Excess Death Anomaly in Finland 2021

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Abstract

Total excess mortality statistics are a reliable metric for detecting changes in death rates at the population level. We present a model based on official statistics for death counts in Finland from the years 2008-2019 to evaluate the mortality in 2020 and 2021. Observed mortality for 2020 and early 2021 was at the expected level based on our model. However, our calculations show a substantial increase in mortality starting in early summer 2021 and continuing until present, totaling over 3000 excess deaths from May 2021 to February 2022, over 5% of yearly total deaths. We verify our finding of excess mortality by multiple independent metrics. Shorter periods of excess mortality are not uncommon, but the extended duration of the present observation represents a clear anomaly. In the period 1990-2019 mortality has consistently been at its lowest during the summer months and peaked during winter. During the weeks 25-42 of 2021 a total of 1752 excess deaths were observed, whereas only 231 covid deaths were recorded during the same period. It is the duty of health and government officials to recognize this anomaly and initiate investigations to understand its cause.

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Introduction

Population mortality statistics constitute a reliable metric for detecting significant events causing changes in death rate at the population level. The number of deaths is usually reported in weekly, monthly or yearly intervals, without attribution of causes of death. Excess mortality or mortality deficit means that, based on an inference from previous mortality, the currently observed mortality is higher or lower than expected.

The Finnish Institute for Health and Welfare (THL) has in press releases and interviews claimed that no notable changes have occurred in the mortality rates in Finland during the pandemic. The official Finnish institute for statistics, Statistics Finland, asserted in an interview in the major finnish newspaper Helsingin Sanomat that the number of recorded deaths in 2021 was not exceptional, comparing it to the year 2020 and noting that there were a mere 500 deaths more.

The statements of THL and Statistics Finland are in conflict with both EuroMOMO and the most recent Population Prognosis published by Statistics Finland itself. In this paper we present a model for expected number of deaths from 2020, relying on official statistics on deaths from the preceding 12 years. We demonstrate that the first year of the covid pandemic 2020 shows completely normal mortality, whereas the year 2021 displays an extended period of excess mortality in the second half of the year. We also verify our model's correctness by comparing it to several independent data sources.

Materials and Methods

Mathematical Model

We present a mathematical function to predict number of deaths per week, with no stratification by age or gender, and then use this function to compare pandemic death rates to previous years. Mortality is highly seasonal, peaking during the flu season in winter and bottoming out in summer. In Finland harsh heat waves are rare, but in some years have seen excess mortality in summer due to extended hot periods. On the other hand, some winters have brought quite large peaks of excess mortality from heavy flu seasons. Such winters are usually followed by periods of mortality deficit once the flu has subsided.

To model these patterns we apply a function consisting of a linear component for the long term trend in mortality and an oscillating cosine component to accommodate the seasonality (Figure 1). Similar mathematical functions underlie the models of EuroMOMO, although its focus is on short term excess mortality caused by epidemics.

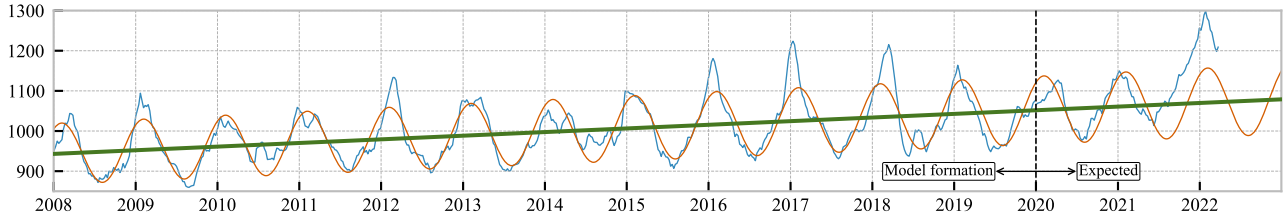

Figure 1. Weekly deaths are modelled by a linear trendline (green) modulated by a seasonal sine curve (orange). The blue line represents a 7 week moving average of the actual recorded deaths.

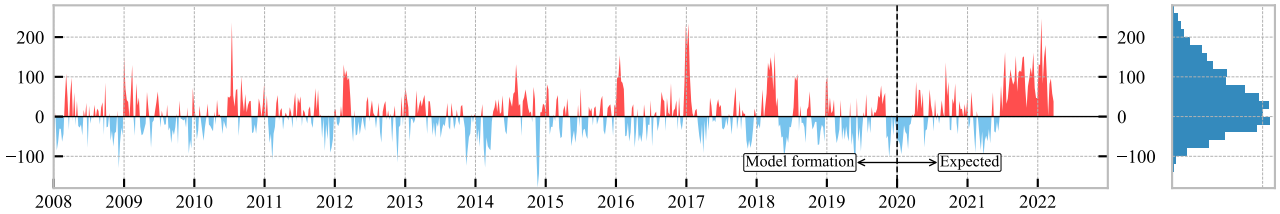

Figure 2. Weekly excess mortality in red, mortality deficit in blue.

The long term trend has been highly linear during the entire reporting period of Statistics Finland, up until the summer of 2021. In the first half of the period, 1990-2006, it was mildly decreasing, and then gently increasing during 2007-2020. We applied our model to the period after 2008, where the trend has been consistently gently increasing.

The seasonal cosine component peaks in winter and bottoms out in summer. The amplitude of the cosine component is proportional to the total mortality, so that the seasonal variability would increase when total deaths increase. The mathematical function of our mortality model is thus:

$$f_b(t) = f_{trend}(t) + a\, f_{trend}(t)\, cos\left(\frac{2\pi}{365.24}t + \theta\right)$$
$$= f_{trend}(t)\left(1 + a\, cos\left(\frac{2\pi}{365.24}t + \theta\right)\right)$$

where:

- Parameter t is time.
- $f_{trend}(t)$ is a linear function running from $x_1 = 1Jan2008$ ja $x_2 = 31Dec2019$.
- Parameter a represents the amplitude and θ is the periodic shift of the of the cosine component.

The fitted parameters y_1, y_2, a and θ were established using the "curve fit"-function of SciPy, which utilizes non-linear least squares regression to minimize the difference between the model function $f_b(t)$ and the weekly deaths. The model was fitted for the time period 1 Jan 2008 - 31 Dec 2019, and the fit parameters were established as follows: $y_1 = 943.8$, $y_2 = 1044.6$, amplitude $a = 0.08$ and periodic shift $\theta = -35.37$ days.

Data Sources

The source for total excess mortality was the weekly publication "Kuolleet viikoittain pikaennakko" by Statistics Finland [1], which contains weekly number of deaths without cause of death or sex and gender information, available since 1990. In addition to this we used monthly number of deaths from Statistics Finland [2] and EuroMOMO's Z-values [3] which represent excess mortality. The source for deaths ascribed to COVID-19 was THL's report "Tartuntatautirekisterin COVID-19-tapaukset" [4], containing weekly covid deaths.

Source Code

The source code for the model and graphics was made with Python programming language, using SciPy and Matplotlib libraries. All source code including PDF-graphics are available online at:
https://github.com/k-ronning/acm_analyzer.

Results and Discussion

Calculating the difference between weekly estimated deaths from our model and actual recorded numbers, we arrive at excess mortality numbers per week, illustrated in Figure 2. Nearly every year the flu season generates mortality numbers that exceed the normal range, followed usually by some months of mortality deficit.

Yearly Cumulative Excess Mortality

The annual flu season varies in timing and may thus greatly skew the yearly mortality numbers depending on whether flu mortality peaks in December or January. To accommodate this variability, yearly cumulative deaths can be analyzed by shifting the calculation starting point to after the flu season. We chose week 16 as the starting point of our cumulative values, as this is used by EuroMOMO as the week when the flu season is generally considered to have ended [5, s. 13]. Figure 3 shows the shifted cumulative excess mortality curves for 2008-2021. Mortality patterns from spring, summer and autumn are seen on the left half of the graph, while the right part of the graph is dominated by the flu season and the high variability it brings. 2020 and 2021 are drawn with bolded lines, and for these years an additional dashed line shows the excess mortality minus covid deaths, by which one can evaluate excess deaths unrelated to covid.

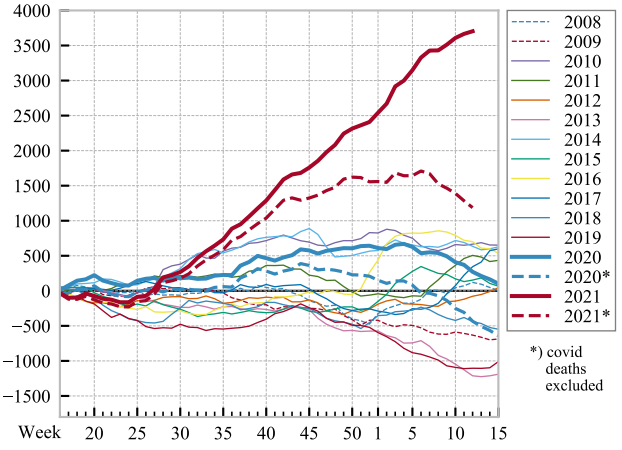

Figure 3. Yearly cumulative excess mortality 1990-2021. Cumulation starts from week 16.

It is evident from the figure that 2020 does not stand out from previous years, regardless of whether we consider the total excess or the excess minus covid deaths. In contrast, the year 2021 shows a dramatic departure from the other years, starting out normally but turning into a steady increase from week 25 and continuing until present (April 2022), totaling

35 weeks. Particularly noteworthy is the period between week 25 and week 42, during which we estimate 1752 excess deaths, while the same period saw only 231 covid deaths.

Cumulative Excess Mortality of the Entire Time Period

Figure 4 shows the cumulated excess mortality of the entire period used for the model. One can deduce from the figure that the linear model component represents the mortality reasonably well, considering that no extended period of excess or deficit mortality is seen, as is expected. If the linear component was a poor fit, the cumulative excess would deviate upwards or downwards for longer periods. While the above is true for the first years of the graph, such deviation does indeed happen in the summer of 2021. What could explain this abrupt change in the mortality pattern in summer 2021, given that the mortality has followed a stable downward trend since 2008? When the previously stable trend suddenly changes upwards, this represents unexpected increased mortality, i.e. excess mortality. Our model estimates that from May 2021 until February 2022 there has been a total of over 3000 deaths more than expected in Finland, and only part of these are covid deaths.

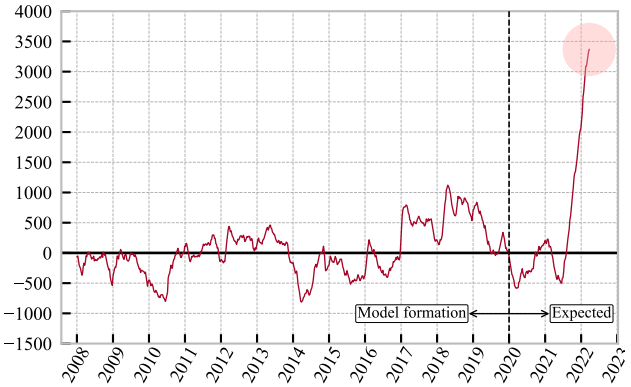

Figure 4. Excess mortality for the entire period 1 Jan 2008 - 20 Feb 2022.

Model Verification

All models are based on assumptions, which may be wrong. To verify our model for correctness, we compared the outcome to three different data sources: EuroMOMO, Statistics Finland's monthly reported deaths and Statistics Finland's population forecast.

EuroMOMO

EuroMOMO is a mortality surveillance tool maintained by the Danish "Statens Serum Institut". The underlying model for the excess death calculations is not in the public domain, but its Z-values refer to the standard normal distribution. $Z = 1$ refers to one standard deviation difference from the mean, and the mean in this case is the EuroMOMO expected number of deaths for the week, as given by the underlying model. EuroMOMO's Z-values serve as a process control chart for mortality, with an upper control limit of $4Z$. This control limit is often exceeded during harsh influenza seasons, indicating a sudden excess mortality as is often the case during influenza waves. However, in the domain of process control charts also extended periods of less pronounced deviations must be considered as possible anomalous events. Nelson's rules are often referred to when interpreting anomalies in control charts, and the EuroMoMo Z-values for 2021 trigger at least three of these rules:

A) Nine or more consecutive observations are on the same side of the mean line ($Z = 0$).

B) Four (or five) of five consecutive observations are farther than 1 standard deviation ($= 1Z$) in the same direction from the from the mean line.

C) Two (or three) of three consecutive observations are farther than 2 standard deviations ($= 2Z$) in the same direction from the from the mean line.

EuroMOMO's weekly Z-values since 2017 from Finland are shown in Figure 5. During the second half of 2021 the above mentioned rules are violated numerous times:

- From Week 24 2021 there are 20 consecutive weeks where $Z > 0$, and 33 of the subsequent 35 weeks $Z > 0$, so rule A is violated dozens of times.
- From Week 35 2021 until Week 7 2022, there are 9 occasions where four or more out of five consecutive weeks have $Z > 1$, so rule B is violated 9 times.
- From Week 27 2021 until week 6 2022 there are 4 occasions where two or more out of three consecutive weeks have $Z > 2$, so rule C is violated 4 times.

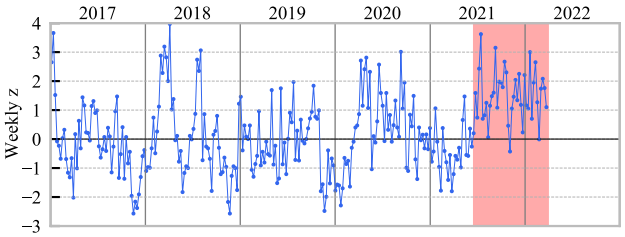

Figure 5. EuroMOMO's Z-values, where the Z-values in the red area violates Nelson's rules.

Together, these observations constitute a strong anomaly during the entire second half of 2021, fully in line with the excess deaths from our model.

Further validating the agreement between our model and EuroMOMO's Z-values, figure 6 shows a strong correlation between the two, with a correlation coefficient of $r > 0.9$. This demonstrates that the two models are well aligned and describe the same phenomenon.

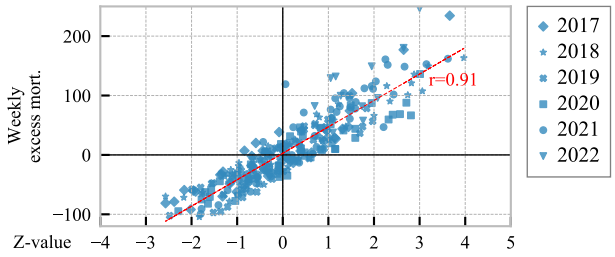

Figure 6. Correlation between EuroMOMO's Z-values and the excess deaths from our model.

Monthly Distribution of Deaths

As a second verification approach, we used monthly deaths statistics from Statistics Finland to calculate the relative distribution of deaths among the months of each year for the period 1990-2021. Figure 7 shows the mortality patterns for 1990-2020 as a blue area, with both 80% and 100% of the range per month indicated. This distribution is very repeatable from year to year, depending mainly on seasonal factors such as winter influenza and summer heat waves. The roughly 10% drop for February is due to the fewer number of days in this month.

This figure shows clearly that already from May, the mortality pattern for 2021 was at the extremes of the range for 1990-2020, and that never during 1990-2020 did the months from July to November contain this high a proportion of total deaths of the year. The value for December 2021 was the third highest, with only 1993 and 2003 being higher, due to the influenza wave of these two years striking in December.

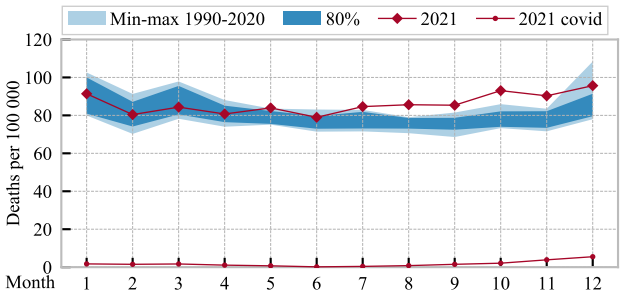

Figure 7. Monthly mortality 1990 – 2020. The second half of 2021 significantly exceeds the range of the previous 30 years. Covid explains only a small part of this pattern.

Distribution Between First and Second Half of the Year

In the methodology of control charts, another approach used is to compare the proportion of events per segment of time. Figure 8 shows the proportion of all deaths per year that happened during the second half of the year plotted as a function of the years. From 1990 to 2020, this proportion has meandered between 47.6% and 50.2%, with a standard deviation of 0.66%pt. Also in this comparison, 2021 deviates profoundly from the other years, with the proportion of deaths during the second half coming in at 51.7%, an astounding 4.4 standard deviations from the mean of 1990-2020. The probability that such an event would occur by pure chance without a special cause is $p = 0.00001$, or in other words once every 100 000 years.

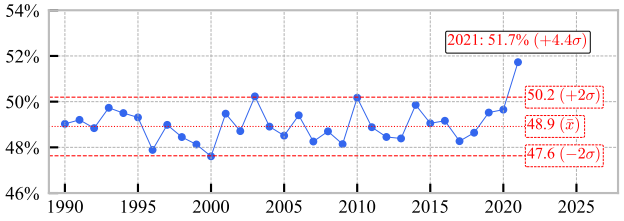

Figure 8. Proportion of deaths in second half of the year. 2021 clearly deviates from the entire previous 30 years.

Population Forecasts

Every 1-3 years, Statistics Finland publishes a Population Forecast, which includes various metrics on the population, including expected deaths. The projections from the most recent publications of 2012, 2015, 2018 and 2019 are shown in Figure 9, and comparing to the actual number of deaths (blue line), one can see that these projections have been mostly slight underestimates. Since our model is fitted to the actual deaths of 2008-2019, it is expected to follow the actual number of deaths closely to the end of 2019.

Of particular interest in this graph, however, is the forecast published 30 September 2021, which estimates the deaths for 2021 at 1679 higher than what the 2019 forecast predicted for the same year. In spite of being from the end of September and adjusting the 2019 clearly upwards, it still falls 1356 deaths short of the total number of deaths for the year, which came in only three months later. The total deaths in 2021 was 3035 more than the Statistics Finland 2019 prediction – a massive deviation from a prediction only two years old.

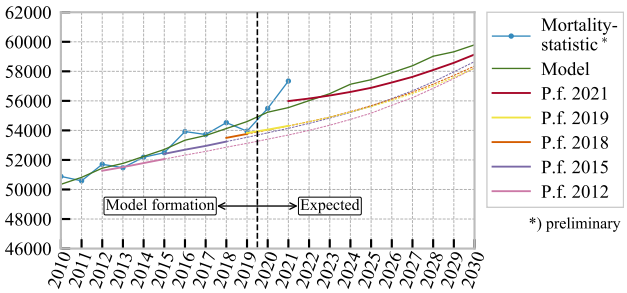

Figure 9. Yearly observed deaths in blue, our model's prediction in green, remaining colors are population forecasts.

Possible Causes for the Excess Mortality

Healthcare Backlog

The policies of the covid period led to increases in healthcare backlogs, which could in part explain the excess mortality, but the effects of such backlogs would hardly lead to sudden changes in deaths, rather causing a gradual increase. In other words, why would missing healthcare follow-up lead to no increased deaths from 2020 until May 2021 only to cause a sudden and persistent increase from Week 25 2021? The effect of healthcare backlogs must be must more gradual to be a feasible explanation.

Covid

If many people died of SARS-CoV2 without a diagnosed infection, this could explain excess deaths. The covid deaths of 2021 were, however, at their lowest in summer – totaling a mere 31 deaths in June and July – when the number of excess deaths during the same period was +367. Correspondingly, the total covid deaths in Weeks 25 through 42 were 231, but excess deaths during the same period were at +1752. If underdiagnosing of covid was the explanation, covid deaths and excess deaths should correlate.

Furthermore, the tentative numbers of covid deaths reported by the Finnish Institute for Health and Welfare (THL) from 2020 – 598 deaths – were adjusted down to 558 when the final cause of death statistics from Statistics Finland arrived. Thus, it is expected that THL's current estimate of 1136 covid deaths for 2021 will be adjusted down. In other

words, covid deaths could at maximum explain one third of the excess deaths from our model, and mainly only the deaths from November and December. Also, considering that the roughly 500 covid deaths in 2020 led to no observable excess mortality, this leaves nearly 2500 unexplained deaths for 2021.

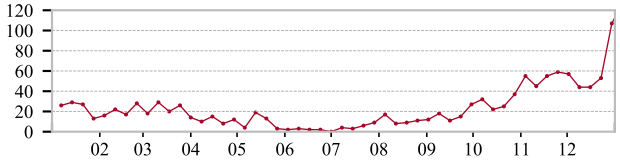

Figure 10. Deaths from covid per week 2021 (Month numbers on x-axis).

Ageing Population

The older age cohorts in Finland have steadily been increasing during recent times, so it is expected that the total amount of deaths will increase accordingly. This explains why the number of deaths per year in Finland has steadily increased over the last 10 years or more. If our model had underestimated this gradual increase, it could explain the observed excess deaths.

However, ageing is a slow process, the effects of which are also slow as a consequence. Our model takes into account such gradual effects, happening over decades. Our data show that the mortality patterns of 2021 are normal until May, when the numbers suddenly rise and remain high for the entire second half of the year, and remained high when this paper was first published in Finnish (Apr 2022).

Conclusions

In the present work, we have shown with multiple different approaches a highly anomalous pattern of excess deaths in Finland starting early summer 2021, currently totaling over 3000 excess lives lost, and only partially explained by covid infections. In particular, during the Weeks 24 through 42 2021 there were 1752 excess deaths, but only 231 covid deaths, leaving 1521 non-covid excess deaths.

While age stratification was not in the scope of this study, EuroMOMO indicates that the majority of the observed excess deaths appears to occur in the age cohorts above 80 years. Neither underdiagnosing of covid infection, healthcare backlog or ageing population explain this sudden and persistent excess mortality.

The excess mortality calculated from our model was cross-checked by three different methods: 1) Comparison with EuroMOMO; 2) Deviations in monthly distribution of each year's deaths; 3) Deviation from 2019 population forecast. All three approaches verified the observed anomaly. Given the strength of the statistical significance as established by EuroMoMo data, the anomaly cannot have arisen from random variation.

Finnish health authorities have thus far (April 2022) either downplayed or altogether ignored this alarming data. In the light of the irrefutable evidence presented in this paper, it is high time health authorities stop understating the severity of the situation and carry out a thorough and independent investigation of the cause for the dramatically elevated mortality.

References

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