Supplementary Material S1: Actual deaths versus forecast deaths in England (2001-2061)

Author RPJ has been following the gap between actuarial forecasts and actual number of deaths in the UK for over 25 years. Deaths are part of the process of estimating future population numbers, via what are called the components of change, namely births, immigration, and deaths. Figure S1 demonstrates that the forecasts for deaths are notoriously unreliable, mainly because the estimation of future mortality rates is clouded in uncertainty. The sudden change in the trajectory of total deaths after 2011 seemingly caught actuaries’ completely off guard. It was only until the 2016-based forecast that they realized that the mortality rate trends had substantially changed.

Indeed, actuarial forecasts are completely unable to explain the volatility in the actual deaths, which greatly depends on infectious outbreaks each winter [40-41]. Hence official forecasts cannot be used to validate the 2019 (pre-COVID-19) base year.

It is well recognized that international estimates of COVID-19 deaths are themselves unreliable [16]. Such sources of uncertainty led to the development of several alternative methods for estimating the equivalent to a pathogen-neutral baseline for male and female single-year-of-age deaths in 2019 (the pre-COVID-19 baseline). Deaths during the COVID-19 era in 2020 and 2021 can therefore be compared against this baseline. These methods are detailed in the Supplementary files S2 to S4. While in S5 this baseline is used to determine the degree of bias in the male and female reported COVID-19 deaths in England and Wales during 2020 and 2021.

Figure S1. Actual deaths versus forecast deaths in England (2001 to 2061). Based on population forecasts prepared every two years by the Office for National Statistics (ONS) since 2000, see [38] for various past forecasts and actual deaths from [28,29].

Supplementary Material S2: Methods for adjusting deaths to the 2019 average baseline value

This is a technical Supplement relating to year of age analysis of excess deaths during the COVID-19 years from 2020 onward and how these can be adjusted to compare against a pre-COVID-19 baseline for 2019. This baseline is established as an ‘average’ number of deaths in 2019 based upon deaths adjusted to the 2019-equivalent in years 2011 to 2018. The resulting year of age excess deaths in 2020 and 2021 can then be compared to the measured levels of deaths ‘due to’ COVID-19 as assessed by the Office for National Statistics (ONS) based upon material contained in the death certificate record for each person. This assessment contains inherent diagnostic ambiguity and cannot exceed the calculated excess mortality. This comparison is made in Supplement S4.

First, we commence with an assessment of the level of year-to-year differences in deaths (or the volatility) for each year of age over the period 1963 to 2019 [from 28,29]. This is achieved by calculating the absolute value of the year-to-year difference and dividing this by the square root of the average of deaths in each pair of years. This adjusts for the effect of size and converts the absolute difference into a Poisson statistic equivalent to a standard deviation (STDEV) distance from the average. The median value for the 55 paired years for the STDEV equivalent is then calculated.

A value of the median close to 1 indicates that the volatility is driven by simple Poisson variation – as would be expected for small numbers. Values higher than 1 indicate increasing levels of special cause variation such as the impact of winter infectious outbreaks [40,41,45]. For example, an earlier study using this method established that some locations in England and Wales experience higher intrinsic volatility than others [41]. The implication being that such locations would have greater difficulty managing their budget for end-of-life and elderly care costs [41]. Note that the maximum number of male deaths of around 9500 per annum occurs at age 84, and around 11300 per annum at age 94 for females [28,29]. One STDEV of Poisson variation at the maximum deaths is therefore ± 97 (1%) for males and ± 106 (0.9%) for females.

Figure S1 shows the outcome of such analysis where the volatility is dominated by small number Poisson variation between the ages of 1 to 30 in males and 1 to 40 in females, rises above this to a maximum of around 3.1 for males aged 70 to 72 and around 3.9 for females aged 87.

**Figure S2. 1.** The median value for the year-to-year volatility in deaths (1963 to 2019).

The median volatility then declines with greater age, although above the maximum female volatility is higher. At age 0 (first year of life) volatility is higher in males. The implication of Figure S1.1 is that assessing the average number of deaths in 2019 (the pre-COVID-19 base year) may be more difficult at ages around those where the maximum volatility occurs – as the outworking of environmental sensitivity including infectious outbreaks.

The next steps are to calculate various adjustment factors to express all years as 2019 equivalents. Each has strengths and weaknesses.

1. Mid-year population. This method is widely used, however, both births and deaths are measured as a 12-month total and not a mid-year figure. As mentioned, the ONS does not provide mid-year population estimates above age 90 [32].
2. Based on actual births [35]. This method has the advantage that births and deaths are matched to 12-month totals. It has the disadvantage that some birth cohorts will suffer attrition in World War II and that inward/outward migration after WW II will modify the population away from the simple birth total.
3. Extrapolation based on raw single year of age deaths. This is an alternative method for age 90+ estimates. A second order polynomial is used.
4. The average of 2017, 2018 and 2019. There was a large infectious event during the winter of 2017/18 with the bulk of excess deaths occurring in 2018 [40,41,45]. This infectious event affected specific ages. Analysis shows that the excess deaths in 2018 were then counterbalanced by an almost equal number of lower deaths in both 2017 and 2019, hence, the average of the three years evens out the effect of the 2018 surge.

For population-adjusted deaths the ONS provided mid-year population estimates based on the most recent decennial census [30,31]. Since the ONS does not provide mid-year population estimates above the age of 89, the average for deaths in 2019 for ages 90+ was calculated using a second order polynomial curve fit to the raw deaths, as per #3 above.

When conducting the population adjustment, it became clear that the World War II baby boom seemed to be affecting the outcome [35]. At this point the World War I baby boom is also relevant for an alternative to the age 90+ estimated population but was also applied to ages below 90, as per #2 above.

Figure S1.2 therefore shows the trend in annual births over the years 1900 to 1950 [35]. Prior to World War I live births were at a maximum followed by various peaks and troughs largely emanating from World Wars I and II. The peak in deaths around 1965 arises from the WW II cohort reaching the age where births are common. The resulting adjustment factors based on live births are given in the Table in Supplement S2

**Figure S2. 2.** Trend in annual live births in England and Wales, 1900 to 1950 [35].

The major limitation of the method based on births is that those born in the WW I birth cohort suffer attrition during WW II, however, this is the only alternative to a population-based estimate.

Finally, the method based on the average of 2018 and 2019 deaths relies on the observation that the infectious event in early 2018 affected specific ages which were then approximately matched by lower deaths in these specific ages in 2019. The final chosen value for the 2019 average was therefore the average of the 3 or 4 available methods. The outcomes of the different methods are shown in Figure S1.3, while full details are shown in the Table given in Supplement S3.

**Figure S2. 3.** Results for different adjustment methods to give a 2019-average deaths baseline.

The Poisson-based variation (as a standard deviation) associated with the chosen average for 2019 was calculated as the square root of the chosen ‘average’ value. It should be noted that that actual calculated standard deviation between the different estimates was lower than the Poisson-based standard deviation in all years except for, Males – age 72-74, 76, 81,94-95, and Females – age 72-74, 76-77, 84,89, 94-100. This seems to be partly the outworking of issues addressed in Figure S1.1. Figure S1.4 shows the detail regarding which years have a high standard deviation between the estimates using different methods and the calculated value of a STDEV using Poisson statistics, as the square root of the estimated ‘average’ value.

It can be assumed that estimates for the 2019 ‘average’ when the ratio in Figure S1.4 is below 100% are reasonably accurate. In the other years a degree of variation appears to be unavoidable.

**Figure S2. 4.** The ratio of the standard deviation of the estimates for 2019 versus a Poisson-based standard deviation (as the square root of the estimated 2019 ‘average’ value.

Supplementary Material S3: Adjustment factors based on births to give 2019-equivalent estimate

Divide age data for each year by the adjustment factor to get the 2019-equivalent. Note that births reached their most recent peak in 2012. The maximum adjustment factor is 1.46 for age 92 in 2012. The minimum factor is 0.66 for age 72 in 2013. Calculation based on raw data from [35].

| **Age in >** | **2021** | **2020** | **2019** | **2018** | **2017** | **2016** | **2015** | **2014** | **2013** | **2012** | **2011** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0.98 | 0.96 | 1.00 | 1.03 | 1.06 | 1.09 | 1.09 | 1.09 | 1.09 | 1.14 | 1.13 |
| 1 | 0.93 | 0.97 | 1.00 | 1.03 | 1.06 | 1.06 | 1.06 | 1.06 | 1.11 | 1.10 | 1.10 |
| 2 | 0.94 | 0.97 | 1.00 | 1.03 | 1.03 | 1.02 | 1.03 | 1.07 | 1.07 | 1.06 | 1.04 |
| 3 | 0.94 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.05 | 1.04 | 1.04 | 1.01 | 1.02 |
| 4 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 | 1.05 | 1.04 | 1.04 | 1.01 | 1.02 | 0.99 |
| 5 | 1.00 | 1.00 | 1.00 | 1.00 | 1.05 | 1.04 | 1.04 | 1.02 | 1.02 | 0.99 | 0.96 |
| 6 | 1.00 | 1.00 | 1.00 | 1.04 | 1.04 | 1.04 | 1.01 | 1.01 | 0.99 | 0.96 | 0.92 |
| 7 | 0.95 | 0.96 | 1.00 | 0.99 | 0.99 | 0.97 | 0.97 | 0.95 | 0.92 | 0.89 | 0.88 |
| 8 | 0.96 | 1.01 | 1.00 | 1.00 | 0.98 | 0.98 | 0.95 | 0.92 | 0.89 | 0.88 | 0.86 |
| 9 | 1.01 | 1.00 | 1.00 | 0.98 | 0.98 | 0.95 | 0.93 | 0.89 | 0.88 | 0.86 | 0.82 |
| 10 | 1.03 | 1.02 | 1.00 | 1.00 | 0.98 | 0.95 | 0.91 | 0.91 | 0.88 | 0.84 | 0.84 |
| 11 | 1.02 | 1.00 | 1.00 | 0.97 | 0.94 | 0.91 | 0.90 | 0.88 | 0.84 | 0.84 | 0.85 |
| 12 | 1.02 | 1.03 | 1.00 | 0.97 | 0.94 | 0.93 | 0.90 | 0.86 | 0.86 | 0.88 | 0.90 |
| 13 | 1.06 | 1.03 | 1.00 | 0.96 | 0.96 | 0.93 | 0.89 | 0.89 | 0.90 | 0.93 | 0.95 |
| 14 | 1.07 | 1.04 | 1.00 | 0.99 | 0.96 | 0.92 | 0.92 | 0.94 | 0.96 | 0.98 | 1.00 |
| 15 | 1.05 | 1.01 | 1.00 | 0.97 | 0.93 | 0.93 | 0.94 | 0.97 | 0.99 | 1.01 | 1.02 |
| 16 | 1.04 | 1.03 | 1.00 | 0.96 | 0.96 | 0.97 | 1.00 | 1.02 | 1.03 | 1.05 | 1.04 |
| 17 | 1.07 | 1.04 | 1.00 | 1.00 | 1.01 | 1.04 | 1.07 | 1.08 | 1.09 | 1.09 | 1.12 |
| 18 | 1.05 | 1.00 | 1.00 | 1.02 | 1.05 | 1.07 | 1.08 | 1.09 | 1.09 | 1.12 | 1.13 |
| 19 | 0.99 | 0.98 | 1.00 | 1.03 | 1.05 | 1.06 | 1.07 | 1.07 | 1.10 | 1.11 | 1.14 |
| 20 | 0.96 | 0.97 | 1.00 | 1.02 | 1.03 | 1.04 | 1.04 | 1.07 | 1.08 | 1.11 | 1.12 |
| 21 | 0.95 | 0.98 | 1.00 | 1.01 | 1.02 | 1.02 | 1.05 | 1.06 | 1.08 | 1.10 | 1.11 |
| 22 | 0.97 | 0.99 | 1.00 | 1.01 | 1.01 | 1.03 | 1.05 | 1.07 | 1.09 | 1.10 | 1.07 |
| 23 | 0.98 | 0.99 | 1.00 | 1.00 | 1.02 | 1.04 | 1.06 | 1.08 | 1.09 | 1.06 | 1.07 |
| 24 | 0.99 | 1.00 | 1.00 | 1.03 | 1.04 | 1.06 | 1.08 | 1.09 | 1.06 | 1.07 | 1.05 |
| 25 | 0.98 | 0.98 | 1.00 | 1.01 | 1.04 | 1.05 | 1.06 | 1.03 | 1.04 | 1.03 | 0.99 |
| 26 | 0.96 | 0.99 | 1.00 | 1.02 | 1.04 | 1.05 | 1.02 | 1.03 | 1.01 | 0.98 | 0.97 |
| 27 | 0.96 | 0.98 | 1.00 | 1.01 | 1.02 | 1.00 | 1.01 | 0.99 | 0.96 | 0.95 | 0.92 |
| 28 | 0.96 | 0.99 | 1.00 | 1.01 | 0.98 | 0.99 | 0.97 | 0.95 | 0.94 | 0.91 | 0.90 |
| 29 | 0.98 | 0.99 | 1.00 | 0.97 | 0.98 | 0.97 | 0.94 | 0.93 | 0.90 | 0.89 | 0.89 |
| 30 | 1.02 | 1.03 | 1.00 | 1.01 | 0.99 | 0.96 | 0.95 | 0.93 | 0.91 | 0.91 | 0.92 |
| 31 | 1.02 | 0.99 | 1.00 | 0.98 | 0.95 | 0.95 | 0.92 | 0.91 | 0.90 | 0.91 | 0.95 |
| 32 | 1.01 | 1.02 | 1.00 | 0.97 | 0.96 | 0.93 | 0.92 | 0.92 | 0.93 | 0.96 | 0.94 |
| 33 | 1.05 | 1.03 | 1.00 | 0.99 | 0.96 | 0.95 | 0.95 | 0.96 | 0.99 | 0.97 | 0.90 |
| 34 | 1.04 | 1.01 | 1.00 | 0.97 | 0.96 | 0.95 | 0.97 | 1.00 | 0.97 | 0.91 | 0.87 |
| 35 | 1.04 | 1.03 | 1.00 | 0.99 | 0.98 | 1.00 | 1.03 | 1.00 | 0.94 | 0.89 | 0.92 |
| 36 | 1.04 | 1.01 | 1.00 | 0.99 | 1.01 | 1.04 | 1.01 | 0.95 | 0.90 | 0.93 | 0.96 |
| 37 | 1.02 | 1.01 | 1.00 | 1.01 | 1.05 | 1.02 | 0.95 | 0.91 | 0.93 | 0.96 | 1.02 |
| 38 | 0.99 | 0.99 | 1.00 | 1.03 | 1.01 | 0.94 | 0.90 | 0.92 | 0.95 | 1.01 | 1.07 |
| 39 | 0.95 | 0.97 | 1.00 | 0.97 | 0.91 | 0.87 | 0.89 | 0.92 | 0.98 | 1.03 | 1.11 |
| 40 | 0.99 | 1.03 | 1.00 | 0.93 | 0.89 | 0.92 | 0.95 | 1.00 | 1.06 | 1.14 | 1.23 |
| 41 | 1.10 | 1.07 | 1.00 | 0.95 | 0.98 | 1.01 | 1.07 | 1.13 | 1.22 | 1.31 | 1.32 |
| 42 | 1.12 | 1.05 | 1.00 | 1.03 | 1.06 | 1.12 | 1.19 | 1.27 | 1.38 | 1.38 | 1.40 |
| 43 | 1.02 | 0.97 | 1.00 | 1.03 | 1.10 | 1.16 | 1.24 | 1.34 | 1.34 | 1.37 | 1.40 |
| 44 | 0.94 | 0.97 | 1.00 | 1.06 | 1.12 | 1.20 | 1.30 | 1.30 | 1.32 | 1.36 | 1.38 |
| 45 | 0.91 | 0.94 | 1.00 | 1.06 | 1.13 | 1.22 | 1.23 | 1.25 | 1.28 | 1.30 | 1.33 |
| 46 | 0.89 | 0.95 | 1.00 | 1.07 | 1.16 | 1.16 | 1.18 | 1.21 | 1.23 | 1.26 | 1.28 |
| 47 | 0.88 | 0.93 | 1.00 | 1.08 | 1.08 | 1.10 | 1.13 | 1.15 | 1.17 | 1.19 | 1.21 |
| 48 | 0.86 | 0.93 | 1.00 | 1.00 | 1.02 | 1.05 | 1.06 | 1.09 | 1.10 | 1.12 | 1.09 |
| 49 | 0.92 | 1.00 | 1.00 | 1.02 | 1.04 | 1.06 | 1.08 | 1.10 | 1.12 | 1.09 | 1.07 |
| 50 | 0.98 | 0.98 | 1.00 | 1.03 | 1.04 | 1.07 | 1.08 | 1.10 | 1.07 | 1.05 | 1.02 |
| 51 | 0.96 | 0.97 | 1.00 | 1.02 | 1.04 | 1.05 | 1.07 | 1.04 | 1.02 | 0.99 | 0.96 |
| 52 | 0.96 | 0.98 | 1.00 | 1.02 | 1.04 | 1.05 | 1.03 | 1.01 | 0.97 | 0.94 | 0.90 |
| 53 | 0.96 | 0.98 | 1.00 | 1.02 | 1.03 | 1.00 | 0.99 | 0.95 | 0.92 | 0.88 | 0.87 |
| 54 | 0.96 | 0.99 | 1.00 | 1.02 | 0.99 | 0.97 | 0.94 | 0.91 | 0.87 | 0.86 | 0.84 |
| 55 | 0.97 | 0.98 | 1.00 | 0.97 | 0.96 | 0.93 | 0.90 | 0.85 | 0.85 | 0.83 | 0.80 |
| 56 | 1.01 | 1.03 | 1.00 | 0.98 | 0.95 | 0.92 | 0.88 | 0.87 | 0.85 | 0.82 | 0.78 |
| 57 | 1.04 | 1.02 | 1.00 | 0.97 | 0.94 | 0.89 | 0.88 | 0.86 | 0.83 | 0.80 | 0.80 |
| 58 | 1.05 | 1.03 | 1.00 | 0.97 | 0.92 | 0.91 | 0.89 | 0.86 | 0.82 | 0.83 | 0.84 |
| 59 | 1.07 | 1.03 | 1.00 | 0.95 | 0.94 | 0.92 | 0.89 | 0.85 | 0.86 | 0.87 | 0.86 |
| 60 | 1.08 | 1.05 | 1.00 | 0.99 | 0.97 | 0.94 | 0.89 | 0.90 | 0.91 | 0.90 | 0.91 |
| 61 | 1.06 | 1.01 | 1.00 | 0.98 | 0.95 | 0.90 | 0.91 | 0.92 | 0.91 | 0.91 | 0.94 |
| 62 | 1.03 | 1.02 | 1.00 | 0.97 | 0.92 | 0.93 | 0.95 | 0.93 | 0.94 | 0.96 | 1.01 |
| 63 | 1.06 | 1.03 | 1.00 | 0.95 | 0.96 | 0.98 | 0.96 | 0.97 | 1.00 | 1.04 | 1.11 |
| 64 | 1.08 | 1.05 | 1.00 | 1.01 | 1.02 | 1.01 | 1.01 | 1.04 | 1.09 | 1.16 | 1.32 |
| 65 | 1.04 | 0.99 | 1.00 | 1.02 | 1.00 | 1.01 | 1.03 | 1.08 | 1.15 | 1.31 | 1.22 |
| 66 | 0.98 | 0.98 | 1.00 | 0.98 | 0.99 | 1.02 | 1.07 | 1.13 | 1.29 | 1.20 | 0.99 |
| 67 | 1.00 | 1.02 | 1.00 | 1.01 | 1.03 | 1.08 | 1.15 | 1.31 | 1.22 | 1.01 | 1.12 |
| 68 | 1.01 | 0.99 | 1.00 | 1.03 | 1.08 | 1.14 | 1.30 | 1.21 | 1.00 | 1.11 | 1.01 |
| 69 | 0.97 | 0.97 | 1.00 | 1.05 | 1.11 | 1.26 | 1.18 | 0.98 | 1.08 | 0.98 | 0.93 |
| 70 | 0.93 | 0.95 | 1.00 | 1.06 | 1.21 | 1.12 | 0.93 | 1.03 | 0.94 | 0.89 | 0.79 |
| 71 | 0.90 | 0.94 | 1.00 | 1.14 | 1.06 | 0.88 | 0.97 | 0.88 | 0.84 | 0.75 | 0.76 |
| 72 | 0.83 | 0.88 | 1.00 | 0.93 | 0.77 | 0.85 | 0.78 | 0.74 | 0.66 | 0.67 | 0.70 |
| 73 | 0.94 | 1.07 | 1.00 | 0.83 | 0.92 | 0.83 | 0.79 | 0.71 | 0.72 | 0.75 | 0.76 |
| 74 | 1.30 | 1.21 | 1.00 | 1.11 | 1.01 | 0.96 | 0.85 | 0.87 | 0.90 | 0.91 | 0.90 |
| 75 | 1.09 | 0.90 | 1.00 | 0.91 | 0.87 | 0.77 | 0.79 | 0.82 | 0.83 | 0.81 | 0.81 |
| 76 | 0.99 | 1.10 | 1.00 | 0.95 | 0.85 | 0.86 | 0.90 | 0.91 | 0.89 | 0.88 | 0.87 |
| 77 | 1.15 | 1.05 | 1.00 | 0.89 | 0.91 | 0.94 | 0.95 | 0.94 | 0.93 | 0.92 | 0.92 |
| 78 | 1.18 | 1.13 | 1.00 | 1.02 | 1.06 | 1.07 | 1.05 | 1.05 | 1.03 | 1.03 | 1.00 |
| 79 | 1.10 | 0.98 | 1.00 | 1.04 | 1.05 | 1.03 | 1.03 | 1.01 | 1.01 | 0.98 | 1.04 |
| 80 | 0.94 | 0.96 | 1.00 | 1.01 | 0.99 | 0.99 | 0.97 | 0.97 | 0.94 | 1.00 | 1.03 |
| 81 | 0.95 | 0.99 | 1.00 | 0.98 | 0.97 | 0.96 | 0.96 | 0.93 | 0.99 | 1.02 | 1.04 |
| 82 | 1.01 | 1.02 | 1.00 | 0.99 | 0.98 | 0.98 | 0.95 | 1.01 | 1.04 | 1.06 | 1.05 |
| 83 | 1.03 | 1.01 | 1.00 | 0.99 | 0.99 | 0.96 | 1.01 | 1.04 | 1.07 | 1.06 | 1.09 |
| 84 | 1.02 | 1.01 | 1.00 | 1.00 | 0.97 | 1.03 | 1.06 | 1.08 | 1.08 | 1.10 | 1.09 |
| 85 | 1.01 | 1.00 | 1.00 | 0.97 | 1.03 | 1.06 | 1.09 | 1.08 | 1.10 | 1.09 | 1.16 |
| 86 | 1.03 | 1.03 | 1.00 | 1.06 | 1.09 | 1.12 | 1.11 | 1.14 | 1.13 | 1.20 | 1.22 |
| 87 | 0.97 | 0.95 | 1.00 | 1.03 | 1.06 | 1.05 | 1.08 | 1.07 | 1.13 | 1.16 | 1.19 |
| 88 | 0.92 | 0.97 | 1.00 | 1.03 | 1.02 | 1.04 | 1.03 | 1.10 | 1.12 | 1.15 | 1.20 |
| 89 | 0.95 | 0.97 | 1.00 | 0.99 | 1.02 | 1.01 | 1.07 | 1.10 | 1.13 | 1.17 | 1.20 |
| 90 | 0.98 | 1.01 | 1.00 | 1.03 | 1.02 | 1.08 | 1.10 | 1.13 | 1.18 | 1.21 | 1.32 |
| 91 | 0.98 | 0.97 | 1.00 | 0.99 | 1.05 | 1.08 | 1.11 | 1.15 | 1.18 | 1.29 | 1.45 |
| 92 | 0.98 | 1.01 | 1.00 | 1.06 | 1.09 | 1.12 | 1.16 | 1.19 | 1.30 | 1.46 | 1.06 |
| 93 | 0.95 | 0.94 | 1.00 | 1.02 | 1.05 | 1.09 | 1.12 | 1.22 | 1.38 | 1.00 | 0.95 |
| 94 | 0.92 | 0.98 | 1.00 | 1.03 | 1.07 | 1.10 | 1.19 | 1.35 | 0.97 | 0.93 | 0.94 |
| 95 | 0.95 | 0.97 | 1.00 | 1.04 | 1.07 | 1.16 | 1.31 | 0.95 | 0.91 | 0.92 | 1.08 |
| 96 | 0.94 | 0.96 | 1.00 | 1.03 | 1.12 | 1.26 | 0.91 | 0.87 | 0.88 | 1.04 | 1.07 |
| 97 | 0.94 | 0.97 | 1.00 | 1.09 | 1.23 | 0.89 | 0.85 | 0.86 | 1.01 | 1.04 | 1.13 |
| 98 | 0.89 | 0.92 | 1.00 | 1.13 | 0.82 | 0.78 | 0.79 | 0.93 | 0.96 | 1.04 | 1.04 |
| 99 | 0.81 | 0.89 | 1.00 | 0.72 | 0.69 | 0.70 | 0.82 | 0.85 | 0.92 | 0.92 | 0.91 |
| 100 | 1.23 | 1.38 | 1.00 | 0.96 | 0.97 | 1.13 | 1.18 | 1.27 | 1.27 | 1.26 | 1.27 |
| 101 | 1.45 | 1.04 | 1.00 | 1.01 | 1.19 | 1.23 | 1.33 | 1.33 | 1.32 | 1.33 | 1.35 |
| 102 | 1.04 | 0.99 | 1.00 | 1.18 | 1.22 | 1.32 | 1.32 | 1.31 | 1.32 | 1.34 | 1.37 |
| 103 | 0.84 | 0.85 | 1.00 | 1.04 | 1.12 | 1.12 | 1.11 | 1.12 | 1.14 | 1.16 | 1.20 |
| 104 | 0.82 | 0.96 | 1.00 | 1.08 | 1.08 | 1.07 | 1.08 | 1.10 | 1.12 | 1.15 | 1.13 |
| 105 | 0.89 | 0.93 | 1.00 | 1.00 | 0.99 | 1.00 | 1.02 | 1.04 | 1.07 | 1.04 | 1.06 |

Supplementary Material S4: Results for the alternative methods to calculate the 2019 ‘baseline’ number of deaths. The raw deaths in 2019 are provided for comparison. A Poisson-based standard deviation (STDEV) based on the chosen ‘average’ value for 2019 is also given as is the STDEV of the estimates. Population-adjusted deaths end at age 89. Raw extrapolated deaths commence at age 80. Hence ages 80-89 are the average of 5 methods while all other ages are an average of 3 methods. Method Birth Adjusted (B) assumes that above the age of 80 the impact of COVID-19 on genuine COVID-19 deaths is minimal and so all years 2011 to 2021 are included in the estimate for the 2019 baseline.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Age** | **Male** | **Male** | **Male** | **Male** | **Male** | **Male** | **Male** | **Male** | **Male** | **Female** | **Female** | **Female** | **Female** | **Female** | **Female** | **Female** | **Female** | **Female** |
| **Raw deaths** | **Birth-adjusted (A)** | **Birth-adjusted (B)** | **Population-adjusted** | **Raw extrapolated** | **2019-2017 average** | **Chosen value** | **STDEV Poisson** | **STDEV raw** | **Raw deaths** | **Birth-adjusted (A)** | **Birth-adjusted (B)** | **Population-adjusted** | **Raw extrapolated** | **2019-2017 average** | **Chosen value** | **STDEV Poisson** | **STDEV raw** |
| 0 | 1435 | 1420 |  | 1415 |  | 1423 | 1419 | 38 | 4 | 1119 | 1100 |  | 1104 |  | 1114 | 1106 | 33 | 7 |
| 1 | 79 | 80 |  | 80 |  | 84 | 81 | 9 | 2 | 78 | 68 |  | 72 |  | 71 | 70 | 8 | 2 |
| 2 | 49 | 48 |  | 48 |  | 47 | 48 | 7 | 0 | 51 | 42 |  | 44 |  | 43 | 43 | 7 | 1 |
| 3 | 33 | 40 |  | 39 |  | 38 | 39 | 6 | 1 | 34 | 32 |  | 33 |  | 34 | 33 | 6 | 1 |
| 4 | 27 | 30 |  | 30 |  | 35 | 32 | 6 | 3 | 27 | 23 |  | 23 |  | 25 | 24 | 5 | 1 |
| 5 | 30 | 27 |  | 28 |  | 32 | 29 | 5 | 3 | 31 | 23 |  | 29 |  | 31 | 27 | 5 | 4 |
| 6 | 40 | 27 |  | 33 |  | 33 | 31 | 6 | 3 | 33 | 23 |  | 27 |  | 28 | 26 | 5 | 3 |
| 7 | 21 | 28 |  | 27 |  | 28 | 28 | 5 | 1 | 21 | 23 |  | 25 |  | 23 | 24 | 5 | 1 |
| 8 | 19 | 25 |  | 25 |  | 25 | 25 | 5 | 0 | 19 | 22 |  | 22 |  | 23 | 22 | 5 | 0 |
| 9 | 19 | 25 |  | 25 |  | 23 | 24 | 5 | 1 | 18 | 20 |  | 21 |  | 20 | 20 | 5 | 1 |
| 10 | 27 | 25 |  | 27 |  | 28 | 27 | 5 | 1 | 26 | 22 |  | 23 |  | 22 | 23 | 5 | 1 |
| 11 | 30 | 28 |  | 28 |  | 31 | 29 | 5 | 2 | 17 | 23 |  | 21 |  | 22 | 22 | 5 | 1 |
| 12 | 43 | 35 |  | 38 |  | 39 | 37 | 6 | 2 | 13 | 20 |  | 17 |  | 20 | 19 | 4 | 2 |
| 13 | 51 | 39 |  | 41 |  | 44 | 41 | 6 | 3 | 32 | 30 |  | 29 |  | 27 | 29 | 5 | 2 |
| 14 | 36 | 40 |  | 40 |  | 39 | 40 | 6 | 0 | 34 | 30 |  | 33 |  | 30 | 31 | 6 | 1 |
| 15 | 45 | 58 |  | 57 |  | 58 | 58 | 8 | 1 | 30 | 38 |  | 36 |  | 33 | 36 | 6 | 2 |
| 16 | 66 | 66 |  | 65 |  | 73 | 68 | 8 | 4 | 40 | 44 |  | 46 |  | 45 | 45 | 7 | 1 |
| 17 | 83 | 95 |  | 94 |  | 100 | 96 | 10 | 3 | 50 | 45 |  | 46 |  | 48 | 46 | 7 | 1 |
| 18 | 117 | 129 |  | 127 |  | 130 | 129 | 11 | 2 | 76 | 63 |  | 73 |  | 68 | 68 | 8 | 5 |
| 19 | 147 | 145 |  | 150 |  | 147 | 147 | 12 | 3 | 66 | 65 |  | 67 |  | 66 | 66 | 8 | 1 |
| 20 | 202 | 182 |  | 187 |  | 181 | 183 | 14 | 3 | 59 | 68 |  | 63 |  | 61 | 64 | 8 | 3 |
| 21 | 196 | 184 |  | 180 |  | 185 | 183 | 14 | 3 | 70 | 72 |  | 71 |  | 72 | 72 | 8 | 0 |
| 22 | 192 | 184 |  | 184 |  | 184 | 184 | 14 | 0 | 91 | 80 |  | 82 |  | 80 | 81 | 9 | 1 |
| 23 | 182 | 193 |  | 190 |  | 182 | 188 | 14 | 5 | 76 | 78 |  | 72 |  | 73 | 74 | 9 | 3 |
| 24 | 207 | 197 |  | 185 |  | 198 | 193 | 14 | 7 | 93 | 80 |  | 82 |  | 80 | 81 | 9 | 1 |
| 25 | 223 | 216 |  | 215 |  | 215 | 215 | 15 | 1 | 86 | 90 |  | 94 |  | 96 | 93 | 10 | 3 |
| 26 | 229 | 233 |  | 225 |  | 220 | 226 | 15 | 7 | 108 | 105 |  | 102 |  | 100 | 102 | 10 | 3 |
| 27 | 255 | 243 |  | 240 |  | 240 | 241 | 16 | 2 | 121 | 110 |  | 107 |  | 111 | 109 | 10 | 2 |
| 28 | 274 | 260 |  | 265 |  | 267 | 264 | 16 | 4 | 118 | 125 |  | 125 |  | 123 | 124 | 11 | 1 |
| 29 | 288 | 279 |  | 280 |  | 280 | 280 | 17 | 1 | 129 | 130 |  | 128 |  | 122 | 127 | 11 | 4 |
| 30 | 313 | 286 |  | 293 |  | 288 | 289 | 17 | 4 | 154 | 145 |  | 149 |  | 144 | 146 | 12 | 3 |
| 31 | 316 | 317 |  | 317 |  | 321 | 318 | 18 | 2 | 165 | 148 |  | 152 |  | 156 | 152 | 12 | 4 |
| 32 | 319 | 333 |  | 320 |  | 312 | 322 | 18 | 11 | 162 | 170 |  | 175 |  | 176 | 174 | 13 | 3 |
| 33 | 354 | 355 |  | 355 |  | 352 | 354 | 19 | 2 | 179 | 180 |  | 184 |  | 186 | 183 | 14 | 3 |
| 34 | 344 | 358 |  | 362 |  | 359 | 360 | 19 | 2 | 220 | 225 |  | 218 |  | 217 | 220 | 15 | 4 |
| 35 | 380 | 397 |  | 385 |  | 389 | 390 | 20 | 6 | 217 | 225 |  | 217 |  | 221 | 221 | 15 | 4 |
| 36 | 383 | 425 |  | 412 |  | 413 | 417 | 20 | 7 | 227 | 230 |  | 241 |  | 234 | 235 | 15 | 5 |
| 37 | 478 | 472 |  | 456 |  | 470 | 466 | 22 | 8 | 298 | 300 |  | 295 |  | 291 | 296 | 17 | 4 |
| 38 | 482 | 490 |  | 463 |  | 452 | 468 | 22 | 20 | 285 | 285 |  | 287 |  | 274 | 282 | 17 | 7 |
| 39 | 516 | 520 |  | 510 |  | 509 | 513 | 23 | 6 | 304 | 300 |  | 309 |  | 307 | 305 | 17 | 5 |
| 40 | 556 | 568 |  | 545 |  | 554 | 556 | 24 | 12 | 341 | 320 |  | 326 |  | 324 | 323 | 18 | 3 |
| 41 | 503 | 570 |  | 547 |  | 555 | 557 | 24 | 12 | 316 | 330 |  | 323 |  | 335 | 329 | 18 | 6 |
| 42 | 538 | 580 |  | 580 |  | 581 | 580 | 24 | 0 | 367 | 370 |  | 362 |  | 355 | 362 | 19 | 8 |
| 43 | 597 | 650 |  | 662 |  | 644 | 652 | 26 | 9 | 380 | 400 |  | 390 |  | 388 | 393 | 20 | 7 |
| 44 | 705 | 710 |  | 717 |  | 685 | 704 | 27 | 17 | 457 | 460 |  | 464 |  | 447 | 457 | 21 | 9 |
| 45 | 819 | 830 |  | 807 |  | 803 | 813 | 29 | 14 | 534 | 530 |  | 522 |  | 502 | 518 | 23 | 14 |
| 46 | 894 | 900 |  | 891 |  | 860 | 884 | 30 | 21 | 600 | 600 |  | 586 |  | 568 | 585 | 24 | 16 |
| 47 | 1005 | 1000 |  | 1045 |  | 982 | 1009 | 32 | 33 | 640 | 640 |  | 657 |  | 631 | 643 | 25 | 13 |
| 48 | 1084 | 1100 |  | 1105 |  | 1087 | 1097 | 33 | 9 | 717 | 750 |  | 743 |  | 733 | 742 | 27 | 8 |
| 49 | 1184 | 1226 |  | 1224 |  | 1210 | 1220 | 35 | 9 | 765 | 790 |  | 764 |  | 773 | 776 | 28 | 13 |
| 50 | 1354 | 1335 |  | 1357 |  | 1296 | 1329 | 36 | 31 | 887 | 880 |  | 869 |  | 856 | 868 | 29 | 12 |
| 51 | 1440 | 1460 |  | 1425 |  | 1412 | 1432 | 38 | 25 | 967 | 970 |  | 950 |  | 944 | 955 | 31 | 14 |
| 52 | 1515 | 1570 |  | 1536 |  | 1520 | 1542 | 39 | 25 | 1042 | 1045 |  | 1036 |  | 1027 | 1036 | 32 | 9 |
| 53 | 1668 | 1690 |  | 1622 |  | 1623 | 1645 | 41 | 39 | 1041 | 1070 |  | 1092 |  | 1080 | 1081 | 33 | 11 |
| 54 | 1797 | 1780 |  | 1800 |  | 1761 | 1780 | 42 | 19 | 1195 | 1180 |  | 1182 |  | 1167 | 1176 | 34 | 8 |
| 55 | 1899 | 1920 |  | 1918 |  | 1908 | 1915 | 44 | 6 | 1296 | 1290 |  | 1305 |  | 1304 | 1300 | 36 | 8 |
| 56 | 2141 | 2130 |  | 2100 |  | 2088 | 2106 | 46 | 22 | 1382 | 1390 |  | 1400 |  | 1388 | 1393 | 37 | 6 |
| 57 | 2141 | 2200 |  | 2190 |  | 2225 | 2205 | 47 | 18 | 1461 | 1470 |  | 1470 |  | 1470 | 1470 | 38 | 0 |
| 58 | 2288 | 2330 |  | 2318 |  | 2346 | 2331 | 48 | 14 | 1527 | 1560 |  | 1560 |  | 1589 | 1570 | 40 | 17 |
| 59 | 2405 | 2390 |  | 2370 |  | 2453 | 2404 | 49 | 43 | 1613 | 1650 |  | 1635 |  | 1661 | 1649 | 41 | 13 |
| 60 | 2553 | 2540 |  | 2550 |  | 2570 | 2553 | 51 | 15 | 1744 | 1740 |  | 1760 |  | 1747 | 1749 | 42 | 10 |
| 61 | 2667 | 2670 |  | 2700 |  | 2731 | 2700 | 52 | 30 | 1799 | 1820 |  | 1830 |  | 1856 | 1835 | 43 | 19 |
| 62 | 2923 | 2920 |  | 2910 |  | 2954 | 2928 | 54 | 23 | 2100 | 2090 |  | 2070 |  | 2074 | 2078 | 46 | 11 |
| 63 | 3019 | 3100 |  | 3070 |  | 3154 | 3108 | 56 | 43 | 2082 | 2120 |  | 2110 |  | 2151 | 2127 | 46 | 22 |
| 64 | 3171 | 3150 |  | 3150 |  | 3204 | 3168 | 56 | 31 | 2168 | 2190 |  | 2200 |  | 2208 | 2199 | 47 | 9 |
| 65 | 3517 | 3450 |  | 3530 |  | 3480 | 3487 | 59 | 40 | 2415 | 2390 |  | 2430 |  | 2406 | 2409 | 49 | 20 |
| 66 | 3728 | 3800 |  | 3780 |  | 3834 | 3805 | 62 | 27 | 2493 | 2600 |  | 2620 |  | 2587 | 2602 | 51 | 16 |
| 67 | 3957 | 4070 |  | 4010 |  | 4041 | 4040 | 64 | 30 | 2701 | 2790 |  | 2720 |  | 2775 | 2762 | 53 | 37 |
| 68 | 4344 | 4500 |  | 4400 |  | 4380 | 4427 | 67 | 64 | 3007 | 3100 |  | 3040 |  | 3053 | 3064 | 55 | 32 |
| 69 | 4832 | 5000 |  | 4870 |  | 4871 | 4914 | 70 | 75 | 3321 | 3400 |  | 3377 |  | 3372 | 3383 | 58 | 15 |
| 70 | 5232 | 5400 |  | 5230 |  | 5259 | 5296 | 73 | 91 | 3865 | 3900 |  | 3890 |  | 3797 | 3862 | 62 | 57 |
| 71 | 6195 | 6100 |  | 6150 |  | 5696 | 5982 | 77 | 249 | 4256 | 4200 |  | 4300 |  | 3986 | 4162 | 65 | 160 |
| 72 | 6847 | 6640 |  | 7000 |  | 6876 | 6839 | 83 | 183 | 5045 | 5000 |  | 5200 |  | 5056 | 5085 | 71 | 103 |
| 73 | 6144 | 6600 |  | 6200 |  | 6917 | 6572 | 81 | 359 | 4662 | 4800 |  | 4650 |  | 5108 | 4853 | 70 | 233 |
| 74 | 6529 | 5930 |  | 6500 |  | 6339 | 6256 | 79 | 294 | 4929 | 4700 |  | 4950 |  | 4746 | 4799 | 69 | 133 |
| 75 | 7092 | 7100 |  | 7150 |  | 7321 | 7190 | 85 | 116 | 5188 | 5300 |  | 5300 |  | 5563 | 5388 | 73 | 152 |
| 76 | 7163 | 7100 | 7600 | 7380 |  | 7286 | 7342 | 86 | 208 | 5489 | 5500 |  | 5700 |  | 5672 | 5624 | 75 | 108 |
| 77 | 6828 | 7200 | 7700 | 7250 |  | 7425 | 7394 | 86 | 226 | 5613 | 5580 | 6000 | 5751 |  | 6008 | 5835 | 76 | 207 |
| 78 | 7078 | 7200 | 7400 | 7075 |  | 7216 | 7223 | 85 | 134 | 5740 | 5950 | 6000 | 5870 |  | 5963 | 5946 | 77 | 55 |
| 79 | 7822 | 7840 | 7900 | 7875 |  | 7752 | 7842 | 89 | 65 | 6726 | 6720 | 6700 | 6700 |  | 6596 | 6679 | 82 | 56 |
| 80 | 8489 | 8490 | 8600 | 8540 | 8600 | 8496 | 8545 | 92 | 54 | 7312 | 7300 | 7400 | 7307 | 7380 | 7304 | 7338 | 86 | 48 |
| 81 | 8795 | 8850 | 9300 | 9150 | 8800 | 8922 | 9004 | 95 | 213 | 7771 | 7780 | 8300 | 7810 | 7880 | 7931 | 7940 | 89 | 210 |
| 82 | 8951 | 8900 | 9200 | 9085 | 8950 | 8992 | 9025 | 95 | 119 | 8204 | 8210 | 8700 | 8300 | 8200 | 8343 | 8351 | 91 | 204 |
| 83 | 9137 | 9250 | 9600 | 9200 | 9135 | 9160 | 9269 | 96 | 190 | 8787 | 8850 | 9300 | 8900 | 8800 | 8949 | 8960 | 95 | 198 |
| 84 | 9364 | 9500 | 9800 | 9595 | 9370 | 9343 | 9522 | 98 | 186 | 9237 | 9250 | 9700 | 9400 | 9100 | 9421 | 9374 | 97 | 223 |
| 85 | 9141 | 9300 | 9800 | 9145 | 9150 | 9229 | 9325 | 97 | 273 | 9588 | 9700 | 10200 | 9700 | 9600 | 9862 | 9812 | 99 | 236 |
| 86 | 9087 | 9100 | 9300 | 9400 | 9300 | 8913 | 9203 | 96 | 195 | 10037 | 10000 | 10300 | 10200 | 10300 | 10021 | 10164 | 101 | 146 |
| 87 | 8935 | 9100 | 9500 | 9310 | 9200 | 8872 | 9196 | 96 | 234 | 10505 | 10700 | 11000 | 10800 | 10800 | 10639 | 10788 | 104 | 137 |
| 88 | 8883 | 8900 | 9400 | 8800 | 8890 | 8613 | 8921 | 94 | 292 | 10882 | 11200 | 11500 | 11300 | 11200 | 11013 | 11243 | 106 | 177 |
| 89 | 8340 | 8360 | 8700 | 8555 | 8340 | 8111 | 8413 | 92 | 225 | 10860 | 11000 | 11500 | 11200 | 10900 | 10877 | 11095 | 105 | 260 |
| 90 | 7405 | 7500 | 7900 |  | 7500 | 7271 | 7543 | 87 | 262 | 10530 | 10700 | 11000 |  | 10600 | 10566 | 10717 | 104 | 197 |
| 91 | 6655 | 6700 | 7000 |  | 6685 | 6585 | 6743 | 82 | 179 | 9917 | 10100 | 10500 |  | 10100 | 10148 | 10212 | 101 | 193 |
| 92 | 5725 | 5700 | 6000 |  | 5798 | 5513 | 5753 | 76 | 203 | 9318 | 9250 | 9600 |  | 9450 | 9224 | 9381 | 97 | 177 |
| 93 | 4950 | 5000 | 5200 |  | 4950 | 4721 | 4968 | 70 | 197 | 8453 | 8600 | 9400 |  | 8700 | 8646 | 8836 | 94 | 378 |
| 94 | 4081 | 4110 | 4110 |  | 4200 | 3856 | 4069 | 64 | 148 | 7574 | 7800 | 8100 |  | 7500 | 7754 | 7788 | 88 | 246 |
| 95 | 3159 | 3200 | 3300 |  | 3350 | 3073 | 3231 | 57 | 122 | 6769 | 7100 | 7042 |  | 7200 | 6910 | 7063 | 84 | 121 |
| 96 | 2449 | 2540 | 2530 |  | 2550 | 2417 | 2509 | 50 | 62 | 5799 | 6000 | 6000 |  | 6400 | 5939 | 6085 | 78 | 212 |
| 97 | 1792 | 1745 | 1800 |  | 1780 | 1678 | 1751 | 42 | 54 | 4814 | 4800 | 4900 |  | 5250 | 4627 | 4894 | 70 | 263 |
| 98 | 1346 | 1250 | 1330 |  | 1180 | 1182 | 1235 | 35 | 71 | 4032 | 4570 | 4122 |  | 4000 | 3702 | 4098 | 64 | 360 |
| 99 | 964 | 943 | 1000 |  | 880 | 904 | 932 | 31 | 52 | 2971 | 2900 | 3200 |  | 2370 | 2936 | 2851 | 53 | 348 |
| 100 | 398 | 405 | 450 |  | 390 | 403 | 412 | 20 | 26 | 1475 | 1600 | 1650 |  | 1450 | 1574 | 1568 | 40 | 85 |
| 101 | 221 | 230 | 250 |  | 222 | 225 | 232 | 15 | 13 | 944 | 1050 | 1070 |  | 950 | 1029 | 1025 | 32 | 53 |
| 102 | 151 | 145 | 145 |  | 158 | 143 | 148 | 12 | 7 | 740 | 720 | 705 |  | 760 | 709 | 723 | 27 | 25 |
| 103 | 80 | 92 | 92 |  | 89 | 82 | 89 | 9 | 5 | 466 | 480 | 500 |  | 470 | 487 | 484 | 22 | 13 |
| 104 | 37 | 54 | 54 |  | 51 | 46 | 51 | 7 | 4 | 309 | 315 | 320 |  | 316 | 307 | 314 | 18 | 6 |
| 105 | 61 | 57 | 58 |  | 53 | 53 | 55 | 7 | 3 | 399 | 405 | 405 |  | 399 | 401 | 403 | 20 | 3 |

Supplementary Material S5: Deaths assessed as ‘due to’ COVID-19 in 2020 and 2021 compared to excess deaths relative to 2019

Deaths assessed as ‘due to’ COVID-19 in 2020 and 2021 cannot be higher than the excess deaths occurring in these years relative to the 2019 baseline. Some have claimed that lockdowns led to excess deaths [46]. Based on this claim excess deaths should logically be higher than deaths assessed as ‘due to’ COVID-19 [47].

Table S5.1 shows the total ‘excess’ or ’extra’ deaths in England and Wales in both 2022 (without vaccination) and 2021 (with vaccination) compared to the deaths which were assessed as ‘due to’ COVID-19. The ‘excess’ deaths are given for both:

1. 2020 or 2021 actual minus 2019 ‘baseline’
2. 2020 or 2021 actual minus 2019 actual

In this comparison recall that for the trend between 2011 and 2019, 2019 was assessed as a low year against the trend due to a large excess of winter deaths at the start of 2018 which led to a compensating drop in deaths during 2019. Hence, method #1 will give a lower estimate for the ‘excess’ deaths.

In 2020 (without vaccination) assessed ‘due to’ COVID-19 deaths are very close to the calculated ‘excess’, however, in 2021 (with vaccination) there is a very large discrepancy where so-called ‘due to’ COVID-19 deaths are far higher than is mathematically possible. This discrepancy is far greater for female deaths. Indeed, regarding the issue of over counting deaths in England and Wales assessed as ‘with’ COVID-19 are another 15% higher than the assessed ‘due to’ deaths.

**Table S5. 1.** Evaluation of potential over counting of ‘due to’ COVID-19 deaths in 2020 and 2021.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Method** | **Sex/Year** | **Calculated excess** | **ONS**  **'due to'** | **Over**  **estimate (n)** | **Over**  **estimate (%)** |
| Actual minus 2019 ‘average’ | Male 2021 | 30 002 | 36 794 | 6 792 | 23% |
| Male 2020 | 40 082 | 40 995 | 913 | 2% |
| Female 2021 | 18 816 | 30 556 | 11 740 | 62% |
| Female 2020 | 30 324 | 32 771 | 2447 | 8% |
| Actual minus 2019 actual | Male 2021 | 32 689 | 36 794 | 4 105 | 13% |
| Male 2020 | 42 769 | 40 995 | -1 774 | -4% |
| Female 2021 | 22 804 | 30 556 | 7 752 | 34% |
| Female 2020 | 34 312 | 32 771 | -1 541 | -4% |

The issue as to which age bands were more prone to over counting is addressed in Table S5.2. As can be seen during 2020 (without vaccination) the highest over counting is limited to ages 65-69 and 80-89 (with yellow highlight), with highest over counting at age 65-69 at +19% males and + 40% females.

In contrast, the degree of over estimation in 2021 (with vaccination) is greatest at ages 65-74 and for all ages above 80 years. Female over counting is greatest in the 85-89 age band at +353%. Such over estimation during the with vaccination period may reflect the moderate ability of COVID-19 vaccines to prevent infection per se [48,49], although viral load is reduced [50].

**Table S5. 2.** Evaluation of potential over counting of ‘due to’ COVID-19 deaths in 2020 and 2021 for males and females by age band.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Age group** | **Males 'due to'** | **Females 'due to'** | **Male excess** | **Female excess** | **Male**  **overestimate (n)** | **Female**  **overestimate (n)** | **Male**  **overestimate (%)** | **Female**  **overestimate (%)** |
| *2021* | *All ages* | *36794* | *30556* | *30002* | *18816* | *6792* | *11740* | *23%* | *62%* |
| 2021 | Under 1 | 2 | 0 | -3 | -20 | 5 | 20 |  |  |
| 2021 | 1 to 4 | 2 | 3 | -24 | -28 | 26 | 31 |  |  |
| 2021 | 5 to 9 | 1 | 6 | -18 | -16 | 19 | 22 |  |  |
| 2021 | 10 to 14 | 3 | 9 | -34 | 7 | 37 | 2 |  |  |
| 2021 | 15 to 19 | 18 | 11 | 81 | -14 | -63 | 25 |  |  |
| 2021 | 20 to 24 | 32 | 15 | -2 | 35 | 34 | -20 |  |  |
| 2021 | 25 to 29 | 55 | 40 | 1 | 28 | 54 | 12 |  |  |
| 2021 | 30 to 34 | 133 | 85 | 129 | 95 | 4 | -10 |  |  |
| 2021 | 35 to 39 | 216 | 147 | 353 | 207 | -137 | -60 |  |  |
| 2021 | 40 to 44 | 366 | 208 | 649 | 348 | -283 | -140 |  |  |
| 2021 | 45 to 49 | 622 | 369 | 618 | 244 | 4 | 125 | 1% | 51% |
| 2021 | 50 to 54 | 1038 | 652 | 1342 | 614 | -304 | 38 | -23% | 6% |
| 2021 | 55 to 59 | 1678 | 982 | 2105 | 1167 | -427 | -185 | -20% | -16% |
| 2021 | 60 to 64 | 2428 | 1354 | 3260 | 1588 | -832 | -234 | -26% | -15% |
| 2021 | 65 to 69 | 2965 | 1847 | 2170 | 1303 | 795 | 544 | 37% | 42% |
| 2021 | 70 to 74 | 4195 | 2642 | 3484 | 2260 | 711 | 382 | 20% | 17% |
| 2021 | 75 to 79 | 5168 | 3417 | 5616 | 3828 | -448 | -411 | -8% | -11% |
| 2021 | 80 to 84 | 6177 | 4775 | 3218 | 2434 | 2959 | 2341 | 92% | 96% |
| 2021 | 85 to 89 | 6177 | 5815 | 2846 | 1283 | 3331 | 4532 | 117% | 353% |
| 2021 | 90+ | 5518 | 8179 | 4213 | 3454 | 1305 | 4725 | 31% | 137% |
| *2020* | *All ages* | *40995* | *32771* | *40082* | *30324* | *913* | *2447* | *2%* | *8%* |
| 2020 | Under 1 | 0 | 0 | -84 | -56 | 84 | 56 |  |  |
| 2020 | 1 to 4 | 0 | 0 | -13 | -31 | 13 | 31 |  |  |
| 2020 | 5 to 9 | 0 | 1 | 8 | -45 | -8 | 46 |  |  |
| 2020 | 10 to 14 | 3 | 1 | -21 | 4 | 24 | -3 |  |  |
| 2020 | 15 to 19 | 5 | 5 | -60 | -28 | 65 | 33 |  |  |
| 2020 | 20 to 24 | 16 | 12 | -96 | -42 | 112 | 54 |  |  |
| 2020 | 25 to 29 | 44 | 25 | -71 | -28 | 115 | 53 |  |  |
| 2020 | 30 to 34 | 67 | 46 | -7 | 43 | 74 | 3 |  |  |
| 2020 | 35 to 39 | 98 | 76 | 168 | 143 | -70 | -67 |  |  |
| 2020 | 40 to 44 | 197 | 132 | 326 | 227 | -129 | -95 |  |  |
| 2020 | 45 to 49 | 386 | 233 | 465 | 250 | -79 | -17 | -17% | -7% |
| 2020 | 50 to 54 | 724 | 423 | 1015 | 484 | -291 | -61 | -29% | -13% |
| 2020 | 55 to 59 | 1277 | 666 | 1817 | 726 | -540 | -60 | -30% | -8% |
| 2020 | 60 to 64 | 1966 | 990 | 2456 | 1206 | -490 | -216 | -20% | -18% |
| 2020 | 65 to 69 | 2730 | 1412 | 2289 | 1008 | 441 | 404 | 19% | 40% |
| 2020 | 70 to 74 | 4462 | 2426 | 4475 | 2409 | -13 | 17 | 0% | 1% |
| 2020 | 75 to 79 | 6229 | 3823 | 6385 | 4086 | -156 | -263 | -2% | -6% |
| 2020 | 80 to 84 | 8158 | 5891 | 7192 | 5258 | 966 | 633 | 13% | 12% |
| 2020 | 85 to 89 | 7980 | 7159 | 6989 | 5420 | 991 | 1739 | 14% | 32% |
| 2020 | 90+ | 6653 | 9450 | 6851 | 9291 | -198 | 159 | -3% | 2% |

There is a simple explanation for the increased over counting in 2021. Toward the end of 2020 COVID-19 testing capacity was greatly expanded [14] resulting in many more persons testing positive. This led to an expansion in the number of persons who died ‘with’ COVID-19. Ambiguity regarding the true cause of death then led to many of these ‘with’ COVID-19 deaths being incorrectly coded as ‘due to’ COVID-19. See below for a more comprehensive view using data from Scotland.

Figure A5 which is a ‘with’ COVID-19 view can therefore be correctly interpreted as being a large overestimate of the real situation from late 2020 onward.

However, limitations aside, available evidence must be used within a knowledge of unavoidable ambiguity.

Regarding the issue of unavoidable ambiguity Figure S4 shows the assessed ‘due to’ (‘underlying cause’ in Scotland) and ‘with’ (‘mentioned’ in Scotland) COVID-19 deaths in Scotland. Note that Scotland has a different death certification process to England and Wales and may be more realistic than the former.

**Figure S5.** Difference between the number of assessed ‘with or mentioned’ COVID-19 and ‘due to or underlying cause’ COVID-19 deaths in Scotland from March 2020 to March 2023. Data is from Table 9 in [51].

From the Scottish data it is evident that the gap between the two measures of COVID-19 death is dependent on the variant and the active phase of any outbreak. Hence in July and August 2020 when the original Wuhan variant wave had fallen to a minimum there is a large gap between the two. The gap then narrows as the second wave rises and is replaced by the Alpha variant. Another large gap ensues as the Alpha wave falls to a minimum. The same applies to the Delta wave. Omicron is far more nuanced since it behaves as an endemic disease – see Figure A5 in the Appendix of the main document. However, after the initial Omicron outbreak, the gap then appears to diminish with time. Assessing the number of deaths where COVID-19 is the underlying cause is less than simple, and even ‘with’ COVID-19 deaths can depend on the level of available testing capacity.

Hence, the primary reason for our emphasis on excess mortality in this study – which is independent of the vagaries of assigning cause of death.