

# Counting pandemic deaths: comparing reported numbers of deaths from influenza A(H1N1)pdm09 with estimated excess mortality

Jon Michael Gran,<sup>a,b</sup> Oliver Kacelnik,<sup>a,c</sup> Andrei M. Grijbovski,<sup>d,e</sup> Preben Aavitsland,<sup>f</sup> Bjørn G. Iversen<sup>a,g</sup>

<sup>a</sup>Department of Infectious Disease Epidemiology, Norwegian Institute of Public Health, Oslo, Norway. <sup>b</sup>Department of Biostatistics, Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway. <sup>c</sup>Norwegian Field Epidemiology Training Programme (affiliated to European Programme for Intervention Epidemiology Training – ECDC), Stockholm, Sweden. <sup>d</sup>Department of International Public Health, Norwegian Institute of Public Health, Oslo, Norway. <sup>e</sup>International School of Public Health, Northern State Medical University, Arkhangelsk, Russia. <sup>f</sup>Epidemi.as, Kristiansand, Norway. <sup>g</sup>World Health Organization for West Bank and Gaza, Jerusalem, Occupied Palestinian territory.

*Correspondence:* Jon Michael Gran, Department of Infectious Disease Epidemiology, Norwegian Institute of Public Health, 0403 Oslo, Norway. E-mail: j.m.gran@medisin.uio.no

Accepted 17 April 2013. Published Online 08 June 2013.

**Background** During the wave 1 of the influenza A(H1N1)pdm09 virus, Norway appeared to be suffering from high mortality rates. However, by the end of the pandemic, it was widely reported that the number of deaths were much lower than previous years.

**Objectives** The mortality burden from influenza is often assessed by two different approaches: counting influenza-certified deaths and estimating the mortality burden using models. The purpose of this study is to compare the number of reported deaths with results from two different models for estimating excess mortality during the pandemic in Norway. Additionally, mortality estimates for the pandemic season are compared with non-pandemic influenza seasons.

**Methods** Numbers on reported influenza A(H1N1)pdm09 deaths are given by the Cause of Death Registry at Statistics Norway and an

ad hoc registry at the Norwegian Institute of Public Health. Overall and Pneumonia and Influenza certified mortality is modeled using Poisson regression, adjusting for levels of reported influenza-like illness and seasonal and year-to-year variation.

**Results and conclusions** Modelling results suggest that the excess mortality in older age groups is considerably lower during the pandemic than non-pandemic seasons, but there are indications of an excess beyond what was reported during the pandemic. This highlights the benefits of both methods and the importance of explaining where these numbers come from.

**Keywords** A(H1N1)pdm09, excess mortality, influenza, modelling, pandemic, reporting.

*Please cite this paper as:* Gran et al. (2013) Counting pandemic deaths: comparing reported numbers of deaths from influenza A(H1N1)pdm09 with estimated excess mortality. *Influenza and Other Respiratory Viruses* 7(6), 1370–1379.

## Introduction

The 2009 H1N1 influenza pandemic was the first pandemic of the twenty-first century, as declared by the World Health Organization in June 2009. During the first weeks of the main pandemic wave in Norway in October 2009, it appeared that Norway was experiencing a higher mortality rate associated with the influenza A(H1N1)pdm09 virus than other European countries. However, by the end of the pandemic period, it was widely reported that there had been much fewer influenza-related deaths than in previous years.

It is often hard to discern between influenza and other risk factors as the cause of death for patients with chronic diseases. Therefore, one can differentiate between two main approaches used to assess the mortality burden.<sup>1</sup> One approach is to count

the number of deaths reported to death registries with influenza as one of the registered direct or underlying causes of death, with or without laboratory confirmation. The true mortality burden is assumed to be much higher than what is reported by these registries<sup>1,2</sup> because most often influenza is not recognized as a contributing factor to death due to varying clinical presentation of influenza, low awareness among clinicians and varying practices and availability of testing for influenza.

The other approach for assessing the mortality burden of influenza as a contributing factor is by using statistical models. Typically, these models estimate the excess mortality as the difference between the observed mortality during an influenza season and the expected baseline mortality in the same period if no influenza were present. There are different ways to determine the baseline mortality, but it is typically

made using a regression or time series method.<sup>2–5</sup> In Norway, both these approaches have been undertaken for the first year of the influenza A(H1N1)pdm09 pandemic.

By the use of these two approaches (registries and models), health authorities' reporting may lead to confusion. Typically, one can cite the excess number of deaths from seasonal influenza when arguing for the importance of public health measures against influenza, such as vaccination. This strategy may backfire if the public at another time is presented with the usually much lower number of registered deaths in the Cause of Death Registry, without a proper explanation of the methods.

The objective of this study was to compare the number of reported influenza-registered deaths with the results from two different models for estimating the excess mortality due to influenza during the 2009 pandemic in Norway. This was to try to understand the real impact of the pandemic on yearly mortality rates and allow for realistic planning for future pandemics. Using one of the models, we also wanted to compare the estimates for the pandemic season with previous regular influenza seasons.

## Methods

### Data material

The Norwegian Institute of Public Health (NIPH), in conjunction with the Directorate of Health, set up an *ad hoc* registry of people reported to have died from influenza A (H1N1)pdm09 during the pandemic. Cases were defined as any person dying in Norway in the period between April 2009 and April 2010 where laboratory-confirmed influenza A (H1N1)pdm09 was considered to have significantly contributed to death. Starting from 20 July 2009, all doctors in Norway were obliged to immediately notify the Norwegian Institute of Public Health of any such cases. Following a notification, we asked the local municipal medical officer to collaborate with the patient's family to complete an exhaustive questionnaire and return it to the Directorate of Health who then removed identifying data before forwarding it to us at the NIPH.

In addition, we received data from the Cause of Death Registry at Statistics Norway on the patients where influenza was coded as a direct or underlying cause of death during the 2009 pandemic. We also received total numbers of Pneumonia and Influenza (P&I)-certified deaths per week (using ICD-10 codes J09–J18) from week 1 in 2000 through week 52 in 2011.

Data on all-cause mortality per week (defined by the ISO standard), overall and for age groups (0–4, 5–14, 15–64 and 65+), were derived from the National Population Register. Data were available until week 10 in 2011.

Data on influenza-like illness (ILI) were derived from the Norwegian Notification System for Infectious Disease

(MSIS). Since autumn 1998, 201 sentinel reporting units have reported the number of consultations where ILI diagnosis is given (ICPC-2 code R80) per total number of consultations per week to the Norwegian Institute of Public Health (NIPH). As outbreaks of influenza typically take place during the winter, they are assigned to a pre-defined influenza season instead of calendar year. Prior to 2009, numbers were reported from week number 40 each year to week number 20 the year after, while in 2009 and 2010, ILI levels were also recorded during the summer (between weeks 20 and 40). To include the 2009 pandemic in the analysis, an influenza season was defined to extend from week 21 in one year to week 20 the year after. In seasons where ILI was not recorded between weeks 21 and 39 (off season), ILI levels were estimated using linear interpolation. In years with 53 weeks, the last week was disregarded. ILI levels for age groups (0–4, 5–14, 15–64 and 65+) were included from autumn 2001.

Norwegian population numbers for January 1 each year were derived from Statistics Norway, together with age-distributed population numbers for 1 January 2011, used to estimate age-distributed population numbers for the period 1998–2011.

### Estimated excess mortality using a Poisson regression model

The number of overall deaths per week was modelled using an overdispersed (quasi) Poisson model similar to the model in Gran *et al.*<sup>2</sup>:

$$Y = \alpha \exp\{\beta_0 + \beta_1 \text{Week} + \beta_2 \text{Season} + \beta_3 \text{ILI} + \beta_4 \text{ILI} \times P\}, \quad (1)$$

where  $Y$  represents the number of overall deaths in a particular week, the offset term  $\alpha$  represents the total population in Norway by January 1 the corresponding year, Week is the week number (between 1 and 52), Season is a factor with a level for every influenza season (1998/1999, 1999/2000, ...), ILI is the reported cases of ILI the week before,  $P$  is a factor variable with three levels – one level for the wave 1 of the 2009 pandemic (weeks 30–40), one level for the wave 2 (weeks 41–50) and one level for any other week, and the  $\beta$ 's are the corresponding regression coefficients. The interaction term  $\text{ILI} \times P$  was included to allow for different impacts of ILI during the two waves of the 2009 H1N1 pandemic than during regular seasonal influenza. The lag of one week in the ILI variable was chosen as it gave the best fit with respect to explained variance compared with no lag and a lag of 2 weeks.

To assess model performance, we also fitted a model similar to Thomson *et al.*<sup>3</sup> and Foppa *et al.*,<sup>4</sup> using cyclic terms for seasonal variation, as well as a combination of this model and the model in Eq. (1), with cyclic terms and a

seasonal factor. The three models were fitted to predict the weekly total number of deaths, as well as weekly number of deaths in age groups. For age-grouped analyses, two different sets of models were compared: one with weekly total ILI and one with weekly age group-specific ILI as a predictor. All three models gave similar estimates of the influenza contribution  $\beta_3$  and of excess mortality (including confidence intervals). The model in Eq. (1) was therefore chosen as our final model to stay close to the model in Gran *et al.*,<sup>2</sup> despite its higher parameterization. The estimated dispersion parameter using the model in Eq. (1) on overall data was 1.75, against 2.32 and 2.43 for the two other models, respectively. For a more formal model, selection one could use the QAIC criterion suggested for quasi-models.<sup>6</sup>

For each week, the estimated excess mortality  $\hat{X}$  can be calculated by:

$$\hat{X} = Y - \hat{Y}_{\text{ILI}=0}, \quad (2)$$

Where  $Y$  is the observed number of deaths that week and  $\hat{Y}_{\text{ILI}=0}$  is the predicted number of deaths when the ILI level is fixed at 0 when making predictions from the above Poisson models. Note that when the model is formulated with seasonal terms as in Eq. (1), using the predicted number of deaths  $\hat{Y}$  instead of  $Y$  in the above estimator will give identical results for overall and per-season estimates of excess mortality.

Corresponding to Gran *et al.*,<sup>2</sup> due to the nature of our ILI data, we moderated our estimator in Eq. (2) and calculated:

$$\hat{X} = Y - \hat{Y}_{\text{ILI=BL}}, \quad (3)$$

where BL is the ever-present baseline of ILI, present also off season. The constant BL was found as the mean of the lowest 19 weeks (the length of the off-season period) of ILI activity from every season.

Confidence intervals for the estimates of excess mortality were found using the 95% bootstrap percentiles from 1000 bootstrap samples, bootstrapping the model residuals.<sup>7</sup>

The analysis was performed using the GLM package in the open-source statistical software R, version 2.15.2.<sup>8</sup>

### Estimated excess mortality using the consensus EuroMOMO protocol

An alternative to the model in Eq. (1) is the model used by EuroMOMO.<sup>9</sup> The aim of the EuroMOMO project was to develop and strengthen monitoring of mortality across Europe to enhance management of serious public health risks such as pandemic influenza, heat waves and cold snaps.

As in the model described above, the main outcome is excess mortality, defined as observed minus expected mortality for a specified time period. Data analysis involves modelling of the expected number of deaths for a given

geographical unit and for different population groups. To compare estimates of excess deaths, a common versatile statistical model is needed, and the key output of EuroMOMO was to provide a European consensus model for mortality monitoring, which is applicable all over Europe and which is piloted and ready to implement.

To obtain the baseline mortality (without influenza), a Poisson regression was modelled on the spring (weeks 16–25) and autumn (weeks 37–44) periods, to systematically remove expected winter and summer excess deaths from the historical data.<sup>10</sup> A sine-cosine cycle with a period of 52.18 weeks and a trend are included in the model to control for seasonality and trend representing a modified Serfling approach.<sup>11</sup> The model is fitted using a historical period of 5 years.

## Results

From the designated surveillance at the NIPH of deaths due to pandemic influenza, a total of 32 fatalities (0.65 per 100 000 of the population) were registered between April 2009 and April 2010 (Table 1). Two further patients found in the Cause of Death Registry were not included as their influenza diagnosis was not laboratory confirmed. Questionnaires were received back for 28.

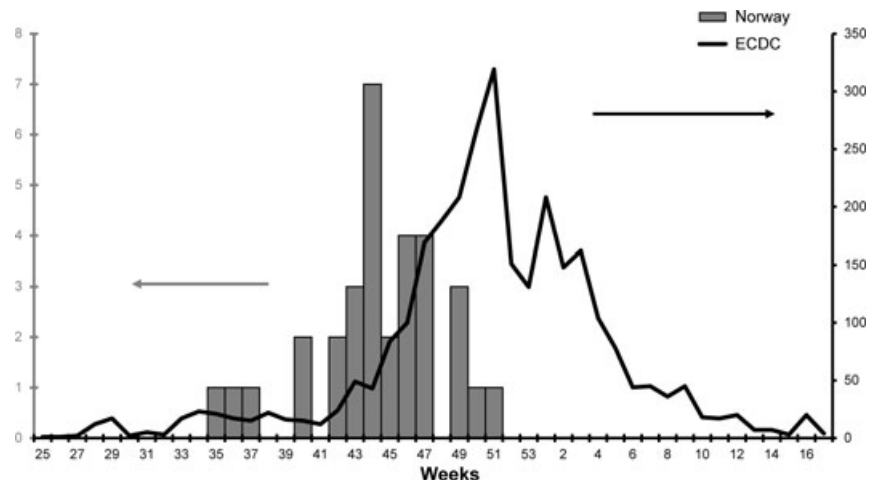
Only one person was not found to have had a medical condition that put the person at higher risk from influenza complications. Ten people were found to have more than one condition that put them at higher risk. The most common condition was chronic pulmonary disease. No cases of vaccine failure were found.

The peak period of deaths from influenza A(H1N1) was earlier in Norway than that the average of countries in Europe (Figure 1); however, the mortality rate was consistent with that seen in other countries.

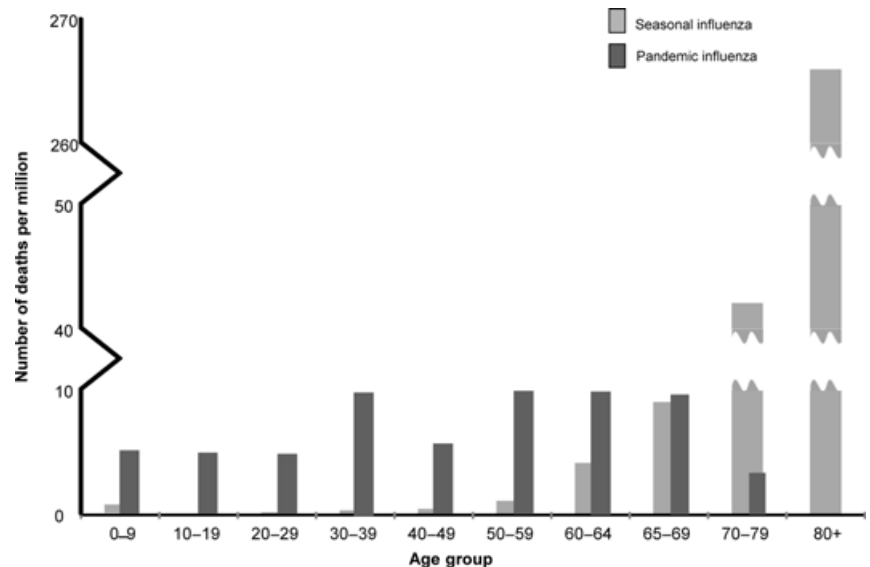
**Table 1.** Number of registered influenza deaths in Norway between April 2009 and April 2010, by gender and age group. Influenza deaths are deaths were laboratory-confirmed influenza A(H1N1)pdm09 was considered to have significantly contributed to death

Age	Men	Women	Total
0–9	2	1	3
10–19	1	2	3
20–29	2	1	3
30–39	3	4	7
40–49	2	2	4
50–59	6	1	6
60–69	0	5	5
≥70	0	1	1
Total	16	16	32

**Figure 1.** Mortality rates (per million) from influenza in the EU/EEA countries (from ECDC) and in Norway, by week during the first pandemic year, 2009–2010.



**Figure 2.** Number of influenza deaths per million by age group reported to the Cause of Death Registry for the seasons 1997–2008 on average (light grey) and to the NIPH for the first pandemic year, April 2009–April 2010 (dark grey).



The numbers of reported deaths by age group for the pandemic season compared with the season between 1997 and 2008 are presented in Figure 2. The figure indicates a significantly different age distribution for the deaths in the pandemic season, with cases spread out in all age groups, compared with the other seasons where almost all deaths are found among the elderly population.

With the Poisson regression model in Eq. (1), the estimated seasonal excess mortality using Eq. (3), from season 1998/1999 to season 2009/2010, varied from 56 deaths in the 2009/2010 pandemic season to 1520 deaths in the 1999/2000 season, when analysing all-cause mortality (Table 2). The mean estimated excess mortality for the entire period was 766 deaths per season (16.6 per 100 000 population). Results analysing P&I-certified deaths were considerably lower, ranging from 394 deaths in the 1999/2000 season to 72 deaths in the 2007/2008 season, with a

mean estimate of 172 excess deaths per season (3.7 per 100 000 population). Note, however, that the P&I analysis does not cover season 1998/1999 and that the first and last seasons in both analysis do not cover a complete 52 weeks.

In Figure 3, the upper panel shows the observed mortality, predicted mortality and reported number of ILI cases per week for the entire period. We see that the predicted mortality is close to the observed, indicating a good model fit. The figure also shows how the mortality and ILI peaks coincided in most seasons, but not in the pandemic 2009/2010 season. The lower panel of Figure 3 shows the observed mortality together with the predicted mortality without the ILI contribution (with 95% confidence intervals for the latter). The estimated excess mortality is, by the definition in Eq. (3), found as the difference between these two solid lines.

Analyses were also carried out for age groups. Table 3 shows the effect of ILI on mortality ( $\beta_3$ ), the effect of the

**Table 2.** Estimated excess mortality using the estimator in Eq. (3), analysing both all-cause and P&I deaths, mean level of reported ILI and dominant virus for all influenza seasons from 1998/1999 to 2010/2011

Season	Estimated excess mortality using all-cause mortality (95% CI)	Estimated excess mortality using P&I deaths (95% CI)	Mean ILI per consultations 100 consultations	Dominant virus
1998/1999	1363 (1193–1559)	–	1.96	A/Sydney/5/97 (H3N2)
1999/2000	1520 (1326–1759)	394 (356–435)	1.42	A/Moscow/10/99 (H3N2)
2000/2001	339 (298–386)	80 (71–89)	0.67	A/New Caledonia/20/99 (H1N1)
2001/2002	761 (666–870)	203 (182–225)	0.98	A/Panama/2007/99 (H3N2)
2002/2003	629 (553–718)	132 (116–150)	0.89	No dominant virus
2003/2004	1083 (945–1242)	246 (219–275)	1.19	A/Fujian/411/2002 (H3N2)
2004/2005	784 (690–897)	151 (133–172)	1.03	A/California/6/2004 (H3N2)
2005/2006	631 (554–720)	125 (112–139)	0.92	B/Malaysia/2506/2004
2006/2007	818 (718–935)	190 (169–213)	1.03	A/Wisconsin/67/2005 (H3N2)
2007/2008	383 (337–437)	72 (64–80)	0.72	A/Solomon Island/3/2006 (H1N1) and B/Florida/4/2006
2008/2009	542 (476–621)	114 (102–126)	1.05	A/Brisbane/10/2007 (H3N2)
2009/2010	56 (–289–419)	96 (43–148)	2.16	A(H1N1)pdm09
2010/2011	607 (531–692)	118 (156–133)	0.97	B/Brisbane/60/08

ILI, influenza-like illness.

interaction between ILI and wave 1 and wave 2 of the pandemic season ( $\beta_4$ ), the overall mean estimated seasonal excess mortality and estimated excess mortality in the pandemic season using the estimator in Eq. (3), for all age groups and in total. The results are compared with an analysis using P&I deaths for all age groups. Note that numbers for all age groups do not equal the sum of the numbers for age groups alone, as they were estimated using separate models. We see that the largest effect of ILI on mortality is in the youngest and oldest age groups. For the 15–64 age group, there is no significant excess mortality. For the interaction terms, only wave 2 is significant in the 0–4, 5–14 or 15–64 groups, while in the 65+ group and for overall data, there is a significant interaction effect both during wave 1 and wave 2. A significant interaction term means that the ILI effect on mortality is significantly different during the specific pandemic wave than during the rest of the season. All the significant effects are negative, meaning that the impact of ILI during the pandemic was less than in regular seasons. Further, we see that the results from the pandemic season do not differ much from the seasonal average for the 0–4, 5–14 and 15–64 age groups, but are much lower than average for the 65+ group (and then naturally also the overall group). Note, however, that the uncertainty is very high for estimates during the pandemic period.

Figure 4 shows the results from the modelling of the P&I data. Even though the analysis of P&I deaths generally gave lower estimates of excess mortality, the estimate for the pandemic season was somewhat higher than when analysing all-cause mortality, with an excess mortality estimate of 96

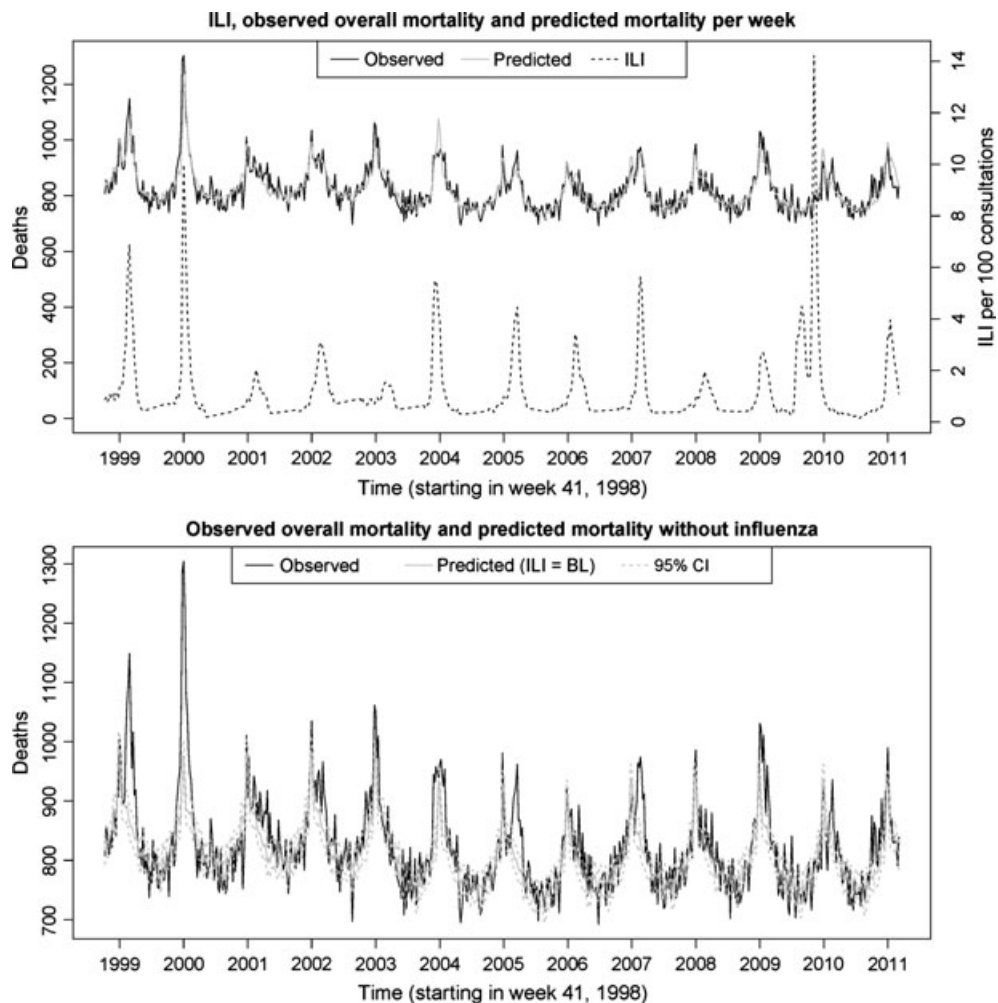
deaths per year (2.0 per 100 000 in the population) for all age groups. Due to what might be less noise in the P&I data, the model uncertainty is smaller than in the analysis of overall deaths, and we find a significant excess mortality during the pandemic period.

Results from the EuroMOMO analysis are presented in Table 4. Note again that the overall numbers do not equal the sum of age-grouped numbers as they were estimated using separate models. The estimates from EuroMOMO are higher in the 15–64 and 65+ groups than the estimates using Eq. (3). The total number of excess mortality in the pandemic season was here estimated to be 252 deaths.

## Discussion

We have compared the number of influenza-certified deaths during the 2009 influenza pandemic in Norway with the results from two models for estimating seasonal excess mortality due to influenza. The model based on Eq. (1) gives an estimated excess mortality of 56 deaths analysing all-cause mortality and an estimate of 96 deaths using P&I-certified deaths. Only the excess mortality found analysing P&I deaths is significant. The EuroMOMO model gives an estimate of 252 deaths, without stating uncertainty. The numbers from the *ad hoc* registry for pandemic deaths at NIPH are smaller than all of the above, with 32 deaths attributed to influenza.

Age-grouped analysis suggests some excess mortality in the lower age groups, although the estimates are far from significant, not noticeably different than in non-pandemic seasons.



**Figure 3.** Observed overall mortality, predicted mortality and reported number of influenza-like illness (ILI) cases per week (upper panel), together with observed mortality and predicted mortality without ILI contribution with 95% confidence intervals (lower panel), for all age groups in Norway 1999–2011, using the Poisson model in Eq. (1).

This finding may seem to contradict the actual reported deaths presented in Figure 2. An explanation can be that the enhanced death surveillance during the pandemic, including a more widespread use of laboratory tests for influenza, detected more of the actual deaths than during non-pandemic periods, especially among children and young adults.

Most of the estimated deaths occurred among the elderly. However, the excess mortality estimates for the 65+ group are lower during the 2009/2010 pandemic season than any other seasons. The model in Eq. (1) gives an estimated excess mortality of 30 deaths in the 65+ group in the pandemic season, versus an average mortality of 766 deaths for all seasons. The data on influenza-certified deaths also indicate a non-typical age distribution, with a much higher proportion of deaths taking place in the younger age groups. The major part of the mortality was among people below the age of 65, contrary to what we see during a typical seasonal winter influenza outbreak.

Our estimated excess mortality using P&I-certified deaths for all seasons was only about a fourth of the estimate using all-cause deaths, but during the pandemic, the P&I estimate was higher, and statistically significant, in contrast to the estimates based on all-cause data. However, even though P&I deaths have less noise than the all-cause mortality data, we believe that using P&I deaths underestimates the mortality burden of influenza, especially among the elderly. Several recent articles point to influenza as a trigger of acute myocardial infarction (AMI), which is a major cause of death in most countries, including Norway. For instance, Warren-Gash *et al.* found that 3.1–3.4% of AMI-associated deaths in England and Wales were attributable to influenza.<sup>12</sup> The association was further supported by their self-controlled cases series study.<sup>13</sup> Foster *et al.* found similar results in USA.<sup>14</sup>

The Poisson regression model in Eq. (1) gave similar results as in Gran *et al.*<sup>2</sup> for all overlapping seasons, even

**Table 3.** Regression results using the model in Eq. (1) and estimated excess mortality for age groups and overall analyses using the estimator in Eq. (3)

Age group	$\beta_3$ ILI (P-value)	$\beta_4$ interaction (P-value) for ILI $\times$ wave 1 and wave 2	Mean estimated excess mortality per season 1998/1999–2010/2011 (rate per 100 000 pop.) [95% CI]	Estimated excess mortality pandemic season (rate per 100 000 pop.) [95% CI]
Analysing all-cause mortality				
0–4	0.0376 (0.0575)	–0.0203 (0.8600)	6 (2.1) [1 (0.3)–11 (3.7)]	7 (2.4) [–15 (–4.8)–30 (9.9)]
		–0.0535 (0.2251)		
5–14	0.0879 (0.0232)	0.0097 (0.9345)	4 (0.7) [1 (0.2)–7 (1.1)]	3 (0.5) [–5 (–0.9)–13 (2.2)]
		–0.0905 (0.1959)		
15–64	0.0055 (0.1787)	0.0106 (0.9791)	22 (0.7) [–9 (–0.3)–54 (1.8)]	13 (0.4) [–96 (–3.0)–128 (4.0)]
		–0.0061 (0.2143)		
65+	0.0339 (<0.0001)	–0.0373 (<0.0001)	727 (104.3) [638 (91.5)–844 (121.1)]	30 (4.1) [–276 (–37.9)–338 (46.4)]
		–0.0345 (<0.0001)		
All	0.0300 (<0.0001)	–0.0314 (<0.0001)	766 (16.6) [667 (14.4)–883 (19.1)]	56 (1.17) [–228 (–6.0)–380 (7.9)]
		–0.0308 (<0.0001)		
Analysing P&I-certified mortality				
All	0.1322 (<0.0001)	–0.0851 (0.0014)	172 (3.7) [156 (3.4)–188 (4.0)]	96 (2.0) [43 (0.9)–148 (3.1)]
		–0.1136 (<0.0001)		

though the data covered twice the time span as in the original study. The results for the pandemic season were lower in comparison with the results using the EuroMOMO model, which partly can be explained by the use of the more moderate estimator in Eq. (3) compared with the more common estimator in Eq. (2). One should also note the large uncertainty present when analysing the pandemic season alone, especially when analysing all-cause mortality. It is likely that uncertainty in the EuroMOMO estimates, which are not reported, are of similar magnitude. Regarding other model choices, such as the different ways to model week-to-week and season-to-season variation, the results from the EuroMOMO model and the different variants of the model in Eq. (1) indicate that the excess mortality estimates are not very sensitive to these model choices.

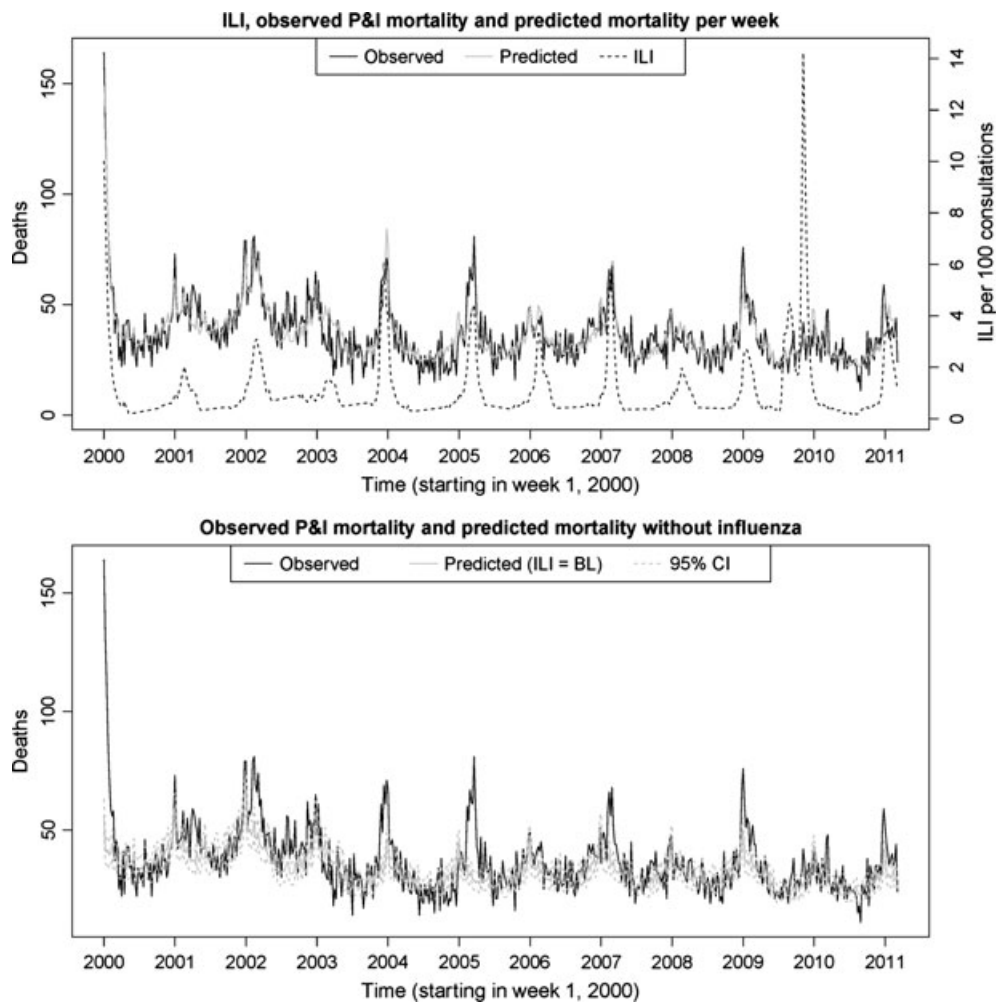
It is important to note that the data from the extended pandemic death surveillance at NIPH and the Cause of Death Registry are not directly comparable with the excess mortality estimated from the model in Eq. (1) and the EuroMOMO method. As previously mentioned, it is often hard to discern between influenza and other contributing factors. And influenza is often seen as a contributing factor as it often aggravates other underlying illnesses such as serious heart and lung diseases. This is especially obvious in the elderly population, above 65 years, as they more often have several chronic underlying illnesses.

The mortality associated with the 2009 influenza pandemic has been a topic in many recent papers,<sup>1</sup> some of which use excess mortality modelling. For example, Poisson models were used to estimate the influenza-related excess mortality

in Hong Kong, before and during the pandemic season.<sup>15</sup> Contrary to our analyses, they found that the mortality during the whole of 2009 was comparable with those in the preceding ten interpandemic years, with no real difference among age groups. A study in USA,<sup>16</sup> on the other hand, estimated a higher excess mortality during the pandemic for people below 65 years of age and lower excess mortality for people in the 65+ group, compared with prior seasons. For people below 15 years of age, the excess mortality was higher than in any prior season between 1962/1963 and 2008/2009. Another US study<sup>17</sup> found a mean age of deaths of 37 years during the pandemic, compared with an estimated mean age of 76 during seasonal influenza epidemics. A study estimating the excess mortality in England and Wales between 1999 and 2010<sup>18</sup> found the highest mortality burden among the 75+ age group, with the lowest mortality during the 2009/2010 pandemic season.

Excess mortality monitoring in England and Wales during the pandemic<sup>19</sup> showed excess all-cause mortality in the 5–14 years age group, and in age groups >45 years ‘during a period of very cold weather’. Surveillance data from Finland<sup>20</sup> and Denmark<sup>21</sup> both showed high morbidity and high rates of hospital admissions in younger age groups compared with previous influenza seasons. A review of pandemic deaths in Alberta, Canada,<sup>22</sup> showed that the mortality rate during the pandemic was the third highest in the period 1983 to 2010 and that the mean age of deaths was significantly younger by close to 30 years.

All the results suggest that the majority of the mortality took place during the main wave of the pandemic (October–



**Figure 4.** Observed P&I mortality, predicted mortality and reported number of influenza-like illness (ILI) cases per week (upper panel), together with observed mortality and predicted mortality without ILI contribution with 95% confidence intervals (lower panel), for all age groups in Norway 2000–2011, using the Poisson model in Eq. (1).

**Table 4.** Observed number of overall deaths, expected deaths and excess deaths, for age groups and overall, in Norway 2009–2010, using the EuroMOMO consensus method

Weeks	Age group	Observed deaths	Expected deaths	Excess deaths (rate per 100 000 pop.)
29–52 (both waves)	0–4	103	98	5 (1.7)
	5–14	24	22	2 (0.3)
	15–64	3049	2975	74 (2.3)
	65+	15 306	15 159	147 (20.1)
	All	18 482	18 230	252 (5.2)

December), which is in line with the general perception of the impact of the pandemic. It also appears that the mortality in Norway peaked earlier, but was not higher than other

European countries. The fact that Norway had enhanced its mortality surveillance and the extremely high media attention probably ensured very rapid reporting of the fatalities.

The results from the two models considered in this study to different extent suggest an additional excess mortality during the 2009 pandemic beyond what is reported to the extended pandemic death surveillance at NIPH and the Cause of Death registry. The analysis of P&I deaths in particular finds an estimated excess mortality which is significantly higher than what was reported. Results as a whole indicates that this additional mortality is mainly found among people in the oldest age groups, and one might also expect that deaths among people in the older age groups in general are less likely to be detected in pandemic surveillance than deaths among younger age groups. However, it is important to note that this higher estimated excess mortality among the elderly is considerably lower during the 2009



pandemic than during regular influenza outbreaks. In other words, the results from the modelling suggest that the 2009 pandemic was less severe for people in the older age groups than during regular seasonal influenza. Reasons for this could be that many elderly people had acquired immunity to the pandemic virus through previous exposure to similar influenza viruses<sup>23</sup> or through vaccination against the A (H1N1)pdm09 virus, which in Norway started at mid-October 2009 and eventually covered around 45% of the population, including the 65+ age group. The early and atypical time of onset of the epidemic may also have played a part.

From our results (Table 2), it is evident that there exists a great variation in mortality between seasonal influenza epidemics. This variation, perhaps partly mediated by variation in age distribution, probably results from a complex interplay between circulating influenza subtype virulence and transmissibility and population immunity to that virus. We note also that the pandemic seemed to be causing a lower excess mortality than recent seasonal epidemics. Thus, the dichotomy between seasonal influenza and pandemic influenza may not be so important for public health planning. Rather, it seems more important to assess the severity of every influenza epidemic, as suggested by the review of WHO's response to the pandemic<sup>24</sup> and followed up by both WHO and Centers for Disease Control and Prevention (CDC).<sup>25</sup>

Our findings may have several implications for public health practice. Surveillance of deaths during a pandemic may provide information for public health action. In communications with the public, authorities need to be absolutely clear about whether they are communicating actual registered deaths or estimated excess deaths. Norway should consider setting up a system, like the EuroMOMO system, for continuous monitoring of excess deaths due to influenza, other infectious diseases and extreme ambient temperatures.

Further research is necessary to understand the true mortality burden of influenza.<sup>1</sup> This requires better criteria for when and how to attribute deaths to influenza.

Data on reported deaths due to influenza have its limitations, as influenza is often overseen as a contributing underlying cause of death among people with other underlying diseases. However, registries of reported causes of deaths serve an important purpose with a high information yield on those actually detected, for example, on comorbidities, demography and virology. To give a good assessment of the total number of deaths, excess mortality modelling can be a better indicator.

Finally, it remains clear that deaths are only one part of the burden of influenza. In Norway, the 2009 pandemic led to far more cases of influenza, hospitalizations and intensive care admissions than regular influenza epidemics.<sup>26–28</sup> Estimates

of influenza-associated excess mortality during the A(H1N1)pdm09 influenza pandemic suggest that the mortality might have been higher than reported, especially among the 65+ age group, but that these numbers were much lower than in regular seasonal influenza epidemics.

## Acknowledgements

We thank Olav Hungnes and Kristian Waalen at Department of Virology, NIPH, for compiling historical data on dominant virus strain for each influenza season and Øistein Løvoll at the Department of Infectious Disease Epidemiology, NIPH, for setting up the *ad hoc* registry for pandemic deaths. The work was funded by the Norwegian Institute of Public Health. Author J. M. Gran was also partly funded by the Research Council of Norway, contract and grant 191460/V50.

## Declaration of interest

None.

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