Health Information and Quality Authority

An tÚdarás Um Fhaisnéis agus Cáilíocht Sláinte

Analysis of excess all-cause mortality in Ireland during the COVID-19 epidemic

3 July 2020

About the Health Information and Quality Authority (HIQA)

The Health Information and Quality Authority (HIQA) is an independent statutory authority established to promote safety and quality in the provision of health and social care services for the benefit of the health and welfare of the public.

HIQA's mandate to date extends across a wide range of public, private and voluntary sector services. Reporting to the Minister for Health and engaging with the Minister for Children and Youth Affairs, HIQA has responsibility for the following:

- **Setting standards for health and social care services** — Developing person-centred standards and guidance, based on evidence and international best practice, for health and social care services in Ireland.
- **Regulating social care services** — The Chief Inspector within HIQA is responsible for registering and inspecting residential services for older people and people with a disability, and children's special care units.
- **Regulating health services —** Regulating medical exposure to ionising radiation.
- **Monitoring services** — Monitoring the safety and quality of health services and children's social services, and investigating as necessary serious concerns about the health and welfare of people who use these services.
- **Health technology assessment** — Evaluating the clinical and cost-effectiveness of health programmes, policies, medicines, medical equipment, diagnostic and surgical techniques, health promotion and protection activities, and providing advice to enable the best use of resources and the best outcomes for people who use our health service.
- **Health information** — Advising on the efficient and secure collection and sharing of health information, setting standards, evaluating information resources and publishing information on the delivery and performance of Ireland's health and social care services.
- **National Care Experience Programme** — Carrying out national service-user experience surveys across a range of health services, in conjunction with the Department of Health and the HSE.

Summary

The Health Information and Quality Authority (HIQA) analysed excess mortality in Ireland from 11 March 2020 to 16 June 2020 to determine whether the reported COVID-19 mortality provides an accurate estimate of excess mortality during the epidemic. The analysis uses data from Ireland's death notices website 'RIP.ie'. Data were analysed using a time series approach whereby expected deaths were predicted using historical RIP.ie death notice data. Sensitivity analyses were conducted to determine the robustness of the findings.

Based on the available data, the main findings of this analysis are:

- Based on the deaths notices reported at RIP.ie, there is clear evidence of excess mortality occurring since the first reported death due to COVID-19 in Ireland.
- Excess mortality is estimated as the number deaths by any cause (all-cause deaths) recorded greater than the number of all-cause deaths predicted based on a time series model of daily deaths. Excess mortality was found to be 1,072 (95% CI: 851 to 1,290) between 11 March 2020 and 16 June 2020 inclusive. The officially reported number of COVID-19 deaths for the same period was 1,709. Therefore, the estimated excess mortality is less than the officially reported COVID-19-related mortality by 637 cases.
- The officially reported COVID-19 deaths may overestimate the true burden of excess mortality specifically caused by COVID-19. This is may be due to the likely inclusion within official COVID-19 figures of people who were known to be infected with SARS-CoV-2 (coronavirus) at the time of death who were at or close to end-of–life independently of COVID-19 or whose cause of death may have been predominantly due to other factors.
- Excess mortality peaked over a six week period (25 March 2020 to 5 May 2020). During those six weeks, excess mortality was 1,200. During that period, 1,332 COVID-19 related deaths were officially reported. Therefore, the estimated excess mortality was less than the officially reported COVID-19 related mortality by 132 cases.
- For the period from 11 March to 16 June, the observed mortality was 13% more than that expected. During the six week peak period, the excess mortality was 33% more than that expected (weekly excess ranging from 10% to 54%).
- COVID-19 may have accelerated time of death in frail and vulnerable individuals over the peak period. The excess mortality observed at the peak is now being followed by a period of decreased mortality as date of death for individuals who would ordinarily have died during this time may have occurred earlier than expected.

- While the data from RIP.ie would appear to accurately represent true overall mortality patterns, there are limitations to the data. These include the lack of data on age and sex, and the lack of reliable information on county of residence. Monitoring of excess mortality would benefit immensely from more timely availability of official death registration data.

Contents

Introduction

In December 2019 the Wuhan Municipal Health Commission in China reported a cluster of cases of severe pneumonia in Wuhan, Hubei Province. The cluster was ultimately linked to a novel coronavirus, which was subsequently named 'Severe Acute Respiratory Syndrome Coronavirus 2', or 'SARS-CoV-2', while the associated disease was named 'coronavirus disease 2019', or 'COVID-19'. Although initially limited to China, the virus began to spread into neighbouring Asian countries in January 2020. By the end of January, cases had been detected in 22 countries, including five in Europe. The first confirmed case in Ireland was reported on 29 February 2020. Due to the severity of the virus and associated disease, it is important to gain an understanding of the resulting mortality. Monitoring of the overall burden of death due to the disease is critical for establishing the success or ongoing challenges of infection and disease control efforts.

The Health Information and Quality Authority (HIQA) has carried out an analysis of excess mortality in Ireland from 11 March 2020 to 16 June 2020 to determine whether the reported COVID-19 mortality provides an accurate estimate of excess mortality during the epidemic.

Issues in measurement of COVID-19 mortality

Mortality associated with COVID-19 may be described in different ways, but has frequently been reported as a case-fatality rate. This approach expresses the number of deaths due to COVID-19 as a proportion of the total number of confirmed cases within a certain period. The accuracy of the case-fatality measure is contingent on the methods used to code cause of death and those used to measure the total number of confirmed cases of COVID-19.

There is substantial variation across countries in how each COVID-19 death and case overall is monitored and recorded. For example, some countries monitoring COVID-19 deaths include only deaths of patients with laboratory-confirmed infection while others include all confirmed and suspected cases. Furthermore, variability across jurisdictions in coding of cause of death results in variations in whether or not deaths are attributed to COVID-19 versus other underlying causes.

In Ireland, deaths due to COVID-19, which is classed under legislation as a notifiable disease, are officially reported via the Computerised Infectious Disease Reporting (CIDR) surveillance system managed by the Health Protection Surveillance Centre (HPSC). All deaths in laboratory-confirmed cases of COVID-19, in both hospital and community settings, are reported. As of mid April, in line with World Health Organization (WHO) guidance, death reporting was extended to include deaths both in patients with probable COVID-19 in addition to deaths among confirmed cases.[1]

By definition, such deaths must result from a clinically compatible illness, in a probable or confirmed COVID-19 case, unless there is a clear alternative cause of death that cannot be related to COVID-19 (for example, trauma).

There is a correlation between the prevalence of COVID-19 and the volume of testing carried out. It is important to note that there may be a high proportion of infected individuals that are asymptomatic or are paucisymptomatic (with few or mild symptoms). Individual countries will have different criteria regarding the number and types of symptoms that must be present for an individual to be referred for COVID-19 testing. Countries with a higher volume of testing tend to detect more cases and so have a higher reported prevalence of COVID-19. The combination of varying approaches to identification of deaths due to COVID-19 and estimation of COVID-19 prevalence clearly creates distinct challenges for interpreting comparisons of COVID-19 mortality across countries.

One alternative to the case-fatality rate is to simply consider the overall population mortality rate, that is, the number of COVID-19 deaths per capita. While such an approach removes the issue of variable prevalence estimates due to differences in recording of cases, there remains the challenge of ensuring that COVID-19 deaths have been accurately identified and reported.

Excess mortality

To avoid issues relating to how COVID-19 deaths are recorded, the concept of excess mortality has been widely used to estimate the burden of mortality occurring as a result of a prevalent health threat. Rather than being concerned with cause of death, excess mortality is concerned only with total observed deaths relative to the expected number of deaths during the same time period. The use of excess mortality as a measure is not without issues as it requires an appropriate estimate of expected mortality. In the case of mortality monitoring during an epidemic, it also requires timely and accurate information on all deaths and not just notifiable cause-specific deaths.

Data on deaths in Ireland are typically sourced from official death registration records. However, death registrations may be completed up to three months after an individual's death in Ireland. The average lag between date of death and registration of death was 63 days in the last quarter of 2019, and these delays hamper timely analysis of Irish mortality data. It has been further noted by the Central Statistics Office (CSO) that there is evidence of additional delays in death registration during the COVID-19 epidemic.[2] An alternative source of mortality data that is available in Ireland is the death notifications website, 'RIP.ie'. While not intended as a source of mortality data, the notifications listed on this website could potentially help to identify mortality patterns.

This report presents an analysis of RIP.ie death notice data from 11 March 2020 (the date of the first reported COVID-19 death within Ireland) to 16 June 2020, in order to estimate the extent of excess mortality in Ireland during the recent COVID-19 epidemic. Excess mortality estimates are calculated based on predicted expected deaths modelled using death notification data from previous years. The estimated excess mortality is further compared to officially reported figures for deaths due to COVID-19 in order to better understand the performance of each of these measures.

Methods

Data sources

All-cause mortality data were obtained from the Irish deaths notifications website RIP.ie.[3] Death notifications are published to this website by funeral directors. CSO mortality data from previous years were used to validate the RIP.ie-derived data.[4 5] To allow comparison of estimated excess mortality with existing figures for the extent of COVID-19 related deaths, numbers of officially reported COVID-19 deaths were obtained from the Health Protection Surveillance Centre's CIDR (Computerised Infectious Disease Reporting) surveillance system.

For the extraction of RIP.ie data, the website search function was used to identify all notifications dated between 1 January 2010 and 16 June 2020. Data were predominantly extracted from the individual page associated with each notification. Each notification is allocated a unique sequential identification number in the RIP.ie system, permitting the identification of notifications missing from search result tables within the specificed range of dates. Numbers missing from the search results were identified and where notification data were available, these were extracted and included in the analysis. All data extraction from the RIP.ie website was handled through the statistical software R, using the httr and RJSONIO packages to manage the HTML and JSON file structures.[6-8]

Data cleaning

Notifications obtained from search results include details on the date of notification and name and address information for the decedent. The level of detail in the address information ranges from county-level data to street address. As the search table information does not enable reliable identification of county of residence or of foreign deaths which happened to be notified on RIP.ie, location details were extracted from the individual notification pages.

Location details may include one or more locations, including previous places of residence. Due to the lack of consistent terminology, a pragmatic approach was adopted to code place of residence. The text string for location was scanned for the presence of any of the names of the 26 counties in Ireland. The string was also scanned for the presence of any one of a list of 324 foreign locations, including all countries and major towns and cities in the UK, USA, Australia and Europe. It was assumed that where an individual should be treated as a non-Irish death, the reference to a foreign location would precede the reference to an Irish county. Cases designated as non-Irish deaths were excluded from the analysis.

Following RIP.ie data extraction and cleaning, the key fields retained for analysis included: date of publication, date of death and county of residence.

Data validation

To validate the RIP.ie data, the numbers of deaths notifications were compared to the officially recorded number of deaths in the vital statistics reports from the CSO at a county and national level (see Appendix) for the equivalent date intervals.[4 5]

Statistical analysis

The data were analysed as a time series of count data using the tsglm function in the tscount package in R.[9] The main analysis was based on daily counts of date of death. A secular trend for increasing mortality was noted to be in place since 2010, most likely due to a combination of increasing population numbers and an ageing population. As such, a model was chosen that would incorporate this trend into the analysis as well as the seasonal component reflecting increased mortality during the winter months. However, following the data validation exercise using CSO data an undercount of mortality for the years 2010 to 2014 was identified in the RIP.ie data. As this undercount could bias the estimate of the underlying trend for increasing mortality, the main analysis was restricted to data from 1 January 2015 onwards.

The model structure allowed for the specification of previous observations on which to be regressed (autoregression), previous conditional means on which to be regressed. The model structure also allows for potential covariates to be included, such as temperature or other potential predictors of mortality patterns. Autoregression is generally specified as recent observations (for example, observations from the last two weeks) while conditional means may be calculated for the same period in the previous year. Within the model the conditional distribution could be specified as Poisson or negative binomial, and the link function can be log or identity. Furthermore, there was flexibility regarding the choice of date from which to forecast. Data from some countries have suggested that COVID-19 cases may have arisen earlier than previously thought, and as such mortality may have begun to deviate from expected figures prior to the date of the first known case. Given these circumstances, the model was specified using a range of potential choices for each parameter as follows:

- previous observations: previous week, previous fortnight, previous four weeks
- previous conditional means: none, fortnight in previous year, month in previous year, fortnight in previous two years
- conditional distribution: Poisson, negative binomial
- link: log, identity
- last week of 2020 included in model fitting: week 7, week 8, week 9, week 10

The choices resulted in 192 model specifications. All were run and the model with the lowest value for the Akaike Informmation Criterion (AIC) was selected as best fitting. The model was fit to the observed weekly count data from 1 January 2015.

Date of death was not reported for all notifications, although the proportion of cases missing date of death was observed to decrease steadily over time (see Appendix). For missing date of death, the date was estimated by applying a lag to the date of publication. The value of the lag was determined by applying a generalised linear model with Poisson distribution to the cases with known date of death. The lag in days between dates of death and publication was fitted with covariates for year, day of week and month of year [of notification]. From the model it was apparent that this lag has been decreasing over time, but is higher during the summer months and at the start of the week.

An analysis was planned of county-level deaths. However, a comparison of county-level figures between RIP.ie data and official CSO data for the years 2015 to 2018 showed systematic over-counting and under-counting in certain counties. As such, any analysis of excess mortality could be heavily biased in those counties and would not be valid, and this planned analysis was therefore not performed.

Sensitivity analysis

A number of alternative approaches to conducting the analysis were identified that could impact on the estimated results. Considerations included changing the date range of the data used to estimate the time series model, and using date of notification rather than date of death given that the date of death was imputed for 10.1% of records. Also, data could be analysed as weekly rather than daily counts (based on date of notification) in order to reduce bias induced by delayed notifications on weekends and after bank holidays. Sensitivity analysis was used to test whether the following choices would substantively alter the results:

- estimate time series model using 2010 to 2020 data
- estimate time series model using 2016 to 2020 data
- force time series model to use data to 10 March 2020
- use of weekly rather than daily mortality counts
- analysis based on date of notification rather than date of death

Cross-country comparisons

Cross-country comparisons were carried out using data from the EuroMOMO project.[10] The EuroMOMO collaboration was set up to detect and measure excess mortality related to influenza and other possible public health threats in European countries. At present there are 23 participating countries including Ireland. The methodology applies a time series model with Poisson distribution to the reported data, with adjustments for incomplete reporting in the most recently submitted data.

The figures are based on registrations and, unlike the RIP.ie data, they include demographic details, enabling age-sex standardisation.

Excess mortality is reported by EuroMOMO as z-scores relative to baseline, that is, the expected number of deaths. The z-score provides the excess as the number of standard deviations from expected. Countries can be directly compared on the basis of z-scores, although consideration has to be given to how variance may differ across countries, particularly given the underlying population size. Data were extracted for all 24 reporting centres (Germany is represented by two centres, Berlin and Hesse) and compared on the basis of cumulative z-scores from weeks 11 to 24 of 2020 (11 March to 16 June). The cumulative z-score can be interpreted as the total number of standard deviations of weekly counts; if there were no aggregate difference from expected, then the cumulative z-score would be zero. As such, a positive value indicates an excess of deaths while a negative value indicates mortality below that expected.

Demography of COVID-19 mortality

To understand excess mortality, it is useful to consider the age-sex distribution of those who died with COVID-19. As already stated, the RIP.ie data do not contain age and sex, so it is not possible to calculate excess mortality for subgroups. The age-sex distribution of COVID-19 deaths in Ireland was estimated using the reported deaths included in the CIDR database between 11 March 2020 and 26 June 2020. The distribution was contrasted with the age-sex distribution of all-cause mortality from the vital statistics data published by the CSO (2015 to 2017).[4]

Results

Data extraction, cleaning and validation

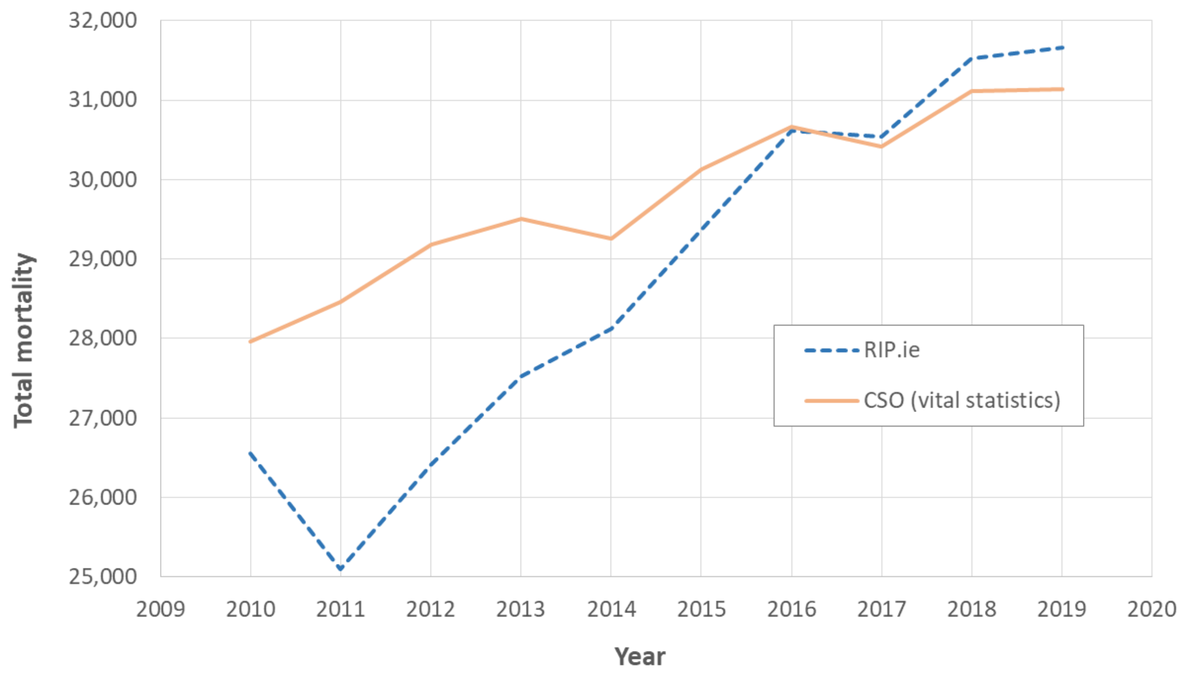
Search results from RIP.ie comprised 317,644 death notices for the period 1 January 2010 to 23 June 2020. From the search table results it was observed that 15,734 of the possible sequential numbers were not included. Of these, 2,443 provided legitimate notifications, yielding a total of 320,087 deaths notices. Among these, a total of 15,887 (5.0%) notifications were classified as non-Irish deaths, leaving 304,200 deaths notified during the period 1 January 2010 to 23 June 2020. To minimise the effect of the lag between death and notification, the most recent week was excluded leaving 303,579 deaths from 1 January 2010 to 16 June 2020.

Date of death was observed to be missing for 10.1% of notices, though that figure has decreased over time from 17.1% in 2010 to 2.0% in 2020. Where date of death was available, the median lag from date of death to date of notification was one day. Almost all deaths (97%) were notified within five days in the years 2019 and 2020.

Deaths would be expected to occur with approximately equal probability (14.3%) by day of week, and this was observed in the date of death. However, only 9.9% of deaths were notified on a Sunday, and 12.3% on a Saturday. This was counterbalanced by additional cases being notified on weekdays (for example, 17.7% on Mondays, 15.7% on Tuesdays).

Both the RIP.ie data and the official vital statistics data from the CSO showed increasing mortality over time (Figure 1). However, from 2010 to 2014, the RIP.ie data represented a substantial underestimate of true mortality in the order of 4% to 12%. Since 2015, the discrepancy has ranged from between 0.2% and 2.5% (Figure 1). As such, data from 1 January 2015 were used in the time series model.

Figure 1. Official and RIP.ie mortality figures by year, 2010 to 2019



Model selection

The main analysis was based on daily count data with the time series model parameters estimated using deaths between 1 January 2015 and 10 March 2020. The latter date was chosen to include all data available prior to the first official COVID-19 death reported in Ireland. The selected model based on the lowest AIC was specified as:

- previous observations: previous four weeks
- previous conditional means: two weeks in previous year and two weeks two years previously
- conditional distribution: negative binomial
- link: log
- data used in model fitting: 1 January 2015 to 18 February 2020

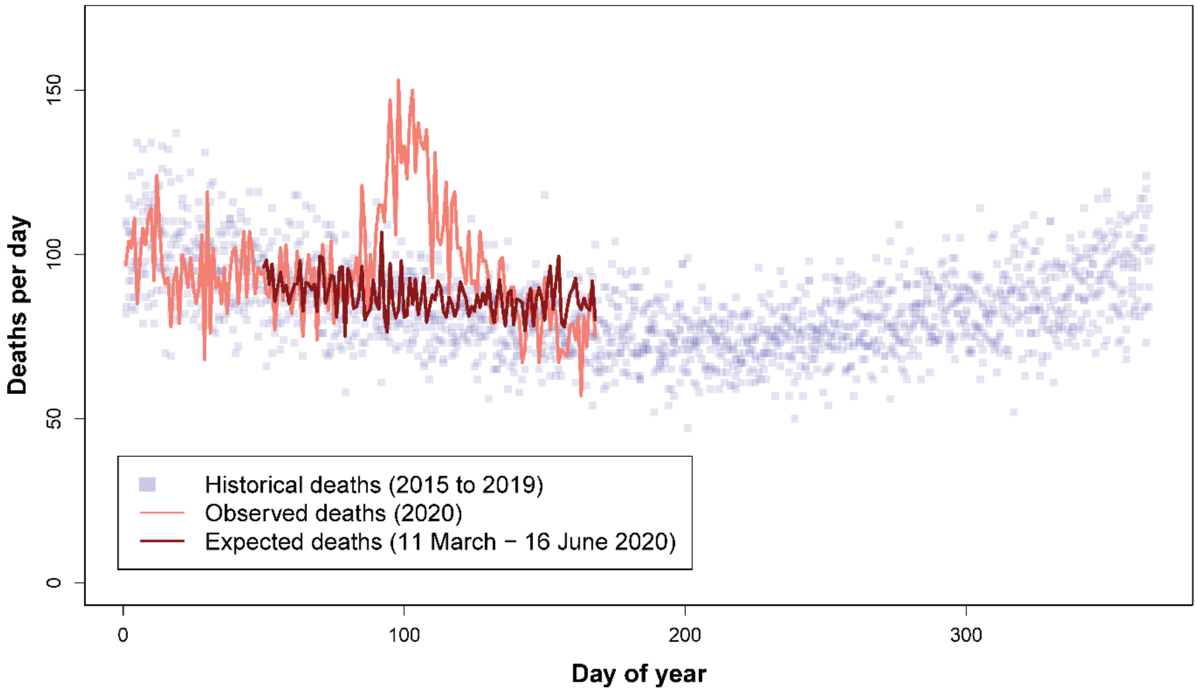
The model fit improved when the data to 18 February were used rather than up to 10 March, potentially indicating a deviation from expected mortality in the weeks prior to 10 March 2020.

Excess mortality

Based on the time series model, the expected number of death notices over the period 11 March 2020 to 16 June 2020 was 8,482 (95% CI: 8,264 to 8,703). The estimated excess mortality for the period is 1,072 deaths (95% CI: 851 to 1,290). The reported number of all COVID-19-related reported deaths on 16 June was 1,709. As such, the excess mortality is less than the reported COVID-19 related mortality by 637 cases.

There is considerable uncertainty around the expected numbers of deaths and, as can be seen from Figure 1, there is substantial fluctuation from year to year. However, the confidence bounds around the excess do not include the reported COVID-19 mortality; therefore, it is highly likely that a portion of deaths recorded as COVID-19-related represent deaths which would have occurred during this timeframe independently of the presence of COVID-19.

Figure 1. Observed and expected daily deaths: 2015 to 2020



The peak in all-cause mortality occurred in week 15 of 2020 (8 to 14 April) with 941 deaths recorded on RIP.ie (Figure 1, Table 1). There were six weeks (25 March to 5 May 2020) during which the observed number of deaths exceeded the upper bound for expected deaths. During those six weeks, the observed deaths (n=4,827) exceeded the expected (n=3,627) by 1,200. During that period, 1,332 COVID-19 related deaths were officially reported to CIDR.

For the last four weeks of the data (20 May to 16 June) the number of observed deaths was less than the mean expected deaths. In one of those weeks (3 to 9 June) the number of deaths was less than the lower bound expected for that week.

Excess mortality is sometimes expressed as a relative measure. For the period from 11 March to 16 June, the observed mortality was 13% more than that expected. During the six-week period when the observed deaths exceeded the upper bound for the expected mortality, the excess mortality was 33% more than that expected (weekly excess ranging from 10% to 54%).

Table 1. Observed and expected (predicted) deaths per week based on RIP.ie data

Week	Dates	Observed deaths	Predicted deaths Mean	[95% CI]
11	11 Mar to 17 Mar	638	637	[580 to 696]
12	18 Mar to 24 Mar	640	614	[557 to 676]
13	25 Mar to 31 Mar	725	601	[546 to 659]
14	01 Apr to 07 Apr	887	611	[553 to 670]
15	08 Apr to 14 Apr	941	612	[555 to 671]
16	15 Apr to 21 Apr	848	608	[550 to 669]
17	22 Apr to 28 Apr	759	591	[536 to 649]
18	29 Apr to 05 May	667	604	[546 to 664]
19	06 May to 12 May	634	599	[540 to 661]
20	13 May to 19 May	631	597	[540 to 656]
21	20 May to 26 May	562	587	[532 to 647]
22	27 May to 02 June	572	616	[557 to 678]
23	03 June to 09 June	508	611	[552 to 671]
24	10 June to 16 June	542	594	[538 to 652]

Notes: where date of death was missing, the date was estimated by applying a lag to the date of publication of the notice. Data were extracted to 23 June 2020 to account for lags between date of death and date of publication of death notices.

Sensitivity analysis

The time series model for the main analysis was applied to daily mortality data, whereby the parameters were estimated using mortality data from 1 January 2015 to 18 February 2020. To determine the extent to which the date range influenced the estimated excess mortality, the model was refit to different date ranges and also applied to weekly data (Table 2).

Extending the historical data to 1 January 2010 or extending to finish with week 10 (10 March 2020) had a minor effect on the expected mortality and estimated excess. Restricting the training data to start at 1 January 2016 or limiting it to finish at 31 December 2019 markedly increased the expected mortality.

Use of weekly data resulted in lower estimates of expected mortality, and consequently higher estimates of excess mortality. Weekly data also resulted in wider confidence bounds and hence greater uncertainty around the estimated excess mortality.

A final sensitivity analysis used the observed data from weeks 11 to 24 in 2019 as the expected mortality for 2020, that is, the expected mortality data for 2020 were calculated based on data from the corresponding weeks in 2019. This resulted in an estimated excess of 1,260 deaths.

Table 2. Estimated excess mortality for a range of models using different time ranges to calculate expected deaths

Model specification (data range used to estimate time series parameters)	Observed deaths (all notifications to RIP.ie, 11 March to 16 June)	Expected numbers of deaths (based on time series model of previous notifications) (11 March to 16 June)		Estimated excess deaths based on difference between observed and expected (11 March to 16 June)	
		Mean	(95% CI)	Mean	(95% CI)
Daily mortality					
01/01/2015 to 18/02/2020 (*main model*)	9,554	8,482	(8,264 to 8,703)	1,072	(851 to 1,290)
01/01/2016 to 18/02/2020	9,554	8,724	(8,492 to 8,958)	830	(596 to 1,062)
01/01/2010 to 18/02/2020	9,554	8,416	(8,135 to 8,703)	1,138	(851 to 1,419)
01/01/2015 to 10/03/2020	9,554	8,467	(8,252 to 8,682)	1,087	(872 to 1,302)
01/01/2015 to 31/12/2019	9,554	8,967	(8,741 to 9,197)	587	(357 to 813)
Weekly mortality					
01/01/2015 to 18/02/2020	9,554	8,332	(7,953 to 8,729)	1,222	(825 to 1,601)
01/01/2010 to 18/02/2020	9,554	8,288	(7,929 to 8,651)	1,266	(903 to 1,625)
01/01/2015 to 10/03/2020	9,554	8,330	(7,954 to 8,708)	1,224	(846 to 1,600)
01/01/2015 to 18/02/2020 (date of publication)*	9,589	8,385	(7,978 to 8,807)	1,204	(782 to 1,611)

Notes:

Each model was selected based on best fit from the parameterisations tested. All models were specified as negative binomial with a log link function.

* Date of publication refers to the date on which the death notice is published on RIP.ie, rather than the date of death. Unlike date of death, which is missing in some cases and needs to be imputed, date of publication is know for all notices. As there is a lag between date of death and publication, the number of published notices does not necessarily match the number of deaths in a given date range.

A cross-country comparison considering the period 11 March to 16 June inclusive shows that Ireland has had similar relative excess mortality to Switzerland and Portugal (Table 3). The highest cumulative excess mortality has been observed in England, followed by Spain, Belgium and the Netherlands. Three countries (Norway, Denmark and Greece) had lower mortality than expected during the period 11 March to 16 June. The distribution of cumulative z-scores is highly skewed: the average is 50.6 and the median is 27.5; Ireland is positioned close to this median value.

Table 3. Excess mortality for 11 March to 16 June 2020 based on EuroMOMO estimates[10]

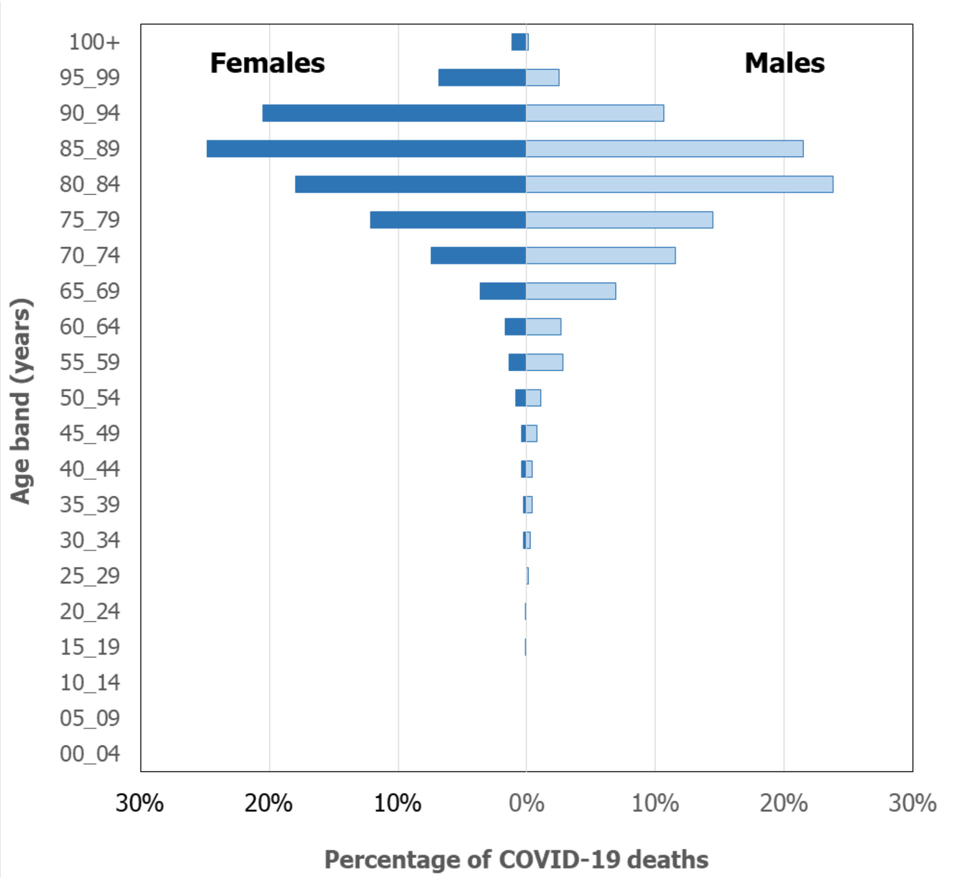
Country	Cumulative z-score	Peak z-score	Week of peak
Norway	-2.59	1.28	23
Denmark	-0.72	2.22	14
Greece	-0.23	1.37	11
Germany (Berlin)	1.49	1.50	15
Finland	3.94	2.50	15
Luxembourg	6.53	3.00	15
Estonia	7.05	1.33	22
Hungary	9.83	1.83	12
Austria	9.84	3.51	14
Germany (Hesse)	13.50	2.69	15
Malta	14.01	3.48	12
Ireland	25.35	9.37	15
Switzerland	29.61	11.28	14
Portugal	31.11	5.40	14
Northern Ireland	44.40	9.15	15
France	77.44	23.79	14
Wales	84.05	18.81	15
Italy	88.53	16.79	14
Sweden	88.69	12.93	15
Scotland	90.24	15.92	15
Netherlands	101.66	21.74	14
Belgium	110.16	24.14	15
Spain	164.87	43.57	14
England	216.28	40.76	15

Considering individual periods within the overall analysis timeframe, the EuroMOMO estimates suggests a return of mortality to below baseline (less than expected) occurred in Ireland since week 20 of 2020. Although several European countries (such as France and Italy) have shown a drop to below baseline figures, most have stayed within or above the normal range since week 20. A comparison of the main model estimates based on RIP.ie data and the EuroMOMO data for Ireland show a close correlation (see Appendix Figure A.4).

Demography of COVID-19 deaths

The age profile of officially reported COVID-19 mortality demonstrates the substantial burden to date on older people (Figure 2). Of all officially reported COVID-19 deaths, 78% have occurred in those aged 75 years and older. This may be compared with the all-cause mortality data, where 64% of deaths occurred in people aged 75 years and older. As such, COVID-19 has disproportionately impacted the elderly.

Figure 2. Age profile represented in officially reported COVID-19 death data in Ireland (11 March 2020 to 26 June 2020)



Discussion

This report estimated the excess mortality that has occurred since the first reported confirmed COVID-19 related death in Ireland using data from RIP.ie, the Irish website of death notifications.

Main findings

Based on the time series model of daily deaths, there were 1,072 more deaths (95% CI: 851 to 1,290) than expected between 11 March 2020 to 16 June 2020. The reported number of COVID-19 deaths for the same period was 1,709. The estimated excess mortality is less than the reported COVID-19 related mortality by 637 cases (95% CI: 419 to 851). There was a six-week period (from 25 March 2020 to 5 May 2020) during which the observed number of deaths exceeded the upper bound for expected deaths. During those six weeks, the number of deaths that occurred (n=4,827) exceeded the expected number (n=3,627) by 1,200. During that period, 1,332 COVID-19 related deaths were reported.

To examine the sensitivity of the results, a range of different model specifications were applied. Where daily data were used, several models generated similar results while two models resulted in lower estimates of excess mortality. Models based on weekly accumulated data generated higher estimates of excess mortality, with the highest across all tested models being 1,266 (95% CI: 903 to 1,625) deaths. With the most extreme model the difference between excess mortality and reported COVID-19 mortality was 443 deaths (95% CI: 84 to 806).

Based on the highest estimate of excess mortality, the confidence bounds for this excess do not overlap with the reported number of COVID-19 deaths. As such, it is likely that the reported number of COVID-19-associated deaths overstates the true mortality burden of COVID-19. There are a number of reasons why this may be the case. The approach to COVID-19 mortality coding in Ireland has been one of precaution: all deaths where the individual had suspected or confirmed COVID-19 are to be classified as a COVID-19 death, as recommended by WHO guidance. It is possible that a proportion of the deaths occurred among people who were known to be infected with SARS-CoV-2 (coronavirus) at the time of death but whose cause of death may have been predominantly due to other factors. Also, where deaths were reported officially due to 'clinically suspected' COVID-19, in the absence of a confirmatory test result it is possible that some of the deceased may not have been infected. It should also be noted that the measure of excess mortality is not ideal for quantifying the full extent of deaths due to COVID-19 due to potential underestimation of same. This may occur where deaths due to COVID-19 occur in persons who may be at or near end-of-life at this time; such deaths may not contribute to the estimate of unexpected deaths during the period and therefore the calculated excess mortality may underestimate mortality due to COVID-19.

Comparison to other countries

The monitoring of excess mortality during the COVID-19 pandemic has been carried out by a number of countries. As stated in the introduction, use of this measure mitigates issues around the coding of cause of death and measurement of disease prevalence. However, such analysis does require up-to-date mortality data and an estimate of the expected mortality. Many countries have short time limits for the registration of deaths, often of the order of seven days after death. In Ireland the time limit is three months and 10% to 15% of deaths are not registered within that time horizon. It is likely that the rate of compliance with the time limit may vary by country, necessitating adjustments to reported figures. The data used for this report demonstrate a high proportion being notified within seven days (97% in 2019 to 2020).

The EuroMOMO data for a range of countries show that while Ireland is mid-table for excess mortality, it is considerably closer to those reporting no excess than those at the extremes of excess mortality. Without detailed information on the variance in weekly mortality by country, it is not possible to determine if the low cumulative z-score in Ireland reflects low excess mortality relative to some of the other participating countries or whether it is influenced by variance. For example, some of the countries with high excess mortality may display little variance in mortality, and hence a small deviation will register as a large z-score.

Limitations

An analysis is dependent on the quality and validity of the data used. The mortality data used in this report is not from an official source, but rather from a website of public death notices. The site does not claim to have a complete listing, nor is notification to the site obligatory. However, by comparison to CSO vital statistics data, it would appear that the deaths notices have excellent coverage in recent years. Nonetheless, the data are not structured in a manner that facilitates analysis or reliable coding. In particular, there are significant challenges in automatically identifying cases that involve deaths that would not be registered in Ireland. Furthermore, the information on the area of residence is unreliable; a single field can contain multiple counties and location references. The data also do not include information on age and sex, so do not support standardisation of the data. These should not be interpreted as criticisms of the data source, as it was not designed or collected for the purpose of monitoring mortality patterns. The major benefit of the data is the timeliness. The vast majority of deaths are notified within a week of occurrence, achieving much better short-term coverage than official death registrations in Ireland. A shortening of the time limit for official death registrations to seven days would have clear benefits to improving near real-time analysis of excess mortality. Ensuring all registrations have detailed address coding, most specifically an Eircode, would also support spatial analysis during epidemics or regional outbreaks.

As noted above, a limitation of the excess mortality approach can be how the expected mortality is computed. Mortality is subject to variability due to chance, seasonal effects, and external circumstances (such as the COVID-19 epidemic) among other factors. Any attempt to forecast mortality should incorporate uncertainty due to chance variation, seasonal effects, and any underlying secular trends, but ideally not those external circumstances for which we wish to detect the impact (for example, an influenza epidemic). A secular trend of increasing mortality is evident in Irish data since 2010, whereas prior to 2010 there was a period of declining mortality. Those underlying trends are driven by demographic changes and changes to health status, most likely relating to the growing population numbers and an ageing population. A strength of the present analysis lies in the time series approach used, which adjusts for seasonality and the secular trend and also incorporates uncertainty. As identified in our validation approach, a potential issue remains in that the RIP.ie data appeared to have incomplete coverage of deaths in 2010, increasing by 2015 and then potentially overestimating mortality in the most recent three years. The over-estimate may be due to the inclusion of foreign deaths that are not registered in Ireland. As already stated, the identification of foreign deaths is challenging given the data structure. As such, this data source may inflate the estimate of the secular trend, producing biased projections. However, we can assume that there is some degree of internal validity to the data. That is, if we contrasted the observed deaths from RIP.ie with expected mortality based on the CSO data, there would be an inconsistency that would bias the results of the analysis. We therefore have assumed that the analysis is broadly accurate and, based on the comparison with CSO data, stands within a couple of percentage points of the true mortality figure.

The lack of age and sex information has meant that there is no prospect of using age-sex standardisation for this analysis. In an examination of excess mortality it is not only important to know the magnitude of the effect, but also which subgroups of the population are affected. Mortality associated with COVID-19 has occurred predominantly in the elderly, so it would be important to know whether other age groups have been affected by increased mortality which may be indirectly due to COVID-19. For example, elective activity in acute hospitals was largely suspended during the first two months of the epidemic. The large amount of healthcare foregone is likely to have lasting impacts on health outcomes including mortality. If there is an effect, it is likely it will be over the longer ter. However, there may also be short-term effects that could potentially be observed with appropriate data. Again, timely collection of deaths registrations would enable such an analysis.

Conclusions

Due to the severity of COVID-19, it is important to gain an understanding of excess mortality to establish the success or ongoing challenges of infection and disease control efforts. Based on the death notices reported on RIP.ie, there is clear evidence of excess mortality occurring during the COVID-19 epidemic in Ireland. Based on daily deaths, the estimated excess is less than the reported number of COVID-19 deaths by at least 419 cases. The officially reported COVID-19 mortality may overestimate the true burden of excess mortality specifically caused by COVID-19. This is possibly due to the likely inclusion within official COVID-19 figures of people who were known to be infected with SARS-CoV-2 (coronavirus) at the time of death who were at, or close to end-of–life, independently of COVID-19 or whose cause of death may have been predominantly due to other factors. Following the excess mortality observed at the peak of the epidemic in Ireland, that trend has now reversed with fewer deaths than expected. COVID-19 is likely to have accelerated death in frail and vulnerable individuals over the peak period.

While the data from RIP.ie would appear to provide an accurate representation of mortality patterns, there are limitations to the data; these include the lack of data on decedent age and sex or reliable county of residence information. Monitoring of excess mortality would benefit immensely from more timely death registrations and geocoding to facilitate spatial analysis.

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Appendix

Validation of RIP.ie data

Coverage of data

The RIP.ie data are based on notifications published to the website by funeral directors. The data include name, town, county, date of death, address and a unique identifier based on a sequential number.

By comparison with monthly mortality from the CSO vital statistics data, the RIP.ie tended to underestimate deaths up to the end of 2014, but tended to overestimate deaths in more recent years (Figure A1). There tends to be more over-estimation during the latter half of the year.

Figure A1. Numbers of monthly deaths based on CSO vital statistics and RIP.ie deaths notices, January 2010 to December 2018

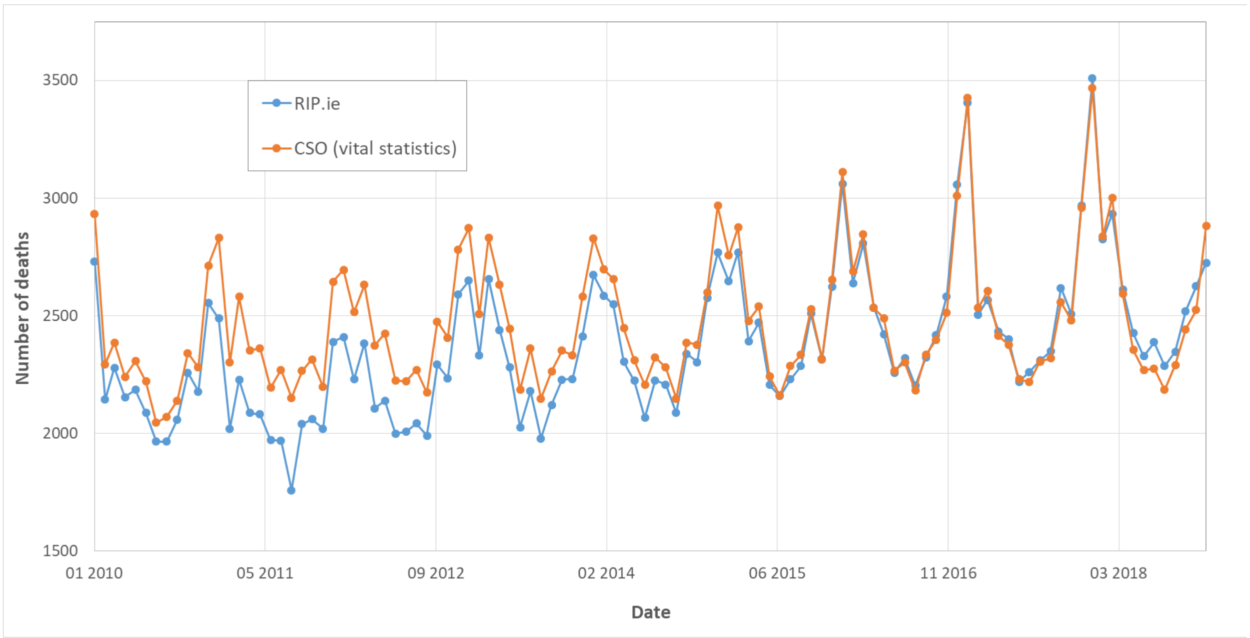


Table A2. Comparison of CSO and RIP.ie deaths by year

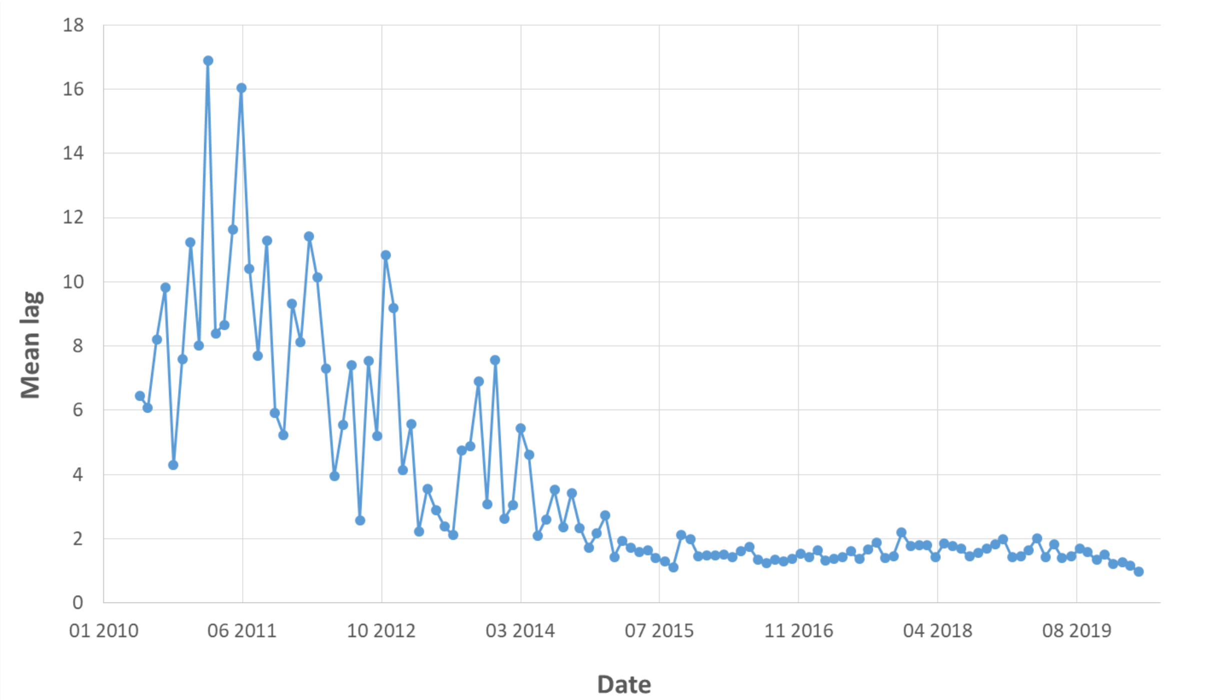
Year	RIP.ie	CSO	Ratio RIP to CSO
2010	26,550	27,961	0.950
2011	25,104	28,456	0.882
2012	26,416	29,186	0.905
2013	27,527	29,504	0.933
2014	28,130	29,252	0.962
2015	29,367	30,127	0.975
2016	30,617	30,667	0.998
2017	30,539	30,418	1.004
2018	31,519	31,116	1.013
2019	31,659	31,134	1.017

Although the data were cleaned to remove deaths outside Ireland, it is possible that some may have been retained. Due to time constraints and the challenges in developing a better understanding of the data, it has been assumed that the cleaned dataset acts as a good proxy for mortality in Ireland as the data from 2015 to date is within 2.5% of the true figure.

Timing of notices

The mean lag between date of death and date of notification has been decreasing over time, and has tended to be less than two days since the start of 2015 (Figure A1).

Figure A2. Mean lag between date of death and date of death notification



The mean lag may be misleading as it can be skewed by a small number of delayed notices or transcription errors. Since the beginning of 2015, in any given month there have never been less than 89% of notices published within two days of death, 96% within seven days and 97% within 10 days.

In cases where the date of death was missing, the date was estimated by applying a lag to the date of publication. This will create a small degree of bias in the most recent week of deaths notices. The lag was calculated using a generalised linear model. As there was evidence of overdispersion based on a Poisson model, a negative binomial regression was used. Covariates of year of publication (as continuous), day of week (as categorical) and month of year (as categorical) were included. The model coefficients indicated decreased lag at the end of the week (relative to publication on a Monday), increased lags from May to August inclusive (relative to January), and a trend of decreasing lag time since 2010.

County-level coding

The data from RIP.ie includes information on area of residence although a notification can be associated with multiple counties. For example, a notification may list the deceased's home at the time of death but also their ancestral home. The individual notifications include a location description, which may list the multiple locations that the deceased is associated with. The location field does not follow a strict format, creating challenges for coding the data. However, an inspection of a number of notices suggested that the area of residence is typically stated first, with previous residences listed subsequently.

Due to the large number of notifications being processed, hand coding of area of residence was not feasible. The locations were pragmatically coded by identifying the first location mentioned in the area description. A function was developed that searched the location text for the names of the 26 counties in Ireland, as well as a list of 324 foreign locations. The foreign locations included all countries and major towns and cities in the UK, US, Australia and Europe. Of the locations identified in the text, the one appearing closest to the start of the text was taken as the residence location.

All notifications could be coded to county or a foreign location based on the available text. After exclusion of the non-Irish deaths, the county-level data was compared against the vital statistics data published by the CSO for the years 2015 to 2018 (Table A.3). Certain counties were associated with consistent over- or under-estimates of mortality. For example, County Clare is associated with a consistent over-estimate of 16% to 22% between 2015 and 2019. County Kildare, on the other hand, has a consistent under-estimate of 4% to 7% over the same time period. While the overall mismatch has decreased slightly (from 4.3% in 2015 to 3.4% in 2019), the concern is that any county-level analysis may seriously misrepresent mortality in certain counties, as it either fails to capture all deaths in that county or because it includes deaths that should be recorded in another county. Furthermore, the inconsistency in some counties suggests that predictions of expected deaths based on historical patterns may be very misleading.

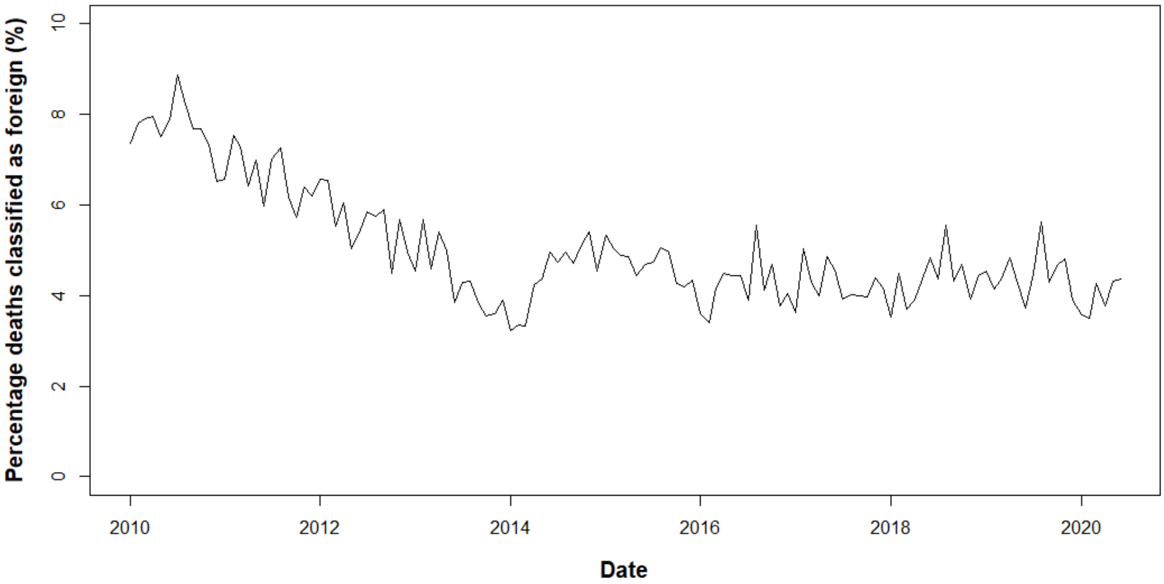
Table A.3 County-level mortality: ratio of RIP data to CSO figures

County	Year				
	2015	2016	2017	2018	2019
Carlow	1.01	1.04	0.99	1.01	1.18
Cavan	0.97	0.99	1.04	1.06	1.00
Clare	1.19	1.16	1.17	1.16	1.22
Cork	1.00	1.01	1.01	1.02	1.03
Donegal	0.91	1.01	0.99	0.99	0.96
Dublin	0.96	0.99	1.00	1.00	1.01
Galway	0.92	0.98	0.96	0.99	0.99
Kerry	1.02	1.01	1.05	1.10	1.02
Kildare	0.96	0.95	0.93	0.96	0.95
Kilkenny	0.97	1.00	1.03	1.05	1.02
Laois	0.97	0.93	1.01	1.04	0.93
Leitrim	1.02	1.01	1.08	1.16	1.02
Limerick	1.00	1.02	1.01	1.01	1.02
Longford	1.02	0.99	0.98	1.00	1.05
Louth	0.99	1.03	0.99	1.03	1.04
Mayo	0.92	0.98	0.97	0.98	1.02
Meath	0.96	1.00	1.00	0.98	1.03
Monaghan	0.82	0.87	0.90	0.94	0.91
Offaly	0.99	1.02	1.02	1.07	1.11
Roscommon	1.00	1.05	1.07	1.09	1.03
Sligo	1.01	1.03	1.04	1.01	1.09
Tipperary	1.02	1.02	1.03	1.02	1.05
Waterford	0.96	0.98	0.99	0.97	0.99
Westmeath	0.95	0.97	0.99	0.98	0.98
Wexford	0.88	0.91	0.93	0.97	0.94
Wicklow	0.96	1.02	0.99	0.99	1.02

The percentage notices that are considered non-Irish deaths has decreased over time, although the percentage has been largely consistent at 5% since 2014 (Figure A.3). Importantly, there is no evidence of an increase in non-Irish deaths included in the data during the COVID-19 epidemic.

In more recent years (2017 to 2019), the RIP.ie data represent an over-count of mortality in Ireland. To check whether this may be associated with deficiencies in the classification non-Irish deaths, the algorithm for identifying non-Irish cases was adjusted so that if a foreign location was identified anywhere in the text then the notice would be marked as non-Irish. While this led to an increased number classified as non-Irish (from x to y), there was still an over-count in the years 2017 to 2019. Notwithstanding the limitations of automated coding of locations, it is unclear whether this might explain the over-count or whether there may be other issues, such as duplicate entries for individuals (possibly entered separately with English and Irish versions of their name, for example).

Figure A.3 Percentage notifications classified as foreign by month

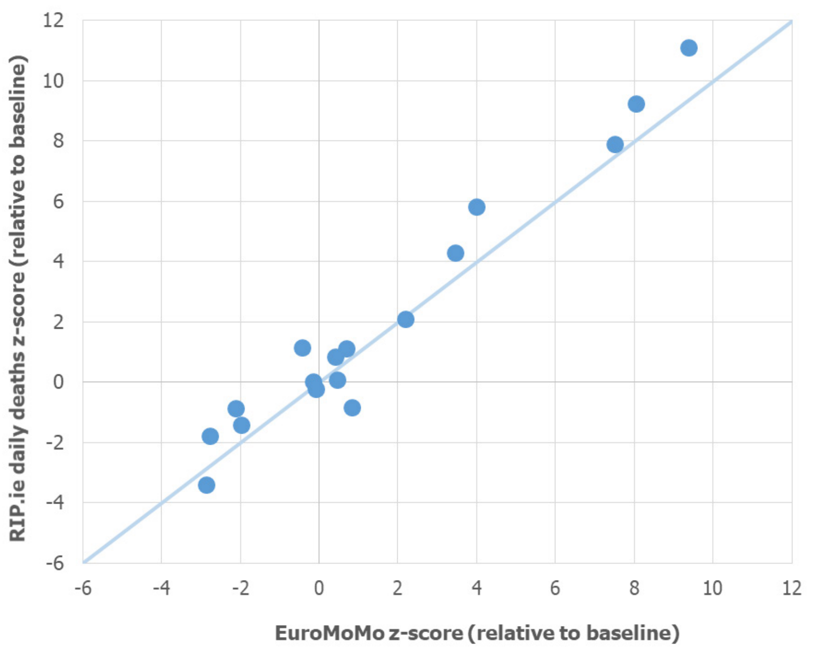


The most common non-Irish codings were Northern Ireland (n=8,237), United Kingdom excluding Northern Ireland (n=4,763), United States (n=1,615) and Australia (n=322). Use of a more extensive list of towns and cities may further improve the identification of non-Irish deaths but this has to be balanced with the potential for foreign place names appearing in Irish addresses thereby leading to misclassification.

Comparison with EuroMOMO

EuroMOMO reports z-scores by week of year. The EuroMOMO figures were compared with z-scores computed using the RIP.ie data (Figure A.4). There is good agreement between the figures and some of the difference may be explained by different approaches to estimating the variance based on historical data.

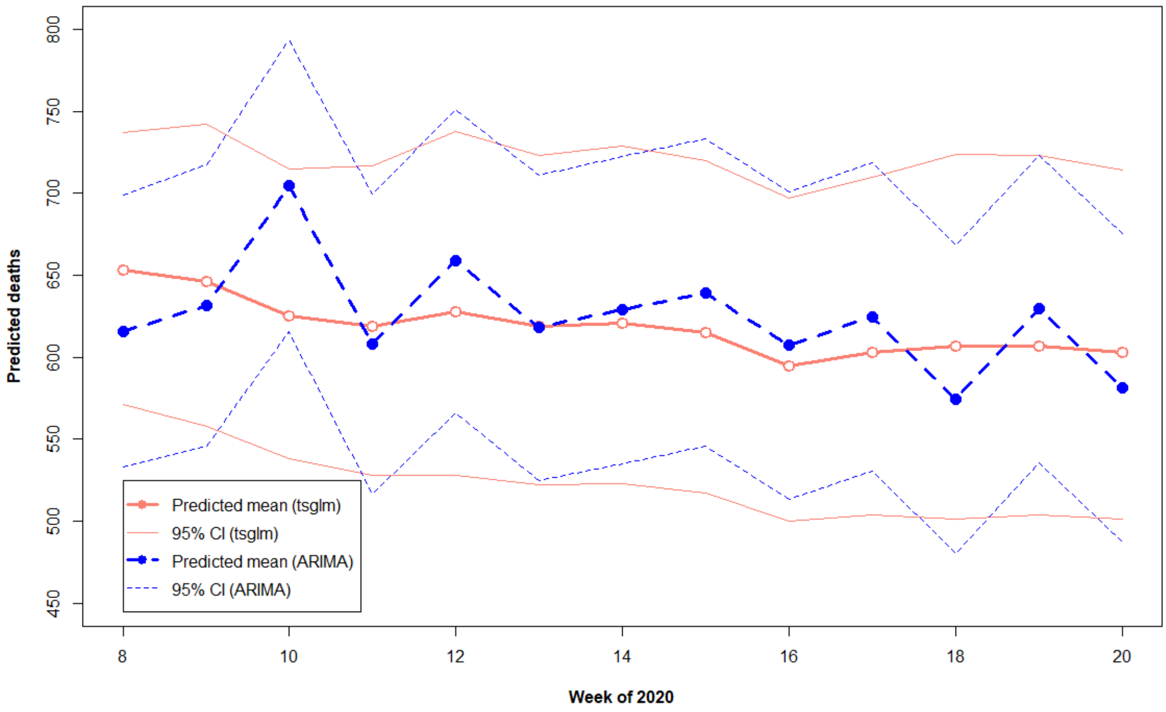
Figure A.4 Comparison of z-scores from EuroMOMO and RIP analyses



Time series model

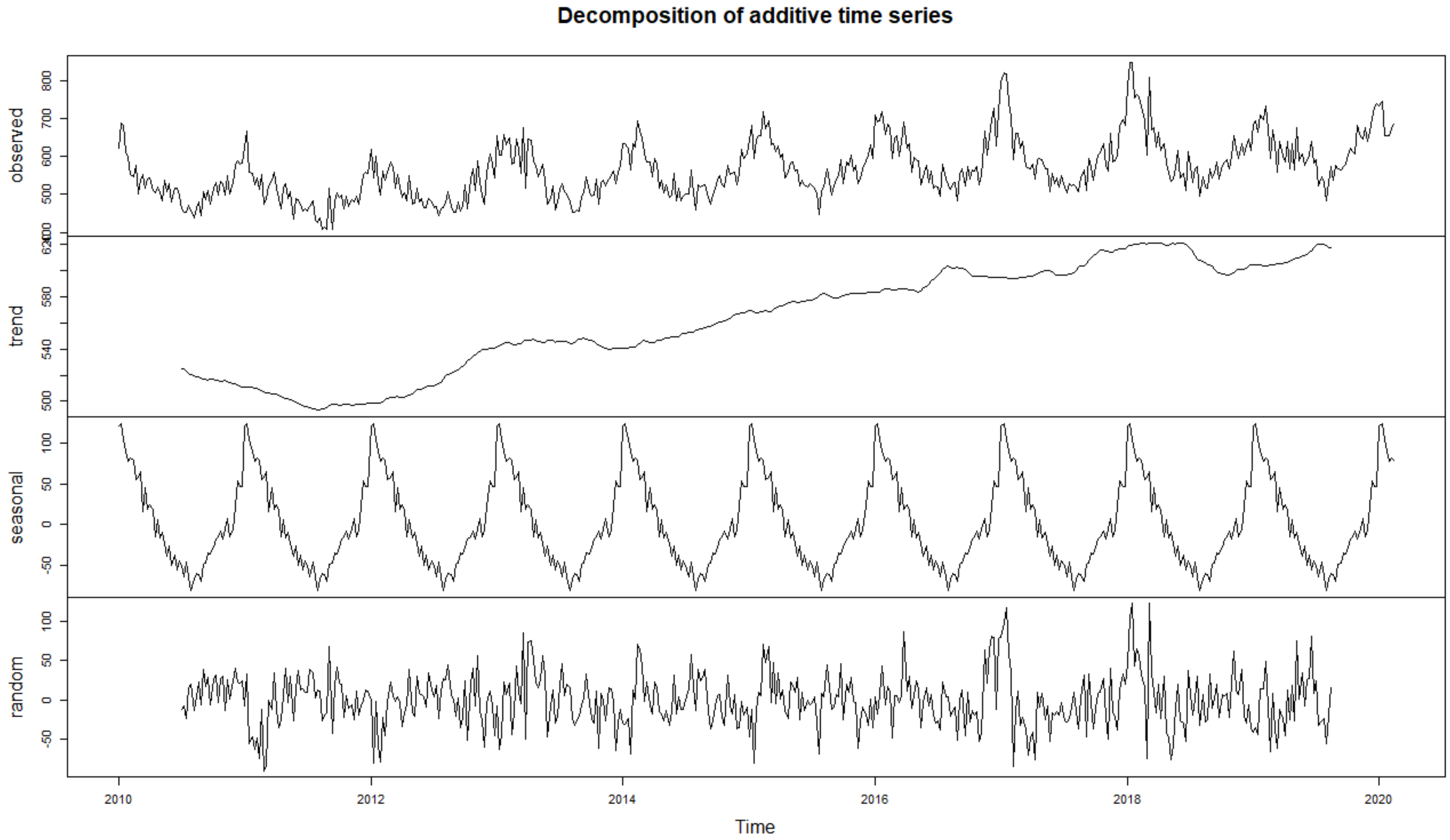
Although a count-based time series model was used, clearly there are a wide range of possible model specifications available. An ARIMA model was also developed using the auto.arima function in the forecast package in R. As with the tsglm function, a model using data to week 7 had the lowest AIC. The selected model was a ARIMA(3,0,0)(1,1,0)[52] with drift. The predictions from the ARIMA model result in 8,123 predicted deaths in weeks 8 to 20, compared to 8,041 generated by the tsglm function.

Figure A5. Predicted deaths based on the tsglm and ARIMA models



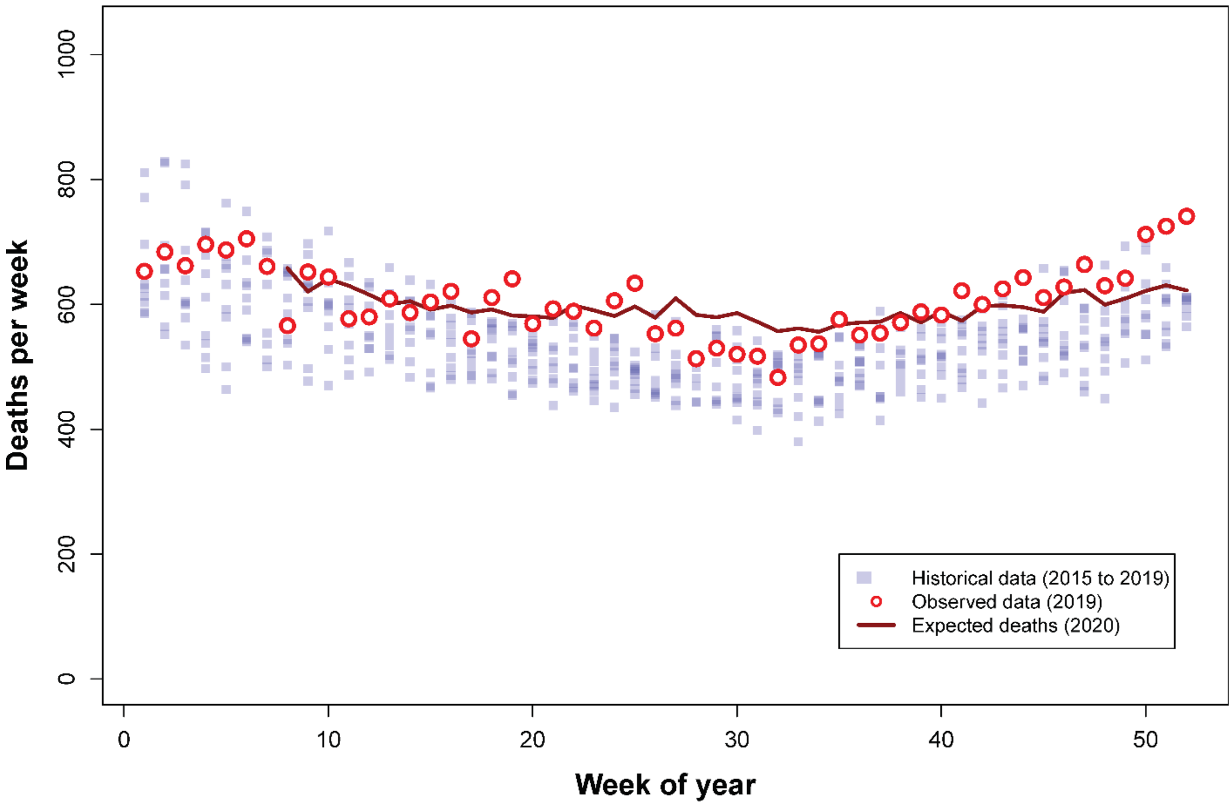
The ARIMA and tsglm therefore produce similar results. The use of a model tailored to count data may make little difference at a national level, but is likely to be more important at a county level.

Figure A6. Decomposition of time series data: 1 January 2010 to 18 February 2020



The forecast number of deaths in 2020 based on the time series model seems high compared to the historical data. However, it follows the 2019 data relatively closely and it should be borne in mind that there is a underlying secular trend for increasing mortality over time (Figure A7).

Figure A7. Comparison of predicted mortality 2020 and observed mortality 2019



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