**Title: Estimating the burden of COVID-19 on mortality, life expectancy and lifespan inequality in England and Wales: A population-level analysis**

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**Section 1. Estimation of the baseline mortality risk using 4 different approaches using training data from 2010 to week 10 of 2020 by age and sex.**

1. Generalized Additive Model assuming a Negative Binomial distribution to account for overdispersion of deaths during the period we study[1]. The model includes smooth effects for the long term trend, age and seasonality, and an interaction between age and seasonality. The smooth effects are stratified by sex. The basic structure of the model is as follows:

Where are the expected deaths in a given week, are the offset, are smooth functions. and are penalized splines for the long term trend and the age effect, respectively. is a penalized cyclic spline for the seasonality and is a smooth interaction between age and seasonality.

1. The second approach is a Generalized Additive Model assuming a Poisson distribution with the same structure as above.
2. The third approach is a Generalized Linear Model assuming a Poisson distribution used to estimate baseline mortality during influenza epidemics and known as Serfling model[2,3]. The basic structure of the model is as follows:

1. We constructed an empirical baseline mortality based on the average mortality rate over the previous five years 2015-19 within each week and stratum. The associated deaths from this approach result from multiplying the average death rates by the population exposed to the risk.

**Excess deaths produced with different models.**

Table 1. Excess deaths by the end of week 26 for ages 15 and above estimated with 4 different models with 95% predictive intervals in England and Wales.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Model** | **Excess deaths** | **Lower bound** | | **Upper bound** |
| GAM- Negative Binomial | 58,982 | | 56,329 | 61,827 |
| GAM- Poisson | 53,938 | | 53,093 | 54,746 |
| GLM- Poisson | 54,150 | | 53,281 | 54,928 |
| Average Mortality | 49,429 | | 48,589 | 50,210 |

Table 2. Excess deaths by the end of week 26 for ages 15 and above estimated with 4 different models by age and sex with 95% predictive intervals in England and Wales.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Females** | | |  | **Males** | | |
| **Model** | **Age group** | **Excess deaths** | **Lower bound** | **Upper bound** |  | **Excess deaths** | **Lower bound** | **Upper bound** |
| GAM Negative Binomial | 15-44 | 198 | 95 | 304 |  | 216 | 53 | 379 |
| 45-64 | 2,191 | 1,823 | 2,534 |  | 4,125 | 3,613 | 4,626 |
| 65-74 | 3,026 | 2,504 | 3,532 |  | 5,286 | 4,591 | 5,993 |
| 75-84 | 6,966 | 6,016 | 7,898 |  | 9,721 | 8,644 | 10,872 |
| 85+ | 15,870 | 14,217 | 17,485 |  | 11,383 | 10,232 | 12,456 |
|  |  |  |  |  |  |  |  |  |
| GAM Poisson | 15-44 | 135 | 57 | 214 |  | 155 | 44 | 259 |
| 45-64 | 1,896 | 1,711 | 2,083 |  | 3,891 | 3,679 | 4,098 |
| 65-74 | 2,587 | 2,380 | 2,785 |  | 4,928 | 4,670 | 5,203 |
| 75-84 | 6,024 | 5,693 | 6,326 |  | 9,067 | 8,731 | 9,375 |
| 85+ | 14,408 | 13,995 | 14,808 |  | 10,848 | 10,489 | 11,167 |
|  |  |  |  |  |  |  |  |  |
| GLM Poisson | 15-44 | 113 | 32 | 187 |  | 93 | -11 | 203 |
| 45-64 | 2,020 | 1,833 | 2,192 |  | 3,786 | 3,588 | 3,992 |
| 65-74 | 2,767 | 2,558 | 2,981 |  | 5,177 | 4,919 | 5,419 |
| 75-84 | 7,038 | 6,752 | 7,348 |  | 9,722 | 9,413 | 10,031 |
| 85+ | 13,249 | 12,841 | 13,662 |  | 10,186 | 9,868 | 10,521 |
|  |  |  |  |  |  |  |  |  |
| Average Mortality | 15-44 | 89 | 7 | 170 |  | 55 | -50 | 161 |
| 45-64 | 1,781 | 1,601 | 1,953 |  | 3,473 | 3,248 | 3,702 |
| 65-74 | 2,438 | 2,223 | 2,642 |  | 4,601 | 4,345 | 4,854 |
| 75-84 | 5,923 | 5,618 | 6,228 |  | 8,482 | 8,169 | 8,807 |
| 85+ | 12,811 | 12,411 | 13,186 |  | 9,776 | 9,457 | 10,107 |

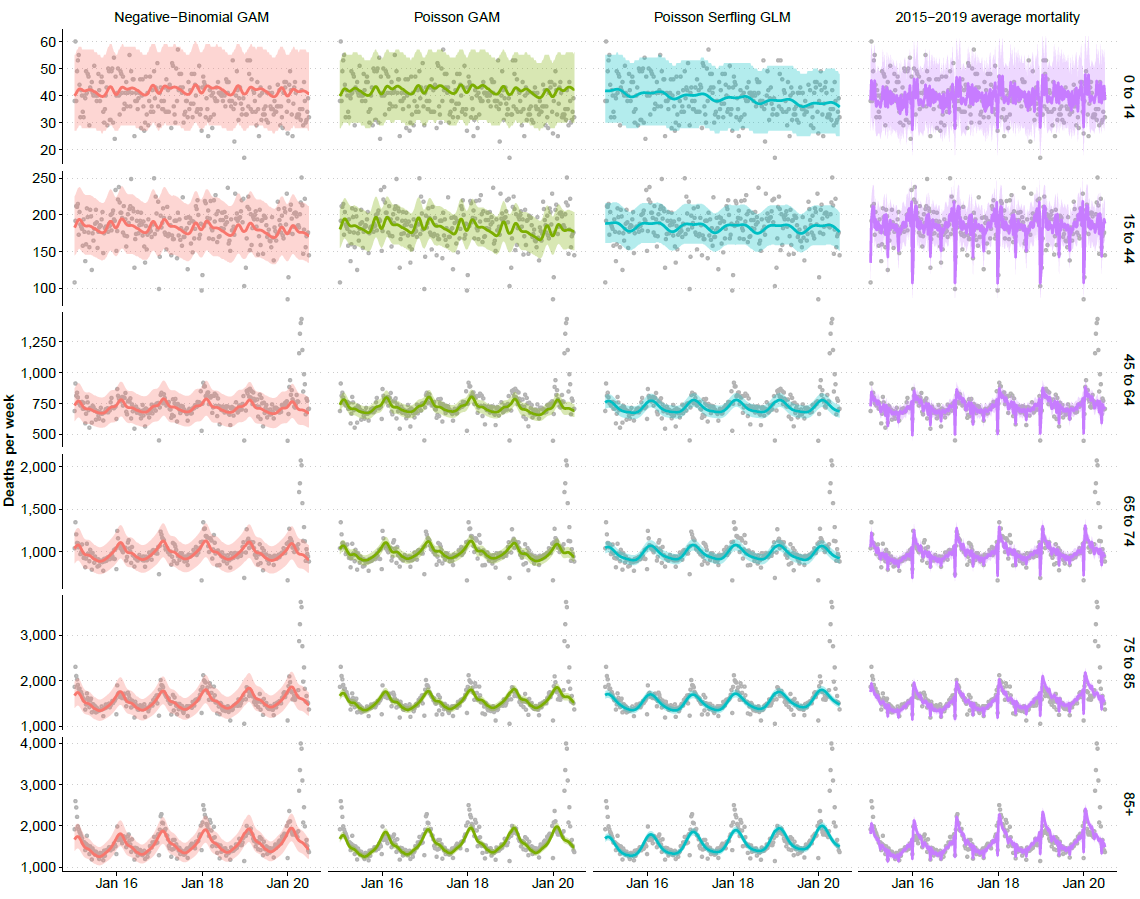
**References**

1 Wood SN. *Generalized Additive Models: An Introduction with R, Second Edition*. CRC Press 2017.

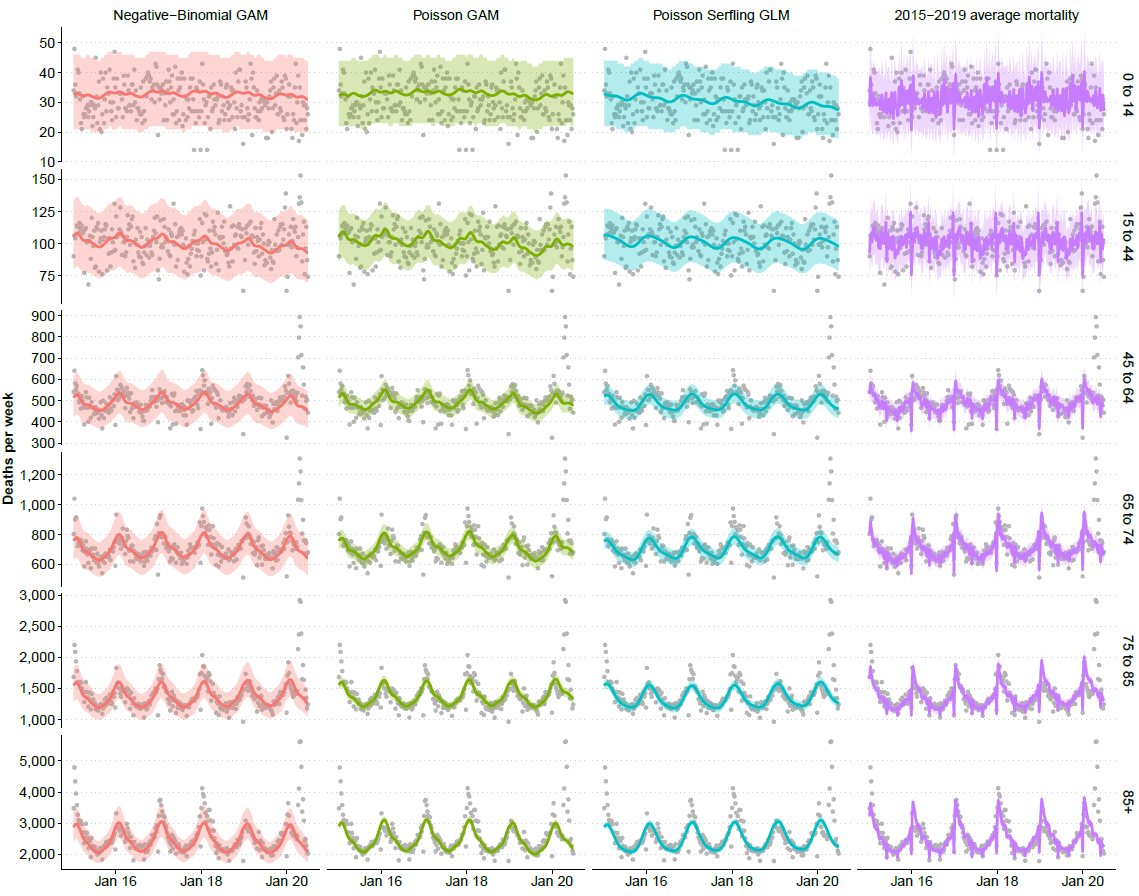
2 Nielsen J, Krause TG, Mølbak K. Influenza-associated mortality determined from all-cause mortality, Denmark 2010/11-2016/17: The FluMOMO model. *Influenza Other Respir Viruses* 2018;**12**:591–604. doi:10.1111/irv.12564

3 Serfling RE. Methods for Current Statistical Analysis of Excess Pneumonia-Influenza Deaths. *Public Health Rep 1896-1970* 1963;**78**:494–506. doi:10.2307/4591848

**Figure 1. Expected (lines) vs Observed deaths (points) counts based on the 4 approaches described above for males by age groups (rows) 0-14, 15-44, 45-64, 65-74, 75-84 and 85-older years of age.**



**Figure 2. Expected (lines) vs Observed deaths (points) counts based on the 4 approaches described above for females by age groups (rows) 0-14, 15-44, 45-64, 65-74, 75-84 and 85-older years of age.**



**Figure 3. Sex ratio males/females of death rates during the course of the pandemic by age groups (rows) 0-14, 15-44, 45-64, 65-74, 75-84 and 85-older years of age.**

