Estimation of Years of Life Lost by Sweden's Relaxed COVID-19 Mitigation Strategy

Martin Rypdal (✉ martin.rypdal@uit.no)

The Arctic University of Norway

Kristoffer Rypdal

The Arctic University of Norway

Ola Løvsletten

The Arctic University of Norway

Sigrunn Sørbye

The Arctic University of Norway

Elinor Ytterstad

The Arctic University of Norway

Filippo Maria Bianchi

The Arctic University of Norway

Research Article

Keywords: COVID-19, excess mortality, mortality displacement

Posted Date: December 28th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-125934/v1>

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RESEARCH

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

Martin Rypdal^{1*}, Kristoffer Rypdal¹, Ola Løvsletten², Sigrunn Holbek Sørbye¹, Elinor Ytterstad¹ and Filippo Maria Bianchi¹

*Correspondence:

martin.rypdal@uit.no

¹Department of Mathematics and Statistics, UiT - The Arctic University of Norway, Norway

Full list of author information is available at the end of the article

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

¹epidemic was reasonably controlled. Among the Western-European countries, Swe-¹
²den was an exception, adopting a more relaxed approach with mainly voluntary²
³measures [7]. As a consequence, the rate of confirmed cases entered a second and³
⁴more substantial wave in June and a third and even stronger one throughout the⁴
⁵autumn, coinciding with the widespread second wave in Europe. Here, the COVID-⁵
⁶19-specific mortality rate saw one broad wave lasting from March until July, then a⁶
⁷calm period from August till October when a second wave started. The confirmed⁷
⁸cumulative COVID-19 death toll in Sweden until November 11 was 6 247, which⁸
⁹corresponds to 611 deaths per million [8]. This figure is typical for Europe but high⁹
¹⁰compared to Sweden's Nordic neighbors. Norway, which is very similar to Sweden¹⁰
¹¹in most respects, has chosen a much more strict approach against COVID-19. As¹¹
¹²a result, by November 11, Norway had only 285 confirmed deaths (53 per million)¹²
¹³related to COVID-19 [8].¹³

¹⁴
¹⁵It has been suggested that the criticism of the Swedish strategy has been based¹⁵
¹⁶on the norm that considers death from coronavirus infection to be more impor-¹⁶
¹⁷tant than death from another infection [9]. The implicit assumption behind this¹⁷
¹⁸suggestion is that the pandemic's mortality rate was not substantially higher than¹⁸
¹⁹during previous seasonal influenzas and that all-cause excess mortality in Sweden¹⁹
²⁰differed significantly from the confirmed coronavirus-related mortality throughout²⁰
²¹the pandemic wave. In this paper, we investigate the validity of these assumptions.²¹
²²Also, we estimate the years of life lost (YYL) in Sweden that can be attributed to²²
²³its relaxed mitigation strategy.²³

²⁴
²⁵Our results and conclusions differ from Juul et al. (2020) [10], who suggest that²⁵
²⁶all-cause mortality in Norway and Sweden during the first wave of the COVID-19²⁶
²⁷epidemic up to July 2020 was largely unchanged compared to the previous four²⁷
²⁸years and that the high excess mortality observed in Sweden during the epidemic²⁸
²⁹wave was partly due to a mild influenza season during the winter 2019/20. In that²⁹
³⁰paper, the 5 741 COVID-19 deaths in Sweden reported between March 11 and July³⁰
³¹26 were interpreted partly as a mortality displacement within the epidemic year³¹
³²2019/20 and from this year to the next, with the implication that few years of life³²
³³were lost.³³

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

¹pandemic year 2019/20, the death number was 517 (-12, 1 074), where the numbers¹
²in the brackets represent the 95% confidence interval. In Sweden, the pre-pandemic²
³year saw -1 596 (-2 508, -680) deaths (below baseline), while the pandemic year had³
⁴an excess number of 4 329 (3 331, 5 325). The 255 reported COVID-19 deaths in⁴
⁵Norway is within the confidence interval for the excess estimates, and the 5 741 in⁵
⁶Sweden is slightly above. For the epidemic period March 11 - November 11, however,⁶
⁷Sweden had 6 247 reported COVID-19 deaths which is within the confidence interval⁷
⁸of the 5 517 (4 701, 6 330) excess deaths for this period. Using the same definition,⁸
⁹we estimated the annual excess numbers for the last twenty epidemic years (Table⁹
¹⁰1 and Figure 2 C and D). 10

¹¹11

¹²2.2 Estimates of years of life lost (YLL) in Sweden 12

¹³Using data on life expectancy in different age groups in Sweden [14] (Table 2) we 13
¹⁴simulated the YLL using the model 14

¹⁵15

$$\text{YLL} = X [0.10r_1 + 0.30r_2 + 0.35r_3 + 0.25r_4], \quad (1) \quad \text{¹⁶}$$

¹⁷17

¹⁸where the random variable X represents the excess mortality, with the estimated¹⁸
¹⁹distribution for 2019/2020, and the random variables $r_1, \dots, r_4$ are the life expectan-¹⁹
²⁰cies in each age group. We assumed the life expectancies to be independent and²⁰
²¹normally distributed random variables. The resulting estimate from these statistics²¹
²²is $\text{YLL} = 45\,850$ (13 915, 80 276). 22

²³23

²⁴2.3 Estimate of displacement effect 24

²⁵We estimated the autocorrelation functions (ACF) based on the twenty years of 25
²⁶weekly excess mortality rate data for Norway and Sweden (Figure 3 A and B). In 26
²⁷Sweden, we saw a slight anti-correlation in the year-to-year excess mortality. Hence, 27
²⁸it is conceivable that the large excess mortality in 2019/20 may cause a response 28
²⁹of negative excess mortality in the next few years. The simplest way to model such 29
³⁰a displacement effect is to use a first-order auto-regressive process (AR1) for the 30
³¹annual excess mortality X_t : 31

³²32

$$X_{t+\Delta t} = \phi X_t + \xi_t \quad (2) \quad \text{³³}$$

¹where $\Delta t = 1$ yr and ξ_t is a white-noise term. The estimated AR1 coefficient for¹
²Sweden is $\phi = -0.11$ $(-0.50, 0.30)$, and the adjustment of excess mortality in 2019/20²
³due to mortality displacement is³

$$X_{\text{adj}} = X + \rho X, \quad (3)$$

⁶where X is the excess mortality in 2019/20. Taking only response in 2020/21 into⁶
⁷account one has $\rho = \phi$, but if including the response over a few years one can use⁷
⁸the sum of the geometric series:⁸

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

¹²The estimated mean of ρ was -0.06. The median was -0.10 , and the 95% CI was¹²
¹³ $(-0.33, 0.43)$. Using the distribution of ρ to take the effect of possible displacement¹³
¹⁴into account the excess mortality in Sweden for 2019/20 was adjusted to a mean¹⁴
¹⁵value of 4 098 (2 706, 6 421) (Figure 4A). Carrying out the estimates of YLL with¹⁵
¹⁶this distribution of excess mortality in 2019/20 we obtained an YLL estimate of¹⁶
¹⁷43 073 (12 160, 85 451). Compared to the result in Section 2.2, the mean is reduced¹⁷
¹⁸by 6% (Figure 4B).¹⁸

¹⁹3 Discussion¹⁹

²⁰It is commonly claimed, as done in [10], that all-cause mortality rates are more²⁰
²¹reliable than reported COVID-19 related deaths. The results presented in this paper²¹
²²show that if our model for estimating the expected mortality rate is used, the two²²
²³rates agree within the confidence range of the estimated all-cause excess rate. Our²³
²⁴corresponding estimates of YLL are consistent with Oh et al. [15].²⁴

²⁵Another central issue raised in [10] is whether the COVID-19 peak in the all-²⁵
²⁶cause mortality rate observed in Swedish data could be explained as mortality²⁶
²⁷displacement, either from the preceding year or from the months preceding the²⁷
²⁸epidemic wave within the epidemic year 2019/20, or from both. We have already²⁸
²⁹seen that the negative excess death number (-1596) in 2018/19 constitutes less than²⁹
³⁰40% of the positive excess (+4329) in 2019/20, so such a displacement can only³⁰
³¹explain part of this excess. Rather than displacements between epidemic years, one³¹
³²can alternatively consider displacement from the twenty months starting in July³²
³³2018 and ending March 2020 into the epidemic period from March until November³³

¹2020. During the first period of lower than normal mortality, approximately 2 500¹
²deaths were avoided, but this can still explain only less than half of the 5.5 thousand²
³excess all-cause deaths so far during the epidemic wave. ³

⁴ We have seen that a negative excess rate before the pandemic creates a pool of⁴
⁵survivors that potentially could be particularly vulnerable to COVID-19. But the⁵
⁶existence of this pool does not imply that it actually contributed more than normal⁶
⁷to the COVID-19 deaths. If this displacement mechanism played an important rôle⁷
⁸in determining the fluctuations of the all-cause excess mortality rate in Scandinavia,⁸
⁹it should be observable in its time series. Year-to-year variations are dominated⁹
¹⁰by variations in seasonal influenza, and we should observe negative correlations¹⁰
¹¹between excesses in a given year and the following year (or years). In other words,¹¹
¹²we should observe this negative correlation in the autocorrelation function (ACF)¹²
¹³for the weekly all-cause excess time series. Figure 3 shows the estimated ACF for¹³
¹⁴Norway and Sweden based on twenty years of weekly data (1040 data points). The¹⁴
¹⁵confidence intervals for each year of time lag are given as error bars in the figures.¹⁵
¹⁶Only a very weak correlation can be detected on time scales longer than the duration¹⁶
¹⁷of the peak season for influenza. We draw from this that mortality displacement¹⁷
¹⁸is not generally a major driver of the excess mortality fluctuations in Norway and¹⁸
¹⁹Sweden. ¹⁹

²⁰ **4 Materials and methods** ²⁰

²¹ **4.1 Data sources** ²¹

²²Weekly mortality data was downloaded from Statistics Sweden (SCB) [14] and²²
²³Statistics Norway (SSB) [16]. COVID-19-related deaths were obtained from our-²³
²⁴worldindata.org [8]. ²⁴

²⁵ **4.2 Estimation of the expected mortality-rate signal** ²⁵

²⁶We first computed the linear trend in mortality by simple linear regression. After²⁶
²⁷subtracting the trend, we computed the expected seasonal variation over a year²⁷
²⁸by averaging the July-to-July signal over those twenty years. By repeating this²⁸
²⁹expected seasonal variation over the twenty years, and adding the linear trend,²⁹
³⁰we obtained the expected mortality-rate signal (the baseline, illustrated as black³⁰
³¹curves in Figure 1 A, B, and C). The excess mortality rate for a given week was³¹
³²defined as the weekly mortality rate that week, minus the expected mortality rate³²
³³
³³

at the time. The 95% CI for the estimate of the expected signal was computed¹
 using a Monte-Carlo simulation. First, we repeatedly randomized the estimated²
 excess mortality-rate signal without changing its correlation structure. The method³
 was to Fourier transform, randomize the phases of the Fourier coefficients, and then⁴
 invert the transform [17]. Then we added this new realization of the excess mortality⁵
 random process to the previously estimated expected mortality signal. Finally, we⁶
 made new estimates of the trend and seasonal variation to obtain new realizations⁷
 of the expected signal. By this procedure, we established a distribution of expected⁸
 signals from which we could establish a mean and a confidence interval. ⁹

4.3 The autocorrelation of the excess mortality signal ¹⁰

We obtained the ACF for the signal by the estimator ¹¹

$$\text{ACF}(\tau) = \frac{1}{(N - \tau)\sigma^2} \sum_{t=1}^{N-\tau} (x_t - x_{t+\tau}) \quad (4) \quad \text{13}$$

where τ is the time lag, μ is the sample mean and σ^2 the sample variance of the¹⁵
 weekly excess mortality rate signal of length $N = 1040$ weeks. The blue points in¹⁶
 Figure 2 is the ACF estimated from the annual data. The error bars were computed¹⁷
 estimating the ACF for the 52 different signals with annual resolution. We had 52¹⁸
 time series since there are 52 weeks in a year. ¹⁹

4.4 Estimates of the AR1 parameter ²⁰

To find the parameter ϕ in Eq. 2 we used the standard maximum-likelihood esti-²²
 mator. The distribution of ϕ was obtained from a bootstrapping method where we²³
 simulated the estimated process and re-estimated the parameter ϕ repeatedly. The²⁴
 maximum likelihood estimator is known to be biased for short time series but for small²⁵
 negative values of ϕ this bias is negligible [18]. ²⁶

Declaration ²⁷

- 1 Ethical declarations - Not applicable ²⁸
- 2 Consent to publication - Not Applicable ²⁹
- 3 Availability of data: Data and material from this study can be requested by contacting Martin Rypdal ²⁹
 (martin.rypdal@uit.no). The analyzed data is also publicly available from Statistics Sweden [14], ³⁰
 Statistics Norway [16], and Our World in Data [8].
- 4 Funding: This work was supported by the UiT Aurora Centre Program, UiT The Arctic University of Norway³¹
 (2020) ³²

Competing interests ³³

The authors declare that they have no competing interests. ³³

¹ Author's contributions

²The authors jointly conceived the study. MR, FMB, and SHS analyzed data. MR and KR wrote the paper with input from all authors.

Author details

¹Department of Mathematics and Statistics, UiT - The Arctic University of Norway, Norway. ²Department of Community Medicine, UiT - The Arctic University of Norway, Norway.

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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 COVID-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.

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)

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

16	Age group (yrs)	Proportion of 2020 deaths	Life expectancy (yrs)	16
17			Estimate (SD)	17
18	50 – 64	10%	27.5 (3.8)	18
19	65 – 79	30%	15.6 (3.3)	19
20	80 – 89	35%	7.0 (1.6)	20
21	> 90	25%	2.5 (0.9)	21

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Figures

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 COVID-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. 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. B: As (A), but for Sweden. C: The annual excess mortality for Norway from 2000/01 to 2019/20. The error bars are the 95% confidence intervals. D: As (C), but for Sweden.

Figure 3

Auto-correlation function of the excess mortality signal. 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. 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