas regions]). Details on the classification of the regions in the NUTS system can be found in the online Supplementary Material (Table S1).(1) We selected the time series of weekly deaths for France and Spain from 2013 through 2020, as the French data series starts from 2013.

2. The later/earlier method

The method is based on the ratio of the death counts between two parts of an epidemic year (epi-year). Epi-years are defined from 1 July through the end of June (30 June for normal years, 29 June for leap years), thus covering part of two adjacent Gregorian calendar years. We used epi-years because they account for one seasonal peak of mortality and thus allow for greater accuracy of short-term mortality forecasts than Gregorian years. Indeed, in countries of the northern hemisphere, a rise in mortality from all causes is usually observed during the winter, mainly in the older-adult population (older than 65 years), while mortality tends to be lower during the summer period (Rau, 2007). The epi-year 2019–2020 can be divided into a pre-COVID-19 period (which we call the earlier segment of the epi-year) and a COVID-19 period (the later segment). The first COVID-19 deaths were reported in Spain on 13 February 2020 and in France the day after. We chose the first day of the week (Monday, 10 February) in which the first COVID-19 deaths were recorded to separate the earlier and later segments and used the same division for preceding epi-years (Figure 1). Therefore, for every epi-year, the earlier segment begins on 1 July and ends on 9 February; the later segment runs from 10 February through the end of the epi-year in June.

The total number of deaths D in the epi-year can be divided into the earlier segment and the later segment. The ratio between the later and earlier death counts is the later/earlier ratio. Formally, if D is the number of deaths during

(1) This material can be retrieved from https://doi.org/10.34847/nkl.31aap9h2

the epi-year, D^+ the death count in the later segment, and D^- the death count in the earlier segment, such that $D = D^- + D^+$, the later/earlier ratio, denoted by υ (upsilon), is given by

$$\upsilon = \frac{D^+}{D^-} . \tag{1}$$

The later/earlier ratio for the epi-year 2019–2020 had the pandemic not occurred is unknown. However, one can assume that it equals the average of the later/earlier ratio in previous years to obtain a counterfactual short-term mortality forecast of the expected deaths during the later segment if COVID-19 had not struck. The values of υ over time can be checked for stationarity. If $\upsilon(t)$ shows no trend, the deaths between 10 February and June 2020 (later segment) can be forecast based on deaths recorded between July 2019 and February 2020 (earlier period) and on the average ratio $\bar{\upsilon}$ in the previous years, according to the formula

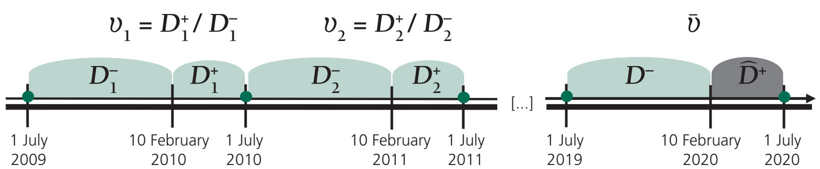
$$\widehat{D^+} \approx \bar{\upsilon} D^- . \tag{2}$$

Then, subtracting the expected deaths $\widehat{D^+}$ from the observed deaths in the same period provides us with the excess death count:

$$\text{Excess death} = D^+ - \widehat{D^+} . \tag{3}$$

Figure 1 illustrates how the epi-years were divided into later and earlier segments to forecast the expected deaths in 2020, based on the average of the later/earlier ratios in previous epi-years and the observed deaths during the earlier segment in 2019–2020. The method is well suited for the first wave of the pandemic because it relies on the deaths from an earlier segment without COVID-19, which can yield a counterfactual forecast. After epi-year 2019–2020, this quantity is not available because the deaths over the whole epi-year are influenced by the COVID-19 pandemic, and estimates of excess deaths must rely on a different method.

Figure 1. Forecasting strategy based on the segments of epi-years



Note: The observation period is in green and the forecasting period in grey. The deaths of some epi-years before 2019–2020 are used to compute the later/earlier ratios. The average ratio is multiplied by the observed deaths of the earlier segment in epi-year 2019–2020 to estimate the expected deaths in the later segment in 2020.

Source: Authors' construction.

3. Application of the later/earlier method to STMF and Eurostat data

Mortality data for both the STMF data series and Eurostat are provided by week. The definition of the week conforms to the standard of the International Organization for Standardization (ISO). All ISO weeks have 7 days, start on a

Monday, and each week belongs to a single year. However, for the scope of our analysis, we need to compute the deaths in the earlier and later segments, which mostly start within ISO weeks. We thus redistributed the deaths of the ISO weeks falling between the two segments in the later and earlier segments, proportionally to the fraction of the week defined by the cut-off (10 February and 1 July[(2)]).

At the national level, we used the weekly death counts by sex and age from the 10 years preceding the COVID-19 pandemic (from epi-year 2009–2010 through epi-year 2018–2019) to compute the series of later/earlier ratios by sex and age for each country. Other lengths of the observation period could have been chosen with the STMF mortality data because the data are available over a long period. The sensitivity analysis of the later/earlier ratios was performed with a shorter time series (5 epi-years from 2014–2015 to 2018–2019) and a longer time series (15 epi-years from 2000–2001 to 2018–2019). The resulting average later/earlier ratios, their standard deviations, and coefficients of variation were found to be similar (Figure S1). Concerning the regional analysis, the French and Spanish time series of weekly death counts provided by Eurostat are shorter; we then computed the later/earlier ratios by sex, age, and first-level NUTS region for 6 years, from epi-year 2014–2015 through epi-year 2018–2019.

4. Prediction intervals

The estimates of excess deaths depend on the assumption that the expected later/earlier ratio in epi-year 2019–2020 (in the absence of COVID-19) equals the average later/earlier ratio in previous years, and are thus uncertain. To assess how much the expected ratio in epi-year 2019–2020 might differ from its average value in previous years, we used a bootstrapping strategy. We drew 10,000 simulated ratios from the sample of 10 ratios from epi-years 2009–2010 through 2018–2019 by age group, country, and sex. For each ratio, we computed the expected number of deaths in the later segment in 2020, multiplying the ratio by the observed number of deaths in the earlier segment of epi-year 2019–2020. We then drew a death count from the Poisson distribution with the mean equal to the expected number of deaths, which resulted in 10,000 simulated values by age group, country, and sex from an empirical distribution of death counts. Empirical 95% prediction intervals were computed by taking the 2.5th and 97.5th percentiles of this resulting distribution.[(3)]

(2) For example, if 1 July is a Wednesday (e.g. epi-year 2015–2016), then the death count from 1 July until the start of ISO Week 28 on 6 July would be 5/7 times the death count in ISO Week 27. Similarly, if 29 June is a Tuesday (e.g. epi-year 2020–2021), then the death count for Monday and Tuesday, 28–29 June, would be 2/7 times the death count in the ISO Week 26. And similarly, for the days before and after 9 or 10 February.

(3) All analyses were performed using the R software program, version 4.0.2. The code for full replicability is available at: https://github.com/AinhoaLeger/Shortcasting-Excess-Mortality

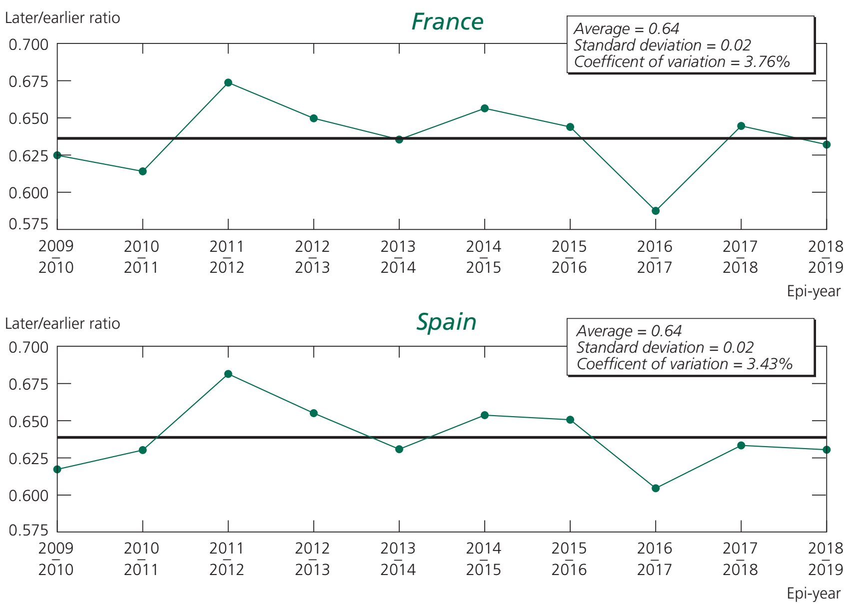
III. Estimates of excess deaths by region, sex, and age group

1. Later/earlier ratios

The later/earlier method assumes that the later/earlier ratios are fairly constant. Figure 2 shows the series of later/earlier ratios for France and Spain at the national level. The series reveal considerable regularity, i.e. a constant mean and a small standard deviation. The series were found stationary via the Ljung–Box test (Ljung and Box, 1978) and the Kwiatkowski–Phillips–Schmidt–Shin test (Kwiatkowski et al., 1992). The latter is a particularly suitable complement for unit root tests, e.g. the augmented Dickey–Fuller test (Dickey and Fuller, 1979), because it directly tests the stationarity and can be used for shorter time series (Arltová and Fedorová, 2016). The averages of the later/earlier ratios are 0.636 for France and 0.639 for Spain, meaning that the number of deaths in the later segment is about three-fifths of the number of deaths in the earlier segment. The standard deviations are quite small compared to the mean, as indicated by the coefficients of variation (3.76% for France and 3.43% for Spain). Based on the observation of a small variation around the mean later/earlier ratio, one would expect a similar value for the later/earlier ratio in epi-year 2019–2020.

The series of ratios stratified by sex and age groups (Figure S2) were also found to be stationary via the Ljung–Box and the Kwiatkowski–Phillips–

Figure 2. Later/earlier ratios in France and Spain, epi-years from 2009–2010 through 2018–2019



Note: The dots represent the ratios for each epi-year, and the black lines the average ratios by country over the epi-years.

Source: Authors' calculations based on the STMF data series.

Schmidt–Shin tests. The averages of the later/earlier ratios range from 0.57 to 0.65, and the standard deviations and coefficients of variation are quite small: the coefficients of variation are lower than 4% in the central age groups and slightly larger but always lower than 7% in the age groups 0–15 and 85+(4). This result indicates a correlation between the deaths in the two halves of the epi-year, providing a simple approach for (short-term) forecasting the deaths in the second segment of an epi-year using the information about deaths in the first segment.

Similar regularities were found when computing the later/earlier ratios for France and Spain at the regional level (Figures S3–S6). The averages of the later/earlier ratios range from 0.59 to 0.70 for females and from 0.53 to 0.71 for males in France, and from 0.60 to 0.68 for females and from 0.58 to 0.71 for males in Spain. The coefficients of variation are below 10% in all age groups and for both sexes in Spain. They are slightly lower in the central age groups (60–69, 70–79, 80–89) and slightly higher but always lower than 10% in the age groups 0–60 and 90+ and in the regions with fewer deaths, such as the Canary Islands. In France, the coefficients of variation for males and females are lower than 10%, with a few exceptions higher than 10% in the regions with fewer deaths, e.g. Centre-Val de Loire, Corsica, Pays de la Loire, and overseas regions.

2. Overall excess mortality in France and Spain

Using the average later/earlier ratios in Figure 2, we applied Equation 2 to estimate the expected deaths for France and Spain from 10 February through the end of June in 2020. Table 1 summarizes the resulting observed, expected, excess, and COVID-19 deaths. The French population is 40% larger than the Spanish population. Therefore, to compare the two, we also compute two relative excess death statistics, reported in Table 1 as excess death risks. In both countries, the number of observed deaths was higher than the expected number of deaths. In France, the impact of the pandemic increased mortality by 21,849 deaths. In relative terms, the observed deaths in France were 9.4% higher than the expected deaths. In Spain, the difference was considerably higher, yielding an excess of 44,505 deaths, an increase of 27.5% over the expected deaths. Another key statistic is that excess deaths accounted for 21.6%—more than a fifth—of observed deaths in Spain but less than 9% in France. If Spain had the same excess death risk (ratio of excess to observed deaths) as France, Spain would have lost about 26,795 fewer lives.(5) The prediction intervals for the expected deaths (Table 1) range from roughly 213,000 to 246,000 deaths for France and 152,000 to 173,000 deaths for Spain. The prediction intervals for the excess deaths indicate that excess deaths were

(4) This variation can be explained by the few deaths occurring in these age groups. The variation of the winter peak of mortality and the harvesting effect that mostly hit over-85s yield a less stable ratio from one season to another for this group.

(5) 206,122 × (0.216 – 0.086)

probably greater than 8,000 but less than 41,000 in France and between 33,000 and 54,000 in Spain. The lower and upper bounds for the excess death risk allow us to say that the excess death risk was statistically significantly lower in France than in Spain (because the upper bound of the confidence interval for France, 15.9%, is less than the lower bound for Spain, 16.4%).

Table 1. Excess deaths, excess death risks, and official COVID-19 deaths in France and Spain, 10 February – 29 June 2020

	France	Spain
Observed deaths	253,950	206,122
Expected deaths	232,101 (213,539–245,597)	161,617 (152,366–172,310)
Excess deaths	21,849 (8,353–40,411)	44,505 (33,812–53,756)
Excess death risk (excess/observed)	8.6% (3.3%–15.9%)	21.6% (16.4%–26.1%)
Excess death risk (excess/expected)	9.4% (3.4%–18.9%)	27.5% (19.6%–35.3%)
Official COVID-19 deaths	29,778	28,346

Note: Expected deaths, excess deaths, and excess death risks are provided with 95% prediction intervals in parentheses.
Source: Authors' calculations based on the STMF data series.

The comparison of excess mortality with the number of reported deaths from COVID-19, by country, indicates the potential under-reporting of COVID-19-related deaths. In France, excess deaths were slightly fewer than reported COVID-19 deaths, whereas in Spain excess deaths exceeded reported COVID-19 deaths. In France, there were 21,849 excess deaths compared to 29,778 COVID-19 deaths. In Spain, out of 44,505 excess deaths, only 28,346 were coded as COVID-19. This results in a ratio of excess to COVID-19 deaths of 0.73 in France versus 1.57 in Spain. The figures suggest that in France, either COVID-19 deaths were over-reported because of deaths in people with influenza or with multiple existing chronic conditions (i.e. with a high risk of dying) assigned to COVID-19 deaths (Guillot and Khlat, 2020), or a potential reduction in deaths from other causes, such as respiratory infections or injuries and violence, because of reduced physical contact (Jones, 2020; Nuñez et al., 2020). On the other hand, either in Spain there was an under-reporting of COVID-19 deaths or the turmoil resulting from the COVID-19 pandemic might have induced an increase in mortality for other causes (Gaudino et al., 2020).

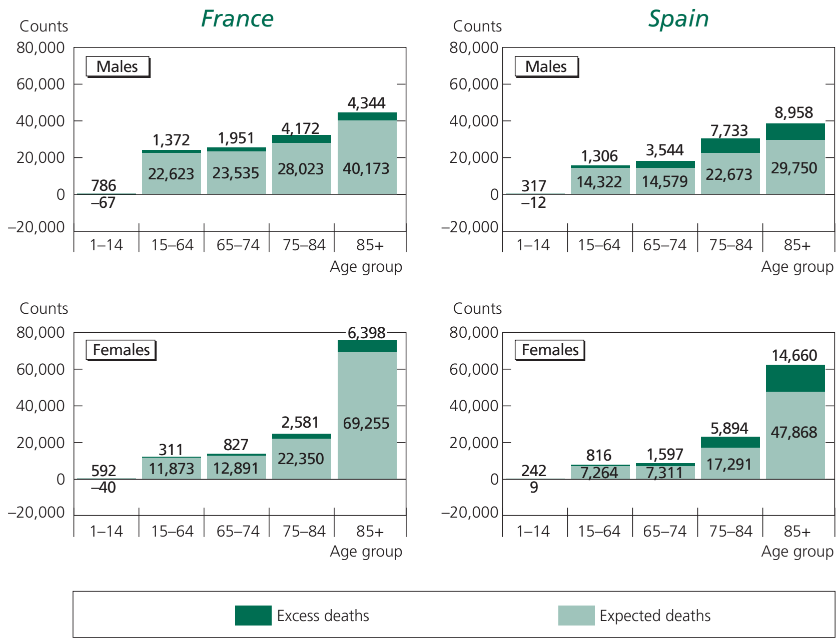
The estimates of excess mortality in France and in Spain broken down by age and sex are reported in Table S2 and illustrated in Figure 3. The sum of the expected deaths and excess deaths represents the observed death count from 10 February to 29 June 2020. In France, half[(6)] of the excess deaths occurred above age 85 and a third[(7)] between ages 75 and 84. These figures show

(6) 0.49 = (6,398 + 4,344)/21,849

(7) 0.35 = (2,581 + 4,172)/21,849

that the burden of excess deaths was concentrated at older ages. Except in the last age group (85+), the toll of excess mortality was higher for men than for women. For females, many excess deaths occurred after age 85; these accounted for 60%(8) of all excess deaths at ages 85+. All ages combined, 63%(9) of all excess deaths among women and almost 37%(10) of the excess deaths among men occurred after age 85. The age and sex breakdowns of excess deaths in Spain are quite similar. Half of the excess deaths occurred after age 85, while a third occurred between 75 and 85. For females, many extra deaths occurred after age 85; these accounted for more than 60% of all extra deaths at ages 85+. All ages combined, 64% of all excess deaths among women and 42% of excess deaths among men occurred after age 85.

Figure 3. Expected and excess deaths in France and Spain by age group and sex, 10 February – 29 June 2020



Source: Authors' calculations based on the STMF data series.

Demographic differences complicate comparability of excess deaths because population age distributions within countries may be different. Comparisons between subgroups can be made using excess death risk statistics, i.e. ratios of excess deaths to observed or expected deaths (Table S2; Figure 4). The people between 75 and 84 were the ones at the highest risk of excess death (14.9% for males and 11.5% for females in France, and 34.1% for both males and females

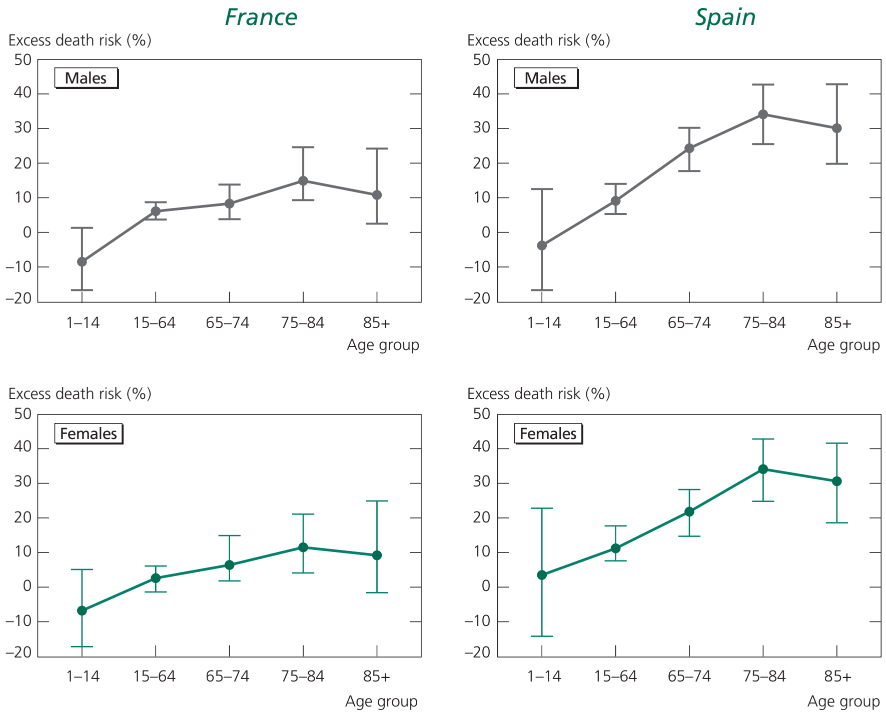
(8) 0.60 = 6,398/(6,398 + 4,344)

(9) 0.63 = 6,398/(–40 + 311 + 827 + 2,581 + 6,398)

(10) 0.37 = 4,344/(–67 + 1,372 + 1,951 + 4,172 + 4,344)

in Spain). The number of excess deaths for females in Spain after age 85 was 30% higher than the expected number, compared to only 9% in France. If in Spain the excess deaths at older ages were at the same level as in France, there would have been 9,317 fewer deaths, 60% of the total of 14,660 Spanish excess deaths for women. While the differences in the excess death risks between some age groups are statistically significant, men and women of the same age group do not exhibit significant differences.

Figure 4. Excess death risk (excess to expected) in France and Spain by age group and sex, 10 February – 29 June 2020

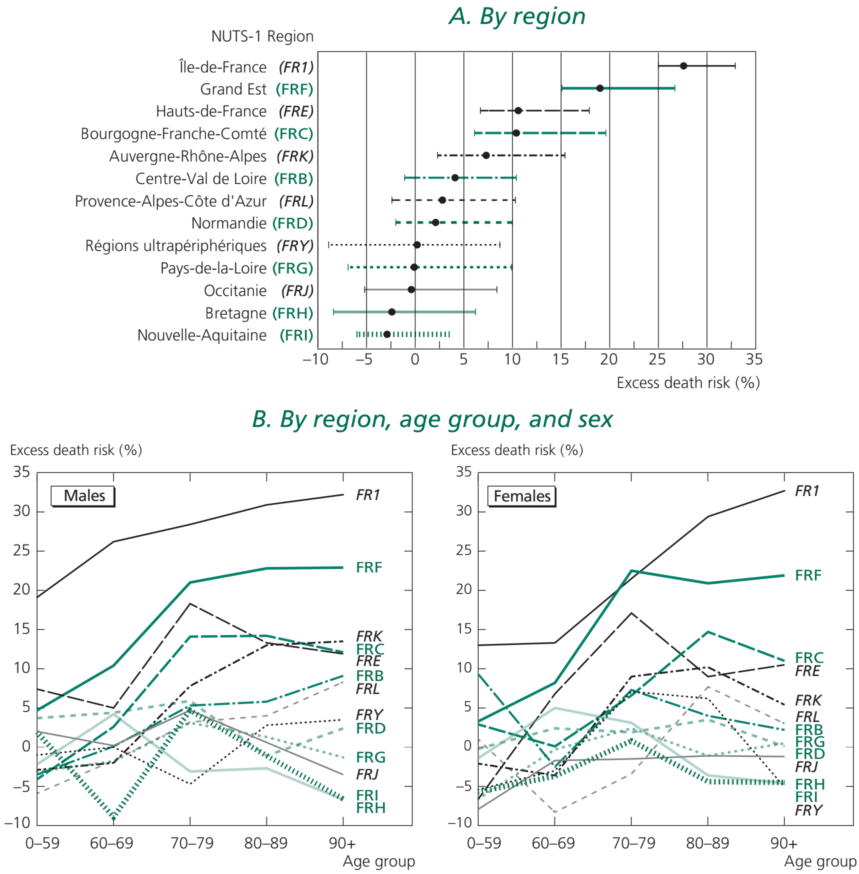


Source: Authors' calculations based on the STMF data series.

3. Regional differences

The same estimation of excess deaths using the later/earlier method was performed stratifying by French and Spanish regions. In France, excess deaths numbered in the hundreds in five regions: Auvergne-Rhône-Alpes, Bourgogne-Franche-Comté, Hauts-de-France, Grand Est, and Île-de-France. For these regions, excess death risk (excess to observed) ranged from 7.3% in Auvergne-Rhône-Alpes to 27.6% in Île-de-France (Figure 5A). The most impacted regions were Île-de-France and Grand Est, where the excess death risk above age 70 exceeded 20%. Older adults (age groups 70–79, 80–89, and 90+) were the most affected; more than 10% of the observed deaths were attributable to excess

Figure 5. Excess death risks in France by region, age group, and sex, 10 February – 29 June 2020

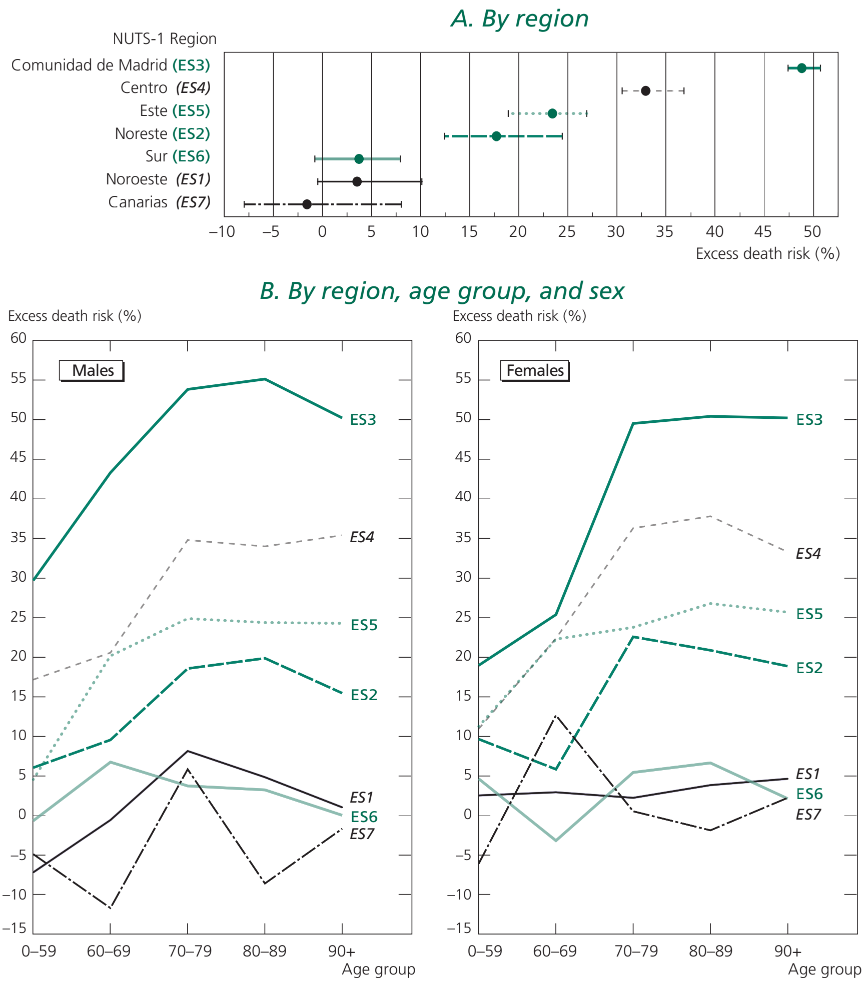


Note: Excess death risk is the ratio of excess to observed deaths.
Source: Authors' calculations based on data from Eurostat.

death in most of the age groups above age 70 (Figure 5B). The highest number of excess deaths was estimated for females above 90 years of age in Île-de-France (2,647 excess deaths, 32.7% of excess to observed deaths). The amount of excess death was relatively low or even negative in the remaining metropolitan regions (Bretagne, Centre-Val de Loire, Normandie, Nouvelle-Aquitaine, Occitanie, Pays de la Loire, and Provence-Alpes-Côte d'Azur) and the overseas regions, and in the younger age groups (0–60 and 60–69). The negative estimates may be due to the protective effect of the lockdown period on other causes of mortality. Only in Île-de-France, a positive excess mortality, leading to an excess death risk higher than 10%, was found at ages 0–60 and 60–69, for both men and women.

In Spain, the most affected regions were Comunidad de Madrid and Centro, with excess death risks of 48.8% and 32.9% (Figure 6A). In these two regions, the excess deaths numbered in the thousands after age 70. In Centro, excess death risk was between 34.0% and 37.8%, and in Comunidad de Madrid, it was between 43.3% and 55.1% (Figure 6B). Excess mortality at younger ages in these regions was also quite high, with an excess death risk ranging from 11.0% to 29.7%. Following Centro and Comunidad de Madrid, in the Este and Noreste regions, 15.5% to 26.8% of the observed deaths were attributable to excess deaths after age 70. Noreste and Sur were less affected regions, where the estimates were negative or the excess death risk was below 10%. For Spain, more clearly than for France, a pattern over the age groups can be observed for both sexes: the excess death risk seems to increase until

Figure 6. Excess death risks in Spain by region, age group, and sex, 10 February – 29 June 2020



Note: Excess death risk is the ratio excess to observed deaths.
Source: Authors' calculations based on data from Eurostat.

age 70 and decrease in the last age group. Full results, together with the 95% prediction intervals to conclude whether the differences are significant, are reported in Tables S3 and S4.

4. Comparison with the 5-year-average method

The value of a forecasting method can be evaluated by measures of prediction error and prediction bias. Prediction error and bias can be estimated based on forecasts in the past; data up to a particular period are used to forecast to some later time in the past, and the forecast is then compared with the known actual outcome. A standard measure of prediction error is the square root of the mean squared errors (RMSE). We define RMSE in mortality forecasts as

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(\widehat{D}_i^{\dagger} - D_i^{\dagger})^2}{N}}, \quad (4)$$

where $D_i^{\dagger}$ is the observed number of deaths, $\widehat{D}_i^{\dagger}$ is the expected number of deaths, and N is the number of years for which the forecasts are made. As an alternative measure of the prediction accuracy of the forecasts, the mean absolute percentage error (MAPE) is defined as

$$\text{MAPE} = \frac{100}{N}\sum_{i=1}^{N}\left|\frac{(D_i^{\dagger} - \widehat{D}_i^{\dagger})}{D_i^{\dagger}}\right|. \quad (5)$$

To evaluate the accuracy of our forecasts at the national level for France and Spain, we computed RMSE and MAPE both for the later/earlier method and for the 5-year-average method for males and females in five age categories. For every epi-year from 2014–2015 through 2018–2019 ($N = 5$), we forecasted the expected number of deaths for the later period based on the previous 5 epi-years, calculated the squared errors as the difference from the observed number of deaths, and averaged them. In the average method, the expected number of deaths is simply the average of the number of deaths in the same periods of the previous years.

The resulting RMSE values for the historical forecasts reveal the advantage of using later/earlier ratios rather than 5-year-averages (Table 2). Indeed, RMSE is smaller for the later/earlier ratios approach in 19 of 20 cases than for the 5-year-average approach. MAPE values for both sexes and over all five age categories in France and Spain using the later/earlier approach were 2.2% versus 5.0% using the 5-year-average method.

The same comparison was performed at the regional level (Tables S5 and S6). As the starting point of the French data is the year 2013, we could compute RMSE for French and Spanish regions for only 1 year by sex and age group. We used data from epi-years 2013–2014 through 2017–2018 to compute the expected number of deaths in the later period in epi-year 2018–2019 and obtained the squared error for this year. RMSE is smaller for the later/earlier ratios approach in 65% of the cases in France and in 67% of the cases for Spain compared with the 5-year-average approach.

Table 2. Comparison of root mean square errors with the later/earlier ratio method and 5-year-average method for estimating excess deaths from 10 February to 29 June 2020, by country, sex, and age group

Age group	France				Spain			
	Female		Male		Female		Male	
	Later/ earlier	5-year-average	Later/ earlier	5-year-average	Later/ earlier	5-year-average	Later/ earlier	5-year-average
0–14	32	45	24	20	22	37	22	49
15–64	273	343	372	1,527	68	115	288	487
65–74	292	1,341	635	2,130	230	310	345	612
75–84	1,141	1,766	1,375	1,637	746	1,696	964	1,533
85+	5,222	6,087	2,521	4,002	2,359	4,425	1,543	3,384

Note: Root mean square errors are based on the forecasts for 5 years (2015–2019) using the data for epi-years from 2009–2010 to 2018–2019.
Source: Authors' calculations based on the STMF data series.

IV. Putting the later/earlier method into perspective

Our estimates for excess deaths in France and Spain are consistent with previous studies, even if our forecasted time window differs slightly (Fouillet et al., 2020; Kontis et al., 2020; Morgan et al., 2020). It was widely reported that adults aged 65 and over had the highest excess deaths and excess death risks, while persons aged 15–64 suffered a moderate excess of deaths. The situation is less clear regarding sex. According to Kontis et al. (2020), the number of excess deaths for all causes and relative increase in deaths are similar for men and women in most countries. They considered two age groups and found before age 65 a male disadvantage in France and a female disadvantage in Spain. After age 65, there were similar relative effects in men and women. Our results obtained through the later/earlier method are consistent with those from the sophisticated modelling by Kontis et al. (2020) before age 65; we considered three age groups over age 65 (65–74, 75–84, and 85+), and the differences in the excess death risks between men and women are not significant in both countries.

Explanations for the differences in excess deaths between France and Spain are not straightforward because they probably lie in complex interactions of the social, economic, environmental, and health-system features of each country. Furthermore, mortality differences might be related but are not entirely attributable to the effect of lockdown measures. This effect is difficult to quantify because lockdown measures were put in place in France and Spain in mid-March, only after the number of deaths had risen to such levels that the epidemic would continue for weeks. Denmark and Sweden illustrate an exceptional case. Although they are similar countries with mutually understandable languages, intertwined histories, related cultures, and comparable political systems, they responded differently to COVID-19. Denmark experienced an early rise in cases, enacted lockdowns soon after, and used effective testing, contact tracing, and isolation to contain the epidemic and its mortality effect, while Sweden adopted a softer response. Therefore, that Denmark experienced a considerably lower risk of death than Sweden did can be attributable, at least in substantial part, to the different policies adopted (Rizzi et al., 2021). The risk of excess mortality was lower in Denmark than in France, while in Sweden it was close to that in Spain. In all four countries, people aged 75 and over accounted for most of the excess deaths.

We aimed at highlighting the importance of excess mortality measurements and at providing evidence about its estimation at the subnational level, filling a gap in the literature about regional differences in excess mortality for France and Spain. Previous analyses for French regions considered a narrower time interval (Fouillet et al., 2020) than the one employed here, or a specific target population, e.g. nursing home residents (Canouï-Poitrine et al., 2021). For Spain, excess death rates have been analysed only at the national level for all of 2020 in a preprint (Martín-Olalla, 2021), and regional differences in the impact of the COVID-19 pandemic have been investigated only in terms of life expectancy drops (Trias-Llimós et al., 2020).

We found that Île-de-France and Comunidad de Madrid suffered from significant, higher excess death risk than other NUTS-1 regions within each country. We therefore examined third-level NUTS regions. In France, these correspond to *départements*, i.e. mid-level administrative divisions between regions and municipalities. The departments most affected by excess deaths and excess death risk were those in the Grand Est region (Bas-Rhin, Haut-Rhin, and Vosges) and Île-de-France (Essonne, Hauts-de-Seine, Paris, Seine-et-Marne, Seine-Saint-Denis, Val-d'Oise, Val-de-Marne, and Yvelines). The excess death risk in these departments ranged between 22% in the Vosges to 35.2% in Seine-Saint-Denis; Bouches-du-Rhône, whose largest city is Marseille, stood out from the other departments in southern France with a higher excess death mortality (7.9% excess death risk). When considering the NUTS-3 Spanish regions, corresponding to the Spanish provinces, the highest excess mortality— exceeding 10,000 deaths—occurred in Madrid (17,108 excess deaths, 48.9% excess death risk) and Barcelona (10,671 excess deaths, 37.6% excess death risk). The other most affected provinces with more than 1,000 deaths were Ciudad Real (1,692; 46.6% excess death risk) and Toledo (1,264; 35% excess death risk), hence the importance of protecting metropolitan areas during pandemics. As several factors such as climate change and human behaviour may increase the future incidence of pandemics, necessary preparation, response, and adaptation measures are needed for cities and urban areas especially (Connolly et al., 2020).

Developed to study the first COVID-19 wave, the later/earlier method can be extended to many countries and to other subpopulations for the same wave. Excess mortality can be calculated by other individual characteristics, such as health status, sociodemographic and economic characteristics, or whether a deceased person lived in a rural or urban area. Estimates of excess deaths can then be obtained through the later/earlier method for various subpopulations for one or more of these characteristics. More generally, the later/earlier method might be used in any situation where a major shock had occurred in order to estimate how many deaths would have happened without it. It could be applied to the study of past and future epidemics and heatwaves.

Excess death measures depend on how expected mortality in the absence of a shock is estimated (Schöley J., 2021; Nepomuceno et al., 2022). In particular, the method, reference period, and mortality index influence the baseline mortality level. The later/earlier method proposes a mortality index, i.e. the ratio of the death counts of two parts of an epi-year over epi-years. These ratios have been shown to be approximately constant, and their average value allows for straightforward, user-friendly, and more accurate short-term forecasts than the 5-year-average method. Moreover, the stationarity of the series of ratios does not depend on the reference period chosen, i.e. estimates using 5- to 15-year windows of later/earlier ratios do not differ.

Conclusion

The later/earlier method is useful for making short-term mortality forecasts of expected mortality barring major shocks, as it is intuitive and requires fewer assumptions than more elaborate approaches. Based on the simple ratio of the deaths between two parts of an epi-year, it assumes that the average across epi-years is informative regarding short-term developments in mortality. The regularity of the time series of later/earlier ratios in France and Spain over the epi-years preceding 2019–2020 allowed us to apply this approach to estimate excess mortality after the health shock caused by the first COVID-19 wave.

Excess mortality was found in both countries over the period 20 February – 29 June 2020. Consistent with previous studies on several European countries (Kontis et al., 2020; Morgan et al., 2020; Islam et al., 2021), excess mortality was higher in Spain than France. It was higher than COVID-19-attributed deaths in Spain but lower in France. In Spain, reported COVID-19-related deaths were 64% of excess deaths. In France, reported COVID-19-related deaths were 36% higher than the excess deaths. These discrepancies highlight the importance of using all-cause excess mortality to capture the true death toll of a pandemic. The estimated excess death risk—the ratio between excess deaths and observed deaths—was much higher in Spain than in France: 8.6% above the baseline for the whole of France (21,849 excess deaths) and 21.6% (44,505 excess deaths) for Spain.

Age and region were found to be risk factors for COVID-19-related mortality. For all ages combined, sex differences were not significant. In both countries, most of the excess deaths occurred among people aged 75 years and over. The ones most affected between 75 and 85 years old were males, while the situation reversed after age 85 with higher excess deaths among females. Adults aged 75+ in France experienced higher excess mortality; those between 75 and 84 were particularly affected, with a 10.4% increase in mortality in women and 13.0% in men. The same age group was the most affected in Spain, with an increase of 25.4% for both women and men.

The estimation of excess death at the regional level showed that spatial disparities in mortality occurred during the pandemic. Five French metropolitan regions experienced moderate excess mortality, and Île-de-France and Grand Est saw the most elevated excess mortality. At ages over 70, the risk of excess death was above 20% in all age groups in Île-de-France and Grand Est, reaching 30% in Île-de-France in the oldest age group (90+). Our results are consistent with those found by Fouillet et al. (2020), as the same regions were found to have the highest excess mortality, although the time frame considered ran from March through May 2020. An unequal impact of the first wave was also found across Spanish regions; Comunidad de Madrid had the highest excess death risk above age 70 (around 50%) compared to all the other regions, followed by the Centro region (between 33% and 37%).

The simplicity of the later/earlier approach is comparable to that of the 5-year-average method. However, the later/earlier approach has the advantage of incorporating more information by considering the dependence between the later and earlier periods of the epi-year. It uses the specific level of the year, through the death counts in the earlier part of the year, and the past information on how the earlier and later segments should relate, through the later/earlier ratios, to forecast the expected deaths in the later part of the year. In the context of the estimation of expected and excess mortality and evaluation of the effects of the first COVID-19 wave, the later/earlier method was more accurate and less biased in forecasting expected deaths.

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Ainhoa-Elena Leger, Silvia Rizzi • Estimating Excess Deaths in French and Spanish Regions During the First COVID-19 Wave with the Later/Earlier Method

Estimates of excess deaths have been widely used to measure the overall impact of the COVID-19 pandemic on mortality. We investigate the validity of a method—the later/earlier method— developed for forecasting the number of deaths one would expect if no shock occurred. We apply this method to estimate excess mortality during the first COVID-19 wave in France and Spain (February–June 2020), stratified by age, sex, and region. Although both countries recorded similar numbers of COVID-19 deaths, Spain had higher excess mortality. The results are informative about differences in COVID-19 vulnerability for population subgroups and spatial areas: adults aged 75–85 were the hardest hit; Île-de-France (Paris region) in France and Comunidad de Madrid in Spain had the highest excess mortality. Applicable to other demographic phenomena, the later/earlier method is simple, requires fewer assumptions than other forecasting methods, and is less biased and more accurate than the 5-year-average method.

Ainhoa-Elena Leger et Silvia Rizzi • Estimation de la surmortalité dans les régions françaises et espagnoles pendant la première vague de Covid-19 : application de la méthode « après/avant »

Des estimations du surplus de décès ont été largement utilisées pour mesurer l'impact global de la pandémie sur la mortalité. Cet article examine la validité d'une nouvelle méthode (« méthode après/avant »), mise au point pour prévoir le nombre de décès qui seraient attendus en l'absence de choc. Cette méthode est appliquée pour estimer la surmortalité durant la première vague de Covid-19 (février-juin 2020) en France et en Espagne, par âge, sexe et région. Bien que les deux pays aient déclaré des nombres similaires de décès par Covid-19, la surmortalité de l'Espagne s'est avérée plus élevée. Les résultats sont riches d'enseignements sur les différences de vulnérabilité à la Covid-19 selon les sous-groupes de population et les zones géographiques considérés : les adultes de 75 à 85 ans ont été les plus durement touchés ; c'est en Île-de-France, pour la France, et dans la Comunidad de Madrid, pour l'Espagne, que la surmortalité a été la plus importante. Applicable à d'autres phénomènes démographiques, la méthode après/avant est simple, nécessite moins d'hypothèses que d'autres méthodes de prévision, et se révèle moins biaisée et plus précise que celle de la moyenne quinquennale.

Ainhoa-Elena Leger et Silvia Rizzi • Estimación del exceso de mortalidad en las regiones francesas y españolas durante la primera ola de Covid-19: aplicación del método antes-después

Se han realizado numerosas estimaciones sobre el aumento de muertes para medir el efecto global de la pandemia sobre la mortalidad. Este artículo examina la validez de un nuevo método («método antes-después»), desarrollado para prever el número de fallecimientos que se esperarían en ausencia de impacto. El método se aplica para estimar el exceso de mortalidad durante la primera ola de Covid-19 (febrero-junio 2020) en Francia y en España, por edad, sexo y región. Aunque los dos países hayan declarado un número similar de muertes por Covid-19, la sobremortalidad en España resulta más elevada. Los resultados informan sobre las diferencias de vulnerabilidad frente a la Covid-19 según los subgrupos de población y las zonas geográficas consideradas: los adultos de 75 a 85 años han sido los más gravemente afectados; en Île-de-France, en el caso de Francia, y en la Comunidad de Madrid, en el caso de España, es donde el exceso de mortalidad ha sido más importante. Aplicable a otros fenómenos demográficos, el método antes-después es simple, necesita menos hipótesis que otros métodos de previsión y resulta menos sesgado y más preciso que el de promedios quinquenales.

Keywords: short-term forecasting, mortality forecasting, excess deaths, COVID-19 pandemic, France, Spain