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# Estimation of years of life lost by Sweden's relaxed COVID-19 mitigation strategy

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**Abstract**

**Objective:** To estimate the weekly excess all-cause mortality in Norway and Sweden, and to estimate the years of life lost (YLL) attributed to COVID-19 in Sweden and the significance of mortality displacement.

**Methods:** We found expected mortality by taking the declining trend and the seasonality in mortality into account. From the excess mortality in Sweden in 2019/20, we estimated the YLL attributed to COVID-19 using the life expectancy in different age groups. We adjusted this estimate for possible displacement using an auto-regressive model for the year-to-year variations in excess mortality.

**Results:** We found that excess all-cause mortality over the epidemic year (July to July) 2019/20 was 517 (95%CI -12, 1 074) in Norway and 4 329 (3 331, 5 325) in Sweden. There were reported 255 COVID-19 related deaths in Norway, and 5 741 in Sweden, that year. During the epidemic period March 11 – November 11, there were 6 247 reported COVID-19 deaths and 5 517 (4 701, 6 330) excess deaths in Sweden. The estimated number of life-years lost attributed to the more relaxed Swedish strategy was 45 850 (13 915, 80 276) without adjusting for mortality displacement and 43 073 (12 160, 85 451) after adjusting for possible displacement.

**Keywords:** COVID-19; excess mortality; mortality displacement

## 1 Introduction

There is an ongoing scientific and public debate worldwide about the optimal strategy for mitigating the negative impacts of the COVID-19 pandemic [1, 2, 3, 4, 5, 6]. In Europe, most countries executed strong non-pharmaceutical interventions in March 2020 to combat the disease's explosive spread, and by early summer, the epidemic was reasonably controlled. Among the Western-European countries, Sweden was an exception, adopting a more relaxed approach with mainly voluntary measures [7]. As a consequence, the rate of confirmed cases entered a second and more substantial wave in June and a third and even stronger one throughout the autumn, coinciding with the widespread second wave in Europe. Here, the COVID-19-specific mortality rate saw one broad wave lasting from March until July, then a calm period from August till October when a second wave started. The confirmed cumulative COVID-19 death toll in Sweden until November 11 was 6 247, which corresponds to 611 deaths per million [8]. This figure is typical for Europe but high compared to Sweden's Nordic neighbors. Norway, which is very similar to Sweden in most respects, has chosen a much more strict approach against COVID-19. As a result, by November 11, Norway had only 285 confirmed deaths (53 per million) related to COVID-19 [8].

It has been suggested that the criticism of the Swedish strategy has been based on the norm that considers death from coronavirus infection to be more important than death from another infection [9]. The implicit assumption behind this suggestion is that the pandemic's mortality rate was not substantially higher than during previous seasonal influenzas and that all-cause excess mortality in Sweden differed significantly from the confirmed coronavirus-related mortality throughout the pandemic wave. In this paper, we investigate the validity of these assumptions. Also, we estimate the years of life lost (YYL) in Sweden that can be attributed to its relaxed mitigation strategy.

Our results and conclusions differ from Juul et al. (2020) [10], who suggest that all-cause mortality in Norway and Sweden during the first wave of the COVID-19 epidemic up to July 2020 was largely unchanged compared to the previous four years and that the high excess mortality observed in Sweden during the epidemic wave was partly due to a mild influenza season during the winter 2019/20. In that paper, the 5 741 COVID-19 deaths in Sweden reported between March 11 and July 26 were interpreted partly as a mortality displacement within the epidemic year 2019/20 and from this year to the next, with the implication that few years of life were lost.

# 2 Results

## 2.1 Estimates of excess mortality

The mortality rate in Scandinavia has a seasonal variation and is higher in the boreal winter [11]. As shown in Figure 1A, the weekly number of all-cause deaths also shows a significant negative linear trend ($p = 10^{-15}$ for Norway and $p = 10^{-7}$ for Sweden) over the last twenty years. The expected mortality-rate signal from the average seasonality and the linear trend is shown as black curves in Figure 1. In the following, we will refer to this as the baseline signal. Our definition of the baseline is different from that in the widely used EuroMoMo model [12], which does not include the expected winter influenza in the baseline. That is reasonable when the seasonal influenza is the main object of study, but not when this object is a pandemic like COVID-19.

The excess mortality rate for a given week is the weekly mortality rate that week minus the baseline at the time. It can be positive or negative, depending on whether the instantaneous mortality rate that week is above or below the baseline.

We plotted the expected all-cause mortality rate for Norway and Sweden over the epidemic seasons from 2016/17 up to 2020/21 and the recorded rate up to November 11, 2020 (Figure 1 B and C). For both countries, mortality during the winters of 2016/17 and 2017/18 was higher than baseline, mostly because of stronger than normal seasonal influenza [13]. In Sweden, the mortality rate in 2018/19 and 2019/20 was below the baseline until the COVID-19 outbreak in March 2020. Still, after March 11, it was way above until July and then remained slightly below until November. We estimated the excess mortality rate during the epidemic from March 11 until November 11 as the difference between the observed and expected rate. We compared it to the numbers of weekly reported COVID-19 deaths (Figure 1 D and E). The excess all-cause deaths were slightly more numerous than the reported COVID-19 deaths in both countries during the peak of the first epidemic wave.

To examine the issue of mortality displacement in further detail, we produced Figure 2 A and B, where we plot the excess mortality rate over the last four years. The blue lines mark the mean excess rate for each epidemic year (from July until July next year).

For both countries, we observe that the two first years are above baseline. For Norway, the year preceding the pandemic was at the baseline, while during the pandemic year 2019/20, the death number was 517 (-12, 1 074), where the numbers in the brackets represent the 95% confidence interval. In Sweden, the pre-pandemic year saw -1 596 (-2 508, -680) deaths (below baseline), while the pandemic year had an excess number of 4 329 (3 331, 5 325).The 255 reported COVID-19 deaths in Norway is within the confidence interval for the excess estimates, and the 5 741 in Sweden is slightly above. For the epidemic period March 11 - November 11, however, Sweden had 6 247 reported COVID-19 deaths which is within the confidence interval of the 5 517 (4 701, 6 330) excess deaths for this period. Using the same definition, we estimated the annual excess numbers for the last twenty epidemic years (Table 1 and Figure 2 C and D).

### 2.2 Estimates of years of life lost (YLL) in Sweden

Using data on life expectancy in different age groups in Sweden [14] (Table 2) we simulated the YLL using the model

$$\mathrm{YLL} = X\left[0.10r_1 + 0.30r_2 + 0.35r_3 + 0.25r_4\right], \tag{1}$$

where the random variable $X$ represents the excess mortality, with the estimated distribution for 2019/2020, and the random variables $r_1, \ldots, r_4$ are the life expectancies in each age group. We assumed the life expectancies to be independent and normally distributed random variables. The resulting estimate from these statistics is YLL = 45 850 (13 915, 80 276).

### 2.3 Estimate of displacement effect

We estimated the autocorrelation functions (ACF) based on the twenty years of weekly excess mortality rate data for Norway and Sweden (Figure 3 A and B). In Sweden, we saw a slight anti-correlation in the year-to-year excess mortality. Hence, it is conceivable that the large excess mortality in 2019/20 may cause a response of negative excess mortality in the next few years. The simplest way to model such a displacement effect is to use a first-order auto-regressive process (AR1) for the annual excess mortality $X_t$:

$$X_{t+\Delta t} = \phi X_t + \xi_t \tag{2}$$

where $\Delta t = 1$ yr and $\xi_t$ is a white-noise term. The estimated AR1 coefficient for Sweden is $\phi = -0.11$ (-0.50, 0.30), and the adjustment of excess mortality in 2019/20 due to mortality displacement is

$$X_{\text{adj}} = X + \rho X, \tag{3}$$

where $X$ is the excess mortality in 2019/20. Taking only response in 2020/21 into account one has $\rho = \phi$, but if including the response over a few years one can use the sum of the geometric series:

$$\rho = \phi + \phi^2 + \cdots = \frac{\phi}{1-\phi}\,.$$

The estimated mean of $\rho$ was -0.06. The median was $-0.10$, and the 95% CI was (-0.33, 0.43). Using the distribution of $\rho$ to take the effect of possible displacement into account the excess mortality in Sweden for 2019/20 was adjusted to a mean value of 4 098 (2 706, 6 421) (Figure 4A). Carrying out the estimates of YLL with this distribution of excess mortality in 2019/20 we obtained an YLL estimate of 43 073 (12 160, 85 451). Compared to the result in Section 2.2, the mean is reduced by 6% (Figure 4B).

## 3 Discussion

It is commonly claimed, as done in [10], that all-cause mortality rates are more reliable than reported COVID-19 related deaths. The results presented in this paper show that if our model for estimating the expected mortality rate is used, the two rates agree within the confidence range of the estimated all-cause excess rate. Our corresponding estimates of YLL are consistent with Oh et al. [15].

Another central issue raised in [10] is whether the COVID-19 peak in the all-cause mortality rate observed in Swedish data could be explained as mortality displacement, either from the preceding year or from the months preceding the epidemic wave within the epidemic year 2019/20, or from both. We have already seen that the negative excess death number (-1596) in 2018/19 constitutes less than 40% of the positive excess (+4329) in 2019/20, so such a displacement can only explain part of this excess. Rather than displacements between epidemic years, one can alternatively consider displacement from the twenty months starting in July 2018 and ending March 2020 into the epidemic period from March until November

2020. During the first period of lower than normal mortality, approximately 2 500 deaths were avoided, but this can still explain only less than half of the 5.5 thousand excess all-cause deaths so far during the epidemic wave.

We have seen that a negative excess rate before the pandemic creates a pool of survivors that potentially could be particularly vulnerable to COVID-19. But the existence of this pool does not imply that it actually contributed more than normal to the COVID-19 deaths. If this displacement mechanism played an important rôle in determining the fluctuations of the all-cause excess mortality rate in Scandinavia, it should be observable in its time series. Year-to-year variations are dominated by variations in seasonal influenza, and we should observe negative correlations between excesses in a given year and the following year (or years). In other words, we should observe this negative correlation in the autocorrelation function (ACF) for the weekly all-cause excess time series. Figure 3 shows the estimated ACF for Norway and Sweden based on twenty years of weekly data (1040 data points). The confidence intervals for each year of time lag are given as error bars in the figures. Only a very weak correlation can be detected on time scales longer than the duration of the peak season for influenza. We draw from this that mortality displacement is not generally a major driver of the excess mortality fluctuations in Norway and Sweden.

## 4 Materials and methods

### 4.1 Data sources

Weekly mortality data was downloaded from Statistics Sweden (SCB) [14] and Statistics Norway (SSB) [16]. COVID-19-related deaths were obtained from ourworldindata.org [8].

### 4.2 Estimation of the expected mortality-rate signal

We first computed the linear trend in mortality by simple linear regression. After subtracting the trend, we computed the expected seasonal variation over a year by averaging the July-to-July signal over those twenty years. By repeating this expected seasonal variation over the twenty years, and adding the linear trend, we obtained the expected mortality-rate signal (the baseline, illustrated as black curves in Figure 1 A, B, and C). The excess mortality rate for a given week was defined as the weekly mortality rate that week, minus the expected mortality rate at the time. The 95% CI for the estimate of the expected signal was computed using a Monte-Carlo simulation. First, we repeatedly randomized the estimated excess mortality-rate signal without changing its correlation structure. The method was to Fourier transform, randomize the phases of the Fourier coefficients, and then invert the transform [17]. Then we added this new realization of the excess mortality random process to the previously estimated expected mortality signal. Finally, we made new estimates of the trend and seasonal variation to obtain new realizations of the expected signal. By this procedure, we established a distribution of expected signals from which we could establish a mean and a confidence interval.

### 4.3 The autocorrelation of the excess mortality signal

We obtainted the ACF for the signal by the estimator

$$\mathrm{ACF}(\tau) = \frac{1}{(N-\tau)\sigma^2} \sum_{t=1}^{N-\tau} (x_t - x_{t+\tau}) \tag{4}$$

where $\tau$ is the time lag, $\mu$ is the sample mean and $\sigma^2$ the sample variance of the weekly excess mortality rate signal of length $N = 1040$ weeks. The blue points in Figure 2 is the ACF estimated from the annual data. The error bars were computed estimating the ACF for the 52 different signals with annual resolution. We had 52 time series since there are 52 weeks in a year.

### 4.4 Estimates of the AR1 parameter

To find the parameter $\phi$ in Eq. 2 we used the standard maximum-likelihood estimator. The distribution of $\phi$ was obtained from a bootstrapping method where we simulated the estimated process and re-estimated the parameter $\phi$ repeatedly. The maximum likelihood estimator is known to biased for short time series but for small negative values of $\phi$ this bias is negligible [18].

**Competing interests**

The authors declare that they have no competing interests.

**Author's contributions**

The authors jointly conceived the study. MR, FMB, and SHS analyzed data. MR and KR wrote the paper with input from all authors.

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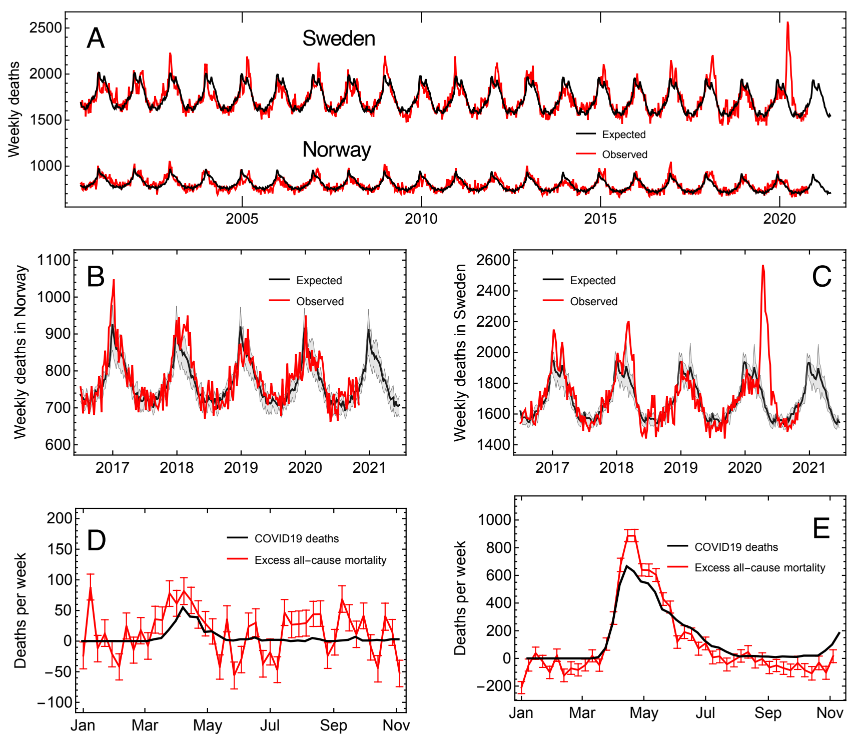


**Figure 1 Expected and observed mortality.** **A:** The weekly deaths in Norway and Sweden (red) together with the estimated baseline (black). **B:** Same as for Norway in (A), but for the years 2016/17 to 2020/21. The gray region shows the interquartile range for the seasonal variation. **C:** As (B), but for Sweden. **D:** The excess weekly mortality in Norway (red) and the COVD-19-related deaths (black). The error bars is the 95% CI for the excess mortality based on the Monte Carlo simulation for the estimate of the baseline. **E:** As (D), but for Sweden.

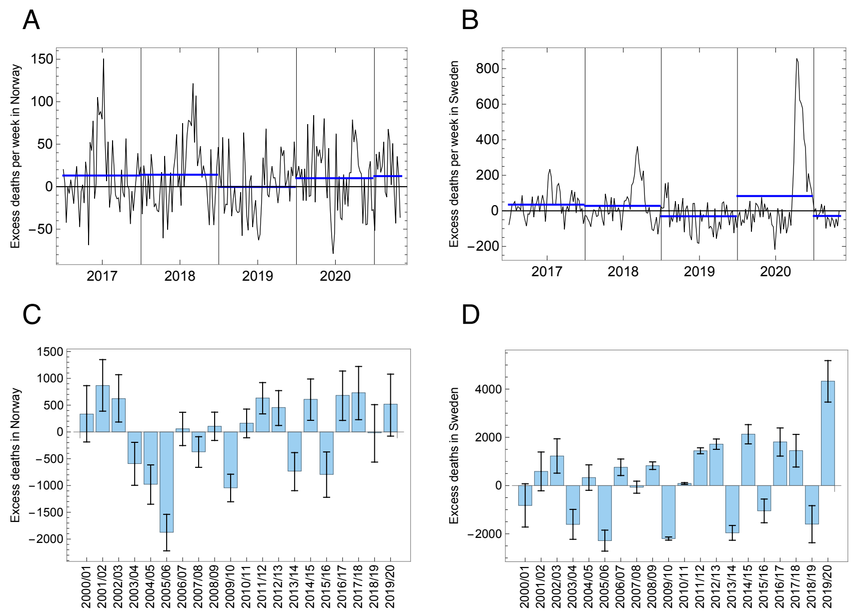


**Figure 2 Excess mortality.** $\mathbf{A}$**:** Weekly excess mortality for Norway from 2016/17 and through the first months of the epidemic year 2020/21. The blue lines are the average values for each of the five epidemic years. $\mathbf{B}$**:** As (A), but for Sweden. $\mathbf{C}$: The annual excess mortality for Norway from 2000/01 to 2019/20. The error bars are the 95% confidence intervals. $\mathbf{D}$**:** As (C), but for Sweden.

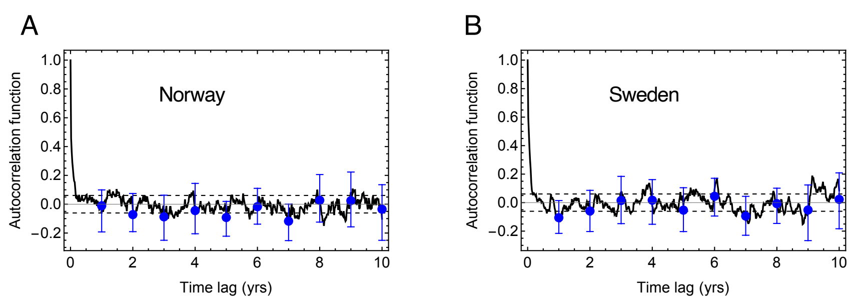


**Figure 3 Auto-correlation function of the excess mortality signal.** $\mathbf{A}$: The black curve shows the autocorrelation function estimated from the weekly excess mortality in Norway. The dashed lines indicate the 95% confidence interval under the assumption of uncorrelated data. The blue points show the autocorrelation function estimated from yearly excess mortality, and the blue error bars show the spread between the correlations estimated using different weeks of each year. $\mathbf{B}$: As in (A), but for Sweden.

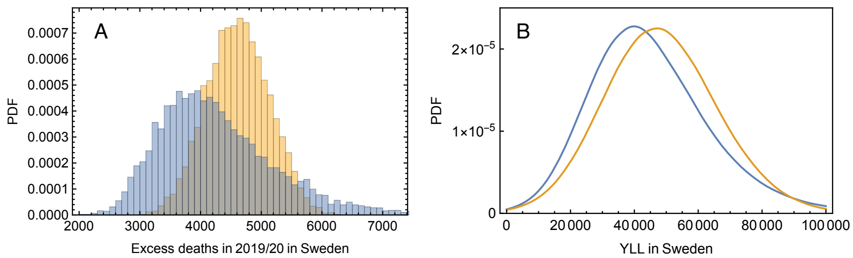


**Figure 4 Effect of mortality displacement A:** The yellow histogram shows the estimated probability density function for excess deaths obtained from the Monte Carlo simulation of the baseline. The blue histogram is the excess mortality adjusted for displacement according to Eq. 3. **B:** The blue curve is the estimated probability density function for YLL obtained from Eq. 1, and the blue curve is the probability density function for YLL after adjusting for mortality displacement.

**Table 1** Excess mortality per year. The excess mortality is defined as the registered deaths per year minus the expected number of deaths. The expected number of deaths are obtained from a model with a linear trend superposed on a seasonal signal. The confidence intervals are obtained by repeated re-estimates of the linear trend and seasonal signal in a Monte Carlo simulation (See Methods).

| Year | Excess mortality in Norway | | Excess mortality in Sweden | |
|---|---|---|---|---|
| | Estimate | (95% CI) | Estimate | (95% CI) |
| 2000/01 | 334 | (−180, 838) | −825 | (−1752, 84) |
| 2001/02 | 866 | (391, 1331) | 587 | (−261, 1410) |
| 2002/03 | 621 | (173, 1050) | 1227 | (466, 1946) |
| 2003/04 | −591 | (−1002, −192) | −1609 | (−2281, −956) |
| 2004/05 | −977 | (−1353, −606) | 331 | (−261, 903) |
| 2005/06 | −1874 | (−2215, −1527) | −2283 | (−2803, −1790) |
| 2006/07 | 59 | (−254, 373) | 758 | (314, 1188) |
| 2007/08 | −371 | (−661, −95) | −67 | (−449, 305) |
| 2008/09 | 105 | (−161, 367) | 825 | (497, 1151) |
| 2009/10 | −1043 | (−1298, −783) | −2197 | (−2505, −1885) |
| 2010/11 | 163 | (−98, 435) | 87 | (−241, 422) |
| 2011/12 | 633 | (362, 933) | 1443 | (1073, 1825) |
| 2012/13 | 456 | (160, 777) | 1718 | (1281, 2156) |
| 2013/14 | −732 | (−1048, −390) | −1959 | (−2467, −1448) |
| 2014/15 | 608 | (254, 980) | 2131 | (1547, 2717) |
| 2015/16 | −793 | (−1178, −390) | −1046 | (−1707, −378) |
| 2016/17 | 682 | (258, 1111) | 1811 | (1069, 2564) |
| 2017/18 | 731 | (281, 1196) | 1450 | (623, 2283) |
| 2018/19 | −15 | (−516, 495) | −1596 | (−2508, −680) |
| 2019/20 | 517 | (−12, 1074) | 4329 | (3331, 5325) |
| 2020/21 | 646 | (362, 957) | −1501 | (−1917, −1079) |

**Table 2** Proportion of deaths in 2020 in Sweden by age group and life expectancy by age group. Data source: Statistics Sweden (SCB)

| Age group (yrs) | Proportion of 2020 deaths | Life expectancy (yrs) Estimate (SD) |
|---|---|---|
| $50-64$ | 10% | 27.5 (3.8) |
| $65-79$ | 30% | 15.6 (3.3) |
| $80-89$ | 35% | 7.0 (1.6) |
| $>90$ | 25% | 2.5 (0.9) |