Health Information and Quality Authority
An tÚdarás Um Fhaisnéis agus Cáilíocht Sláinte

Descriptive analysis of COVID-19 epidemiological indicators and associated contextual factors in European countries

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About the Health Information and Quality Authority

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, Equality, Disability, Integration and Youth, 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.

Foreword

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a highly infectious virus which has caused hundreds of millions of COVID-19 cases since its emergence in 2019, with a considerable level of associated morbidity and mortality. Despite high uptake of the COVID-19 vaccine in Ireland, and the roll-out of booster vaccination to certain populations, SARS-CoV-2 remains a significant public health concern due to its high basic reproduction rate, the limited evidence of effective treatments, the waning of vaccine effectiveness over time, the risk of reinfection in those recovered from COVID-19, and emerging variants of concern.

The Health Information and Quality Authority's (HIQA) COVID-19 Evidence Synthesis Team at the request of the Department of Health, undertook a descriptive analysis of epidemiological indicators in order to describe the burden of COVID-19 as it has occurred across a range of European countries. This report focuses on the time period from the beginning of the COVID-19 pandemic up to the emergence of the Omicron variant in Ireland (that is, from 1 January 2020 up to 30 November 2021).

HIQA would like to thank its COVID-19 Evidence Synthesis Team, the members of the COVID-19 Expert Advisory Group and all who contributed to the preparation of this report.

Dr Máirín Ryan

Deputy CEO & Director of Health Technology Assessment

Health Information and Quality Authority

List of abbreviations used in this report

CIDR	Computerised Infectious Disease Reporting
COVID-19	coronavirus disease 2019
EAG	expert advisory group
ECDC	European Centre for Disease Prevention and Control
EU-27	27 European Union member states
EuroMOMO	European Mortality Monitoring
Eurostat	European Statistical Office
HIQA	Health Information and Quality Authority
HPSC	Health Protection Surveillance Centre
ICU	intensive care unit
OECD	Organisation for Economic Co-operation and Development
OWID	Our World in Data
WHO	World Health Organization
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2

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Organisations that assisted the Authority in providing information, in writing or through meetings, included:

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- National Office of Clinical Audit.

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Not all members of the Expert Advisory Group and Evidence Synthesis Team are involved in the response to each research question. The findings set out in the report represent the interpretation by HIQA of the available evidence and do not necessarily reflect the opinion of all members of the Expert Advisory Group.

Conflicts of interest

None declared.

Key points

- The purpose of this report was to provide a high-level summary of key epidemiological indicators and some of the associated contextual factors relating to the burden of COVID-19 across European countries, over the course of the pandemic, and prior to the emergence of the Omicron variant in Ireland.

- There were five distinct peaks in confirmed COVID-19 cases in Ireland, occurring in April 2020, October 2020, January 2021, August 2021 and November 2021. These peaks varied in magnitude and duration. By the end of November 2021, 570,115 cases of COVID-19 had been confirmed in Ireland. Cumulative case rates for Ireland were in line with the EU-27 average until the end of November 2020, but subsequently grew at a slower rate until the end of October 2021.

- In Ireland, there were notable peaks in both new hospital admissions and the total number of patients in hospital with COVID-19 in April 2020 and January 2021. Other European countries also experienced significant increases in hospitalisations around these times; however, the surges in hospitalisations experienced in Ireland were lower and of a shorter duration than those experienced by many European countries.

- Ireland experienced two peaks in the rate of new ICU admissions of patients with COVID-19 during April 2020 and January 2021, and two notable peaks in the total number of patients in ICU with COVID-19 in April 2020 and February 2021.

- There were 5,514 COVID-19 deaths reported in Ireland up to 30 November 2021, with two peaks which occurred in April 2020 and February 2021. The cumulative rate of recorded COVID-19 deaths per million population in Ireland remained consistently below the EU-27 average throughout the pandemic.

- There were an estimated 2,019 excess deaths in Ireland between 2 March 2020 and 28 November 2021. The excess deaths occurred during a seven-week period from late March to mid-May 2020 and an eight-week period from early January to late February 2021. Throughout the study period, there was substantial variability in the magnitude and duration of peaks in excess mortality across European countries. Between mid- and late-2021, the excess mortality in Ireland was observed to be amongst the lowest in Europe.

- A range of contextual factors were considered that may have influenced the burden of COVID-19, such as demographic indicators, healthcare capacity, rollout and uptake of COVID-19 vaccination and the extent of public health restrictions implemented. There was substantial variability in these factors across European countries.

- The timing, magnitude and duration of peaks in the five epidemiological indicators varied across individual countries. The lack of directly comparable data, and the methodological challenges in determining cause and effect, strongly limit direct comparisons of these epidemiological indicators, and the reasons behind their patterns, across countries.

Executive Summary

Introduction

This report describes five key epidemiological indicators of the burden of COVID-19 from 1 January 2020 up to 30 November 2021:

- confirmed cases of COVID-19
- hospitalisations (new admissions and current patients) with COVID-19
- intensive care unit (ICU) admissions and numbers of patients currently in ICU among patients with COVID-19
- reported COVID-19 deaths
- excess mortality.

This report also describes various contextual factors that may be important in understanding the trajectory of the pandemic across countries:

- population age, population density, household size and hospital and ICU capacity (that is, baseline conditions in place)
- test positivity rate, vaccination coverage, and a measure of the stringency of restrictions (that is, factors relating to interventions taken to mitigate the effects of the pandemic).

Methods

The primary data source used was the Our World in Data COVID-19 data repository, which collates data from a variety of official national and international organisations. Excess mortality data for Ireland were provided by the Health Protection Surveillance Centre (HPSC), while excess mortality data for other countries were taken from the European Mortality Monitoring dataset (EuroMOMO). Data from the European Centre for Disease Prevention and Control (ECDC), Organisation for Economic Co-operation and Development (OECD), and World Health Organization (WHO) were also used.

Results

Epidemiological indicators

There were five distinct peaks in confirmed COVID-19 cases in Ireland, occurring in April 2020, October 2020, January 2021, August 2021 and November 2021. Circulation of a number of new variants with increased transmissibility, compared with wild-type SARS-CoV-2, contributed to surges. The peak in January 2021 was likely attributable to increased socialisation over the December 2020 period, combined with increased circulation of the Alpha variant. The sharp rise in cases between August 2021 and November 2021 was likely attributable to the significantly increased transmissibility of the Delta variant. By the end of November 2021, 570,115 cases of COVID-19 had been confirmed in Ireland. Cumulative case rates for Ireland were in line with the EU-27 average until the end of November 2020, but subsequently grew at a slower rate until the end of October 2021, with COVID-19 case numbers increasing more rapidly thereafter.

In Ireland, there were notable peaks in both new hospital admissions and the total number of patients in hospital with COVID-19 in April 2020 and January 2021. Other European countries also experienced significant increases in hospitalisations around these times; however, the surges in hospitalisations experienced in Ireland were lower and of a shorter duration than those experienced by many European countries. Of note, these data do not distinguish between people admitted to hospital due to COVID-19 from those that were admitted to hospital for other reasons, but who tested positive for SARS-CoV-2.

Ireland experienced two peaks in the rate of new ICU admissions of patients with COVID-19 during April 2020 and January 2021, and two notable peaks in the total number of patients in ICU with COVID-19 in April 2020 and February 2021.

In Ireland, there were two peaks in reported COVID-19 deaths; these occurred in April 2020 and February 2021. However, these peaks in mortality were typically shorter in duration than those which occurred in many other European countries. There were 5,514 COVID-19 deaths reported in Ireland up to 30 November 2021. The cumulative rate of recorded COVID-19 deaths per million population in Ireland remained consistently below the EU-27 average throughout. The criteria for recording deaths as COVID-19 deaths differed across European countries and in some countries changed over time, thus limiting direct comparisons.

Overall, 91% of recorded COVID-19 deaths in Ireland occurred among those aged 65 years or older. Within this population, peaks in COVID-19 deaths occurred during April 2020 and January 2021. Increased mortality in older age groups throughout the pandemic was mirrored across Europe. In people aged 65 years and older, the cumulative rate of reported COVID-19 deaths in Ireland exceeded that of the EU-27 average in 2020. In 2021 this death rate slowed in Ireland, so that for the period from January 2021 to November 2021 the cumulative death rate was slightly lower than that of the EU-27 average.

Excess deaths are calculated by estimating the expected number of all-cause deaths for a particular time period, based on historical trends, and then subtracting these from the actual number of all-cause deaths observed during that time. There were an estimated 2,019 excess deaths in Ireland between 2 March 2020 and 28 November 2021. The excess deaths occurred during a seven-week period from late March to mid-

May 2020 and an eight-week period from early January to late February 2021. No consecutive weeks of excess deaths occurred outside of these periods. There was substantial variability in the magnitude and duration of peaks in excess mortality across European countries throughout the study period. Between mid- and late-2021, the excess mortality in Ireland was observed to be amongst the lowest in Europe.

The majority (82%) of excess deaths in Ireland occurred among those aged 65 years or older (n=1,665). As for the total population, excess deaths in the population aged 65 years and older occurred during two distinct peaks, with similar excess mortality across the two waves.

Across all countries, large variation was observed in the timing, magnitude and duration of COVID-19 peaks in terms of cases, hospital admissions and mortality, particularly between October 2020 and June 2021. This limits the comparability of countries.

Contextual factors

Given the association between age and COVID-19 severity, countries with a younger population could be anticipated to have a lower burden of severe disease. Ireland has a smaller proportion of older adults relative to most countries within Europe, with 13.9% of the population aged 65 years or older (EU-27 average: 18.7%) and 8.7% of the population aged 70 years or older (EU-27 average: 12.4%), based on data collected in 2015.

Lower population densities may lead to reduced SARS-CoV-2 transmission as it may be less challenging to follow advice regarding social distancing. However, population density can vary significantly within countries, for example, between urban and rural areas, and does not reflect the different patterns of population dispersion within countries. Ireland has a low population density relative to the majority of European countries.

Countries with larger households could be anticipated to have higher case numbers. The household composition is also important, particularly in the context of multi-generational households, which may lead to an increased transmission risk for older adults. Relative to most other European countries, Ireland has a high proportion of people living in households of three or more persons (44.8%) and a low proportion of people living in one-person households (25.7%).

Hospital capacity is important when comparing hospital and ICU admission rates across countries, as capacity may influence admission and discharge policies. Hospital and ICU bed capacity in Ireland is low compared with other European countries.

- Data from 2019 showed that hospital bed capacity in Ireland was 3.0 beds per 1,000 population; across Europe it ranged from 2.2 to 8.8 beds per 1,000 population.
- A 2020 publication by the OECD reported critical care beds capacity across Ireland and 13 other OECD countries in Europe, ranging from 5.1 beds per 100,000 population in Ireland to 33.9 beds per 100,000 population in Germany.
- Many countries increased their hospital and ICU bed capacity during the pandemic. For example, in Ireland, ICU capacity increased to a maximum of 7.0 beds per 100,000 population in January 2021; these changes are not reflected in the OECD data.

The test positivity rate is important when interpreting variation in case numbers over time and between countries. A high test positivity rate likely reflects under-ascertainment of cases. In Ireland, test positivity rates peaked at 23% in April 2020 and 26% in January 2021, coinciding with the timing of waves of COVID-19 cases. Substantial variation in test positivity rates was observed between and within countries over time.

Vaccination against COVID-19 was introduced to reduce morbidity and mortality associated with COVID-19, with the greatest potential for benefit in those at highest risk of severe disease. Vaccine rollout began in early 2021, but vaccine uptake and rollout approaches differed by country, which may have contributed to significant differences in observed morbidity and mortality. While vaccination coverage in Ireland was below the European average for the total population until the end of June 2021, almost all people aged 70 years and older had been fully vaccinated at that point; this reflects Ireland's policy of prioritising vaccination of those at the highest risk of severe disease or exposure first.

The Stringency Index, a composite measure of nine restrictive measures implemented, tracks how strict a country's pandemic response was at a given time. The extent to which restrictive measures were adopted varied over time throughout Europe. Ireland's Stringency Index values were among the highest in Europe during April/May 2020, August/September 2020, November 2020, and January to May 2021. Ireland's stringency index reduced in May 2021, coincident with achieving high vaccination coverage in those aged over 70 years.

Conclusion

Between January 2020 and November 2021, COVID-19 resulted in a substantial burden of disease across European countries. This descriptive analysis demonstrated that the timing, magnitude and duration of peaks in the included epidemiological indicators of the burden of COVID-19 varied across individual countries in Europe. Differences in how outcomes were measured and reported and differences in demography and in the suite of public health measures implemented were noted. The lack of directly comparable data, and the methodological challenges in determining cause and effect, strongly limit direct comparisons of these epidemiological indicators, and the reasons behind their patterns, across countries.

1 Introduction

At the request of the Department of Health, the Health Information and Quality Authority's (HIQA) COVID-19 Evidence Synthesis Team undertook a descriptive analysis of epidemiological indicators in order to describe the burden of COVID-19 as it has occurred across a range of European countries. This report focuses on the time period from the beginning of the COVID-19 pandemic up to the emergence of the Omicron variant in Ireland (that is, from 1 January 2020 up to 30 November 2021).[1, 2] The countries included in this report comprise the EU-27 countries together with Norway, Switzerland, Ukraine and the United Kingdom. Several sources of data were used, all but one of which were publicly available.

The report describes five epidemiological indicators considered key indicators specifically of the burden of COVID-19. The burden associated with other causes of morbidity and mortality were not considered in the descriptive analysis. The epidemiological indicators examined, described further in Section 2.3, were:

- confirmed cases of COVID-19
- hospital admissions with COVID-19
- intensive care unit (ICU) admissions with COVID-19
- reported COVID-19 deaths
- excess mortality.

This report also describes various contextual factors that may have an individual and combined impact on the epidemiological indicators, and, as such, are important in understanding the course and burden of the COVID-19 pandemic across countries. These contextual factors are used to illustrate the variation across countries in characteristics that may have contributed to a greater or lesser burden of disease. These contextual factors, described further in Section 2.4, included the following baseline factors:

- population age
- population density
- household size
- hospital and ICU capacity.

The contextual factors also included the following indicators, which are described in detail in Section 3.2, related to public health measures introduced in response to the pandemic:

- test positivity rate
- vaccination coverage

- strictness of public health restrictions.

2 Methods

2.1 Overview

This report presents data collated from multiple sources to describe the burden of COVID-19 across a range of European countries from 1 January 2020 up to 30 November 2021. This period was selected to coincide with the detection of the first reported case of COVID-19 in Europe (24 January 2020),[1] and a cut-off point prior to the emergence of the Omicron variant in Ireland (the burden of which is still evolving).[2] Where available, data for the EU-27 countries and Norway, Switzerland, Ukraine, and the UK are presented. A full description of the methods employed is provided in the accompanying protocol.

2.2 Primary data sources

The Our World in Data (OWID) database was the primary data source used in this descriptive analysis.[3] OWID comprises an open-source repository that collates data on a range of topics of global relevance (for example, poverty, disease and climate change). Since 22 January 2020, OWID has published an online repository relating to the COVID-19 pandemic.[4] The dedicated COVID-19 data repository is updated daily and collates data from the COVID-19 dashboard operated by the Center for Systems Science and Engineering at Johns Hopkins University (Baltimore, US),[5] and a variety of official national and international organisations, including the World Health Organization (WHO), European Centre for Disease Prevention and Control (ECDC), and the European Statistical Office (Eurostat). All data collected and displayed by OWID are made freely available through a GitHub repository.

As the OWID dataset for Ireland did not fully capture the relevant data for the time period between 1 March and 30 April 2020, data for hospital admissions, ICU admissions and reported COVID-19 deaths were extracted from the Health Protection Surveillance Centre's (HPSC's) Computerised Infectious Disease Reporting (CIDR) database and incorporated this time period. For consistency, confirmed cases of COVID-19 reported by CIDR were also extracted for this period. A number of caveats are noted with respect to the CIDR data:

- Confirmed cases are based on the date of notification in the CIDR database. Due to validation steps, the date of notification may be a few days after the date of diagnosis. Ninety percent of notifications are within two days of the date of diagnosis.
- Hospitalisation figures in the CIDR database are based on date of hospitalisation unless that precedes date of notification, in which case it is date

of notification.

- Date of ICU admission was unavailable. For this analysis the date of hospital admission was used unless that preceded date of notification, in which case date of notification was used.
- Date of death in the CIDR database refers to the reported date of death rather than date of COVID-19 notification.

Data on Irish-specific excess mortality were provided by the HPSC.[6] Standardised excess mortality estimates across Europe were obtained from the European Mortality Monitoring (EuroMOMO) project.[7] EuroMOMO is a European mortality monitoring collaboration that aims to detect and measure excess mortality related to seasonal influenza, pandemics and other public health threats. The database is populated with official national mortality statistics which are provided weekly from the 27 European countries (including Ireland) within the collaborative network. It is supported by the ECDC and the WHO and hosted by Statens Serum Institut in Denmark.

The OWID database was the main data source used for presentation of contextual factors. When data on specific contextual factors of interest were not available from OWID, additional sources were used. These included the National Office of Clinical Audit,[8] Eurostat,[9] the WHO,[10] and the Organisation for Economic Co-operation and Development (OECD).[11] Website links to the publicly accessible databases used in the analysis are presented in Table 1.

Table 1. Key publicly accessible data sources

Database	URL	Date accessed
Epidemiological indicators		
EuroMOMO	https://www.euromomo.eu/	26 January 2022
OWID	https://ourworldindata.org/	26 January 2022
Contextual factors		
ECDC	https://www.ecdc.europa.eu/en/cases-2019-ncov-eueea	26 January 2022
Eurostat	https://ec.europa.eu/eurostat/web/main/data/database	31 January 2022
OECD	https://stats.oecd.org/	28 January 2022
WHO	https://covid19.who.int/	17 February 2022

Key: ECDC – European Centre for Disease Prevention and Control; EuroMOMO – European Mortality Monitoring; OECD – Organisation for Economic Co-operation and Development; OWID – Our World in Data; URL – Uniform Resource Locator; WHO – World Health Organization.

2.3 Epidemiological indicators

International data on the number of confirmed COVID-19 cases, hospitalisations with COVID-19, ICU admissions with COVID-19 and reported COVID-19 deaths were collated from the OWID COVID-19 repository.

Confirmed cases of COVID-19 and reported COVID-19 deaths

The ECDC defines a confirmed case of COVID-19 as any person meeting the laboratory criteria for detection of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) nucleic acid or antigen in a clinical specimen.(12) Up to 30 November 2020, data published by the ECDC were the main source of data on COVID-19 cases and deaths underlying the OWID COVID-19 repository.(13, 14) However, the ECDC data were superseded by the COVID-19 data repository, maintained by the Johns Hopkins University, following a switch by the ECDC from a daily to a weekly reporting schedule.(14) A full list of the data sources used in the Johns Hopkins University repository is available from GitHub.

It is important to note that differences exist between countries with regards to the reporting of COVID-19 cases and deaths. While the majority of European countries include only laboratory-confirmed cases among death totals, some include both laboratory-confirmed and probable cases. Similarly, while the majority include deaths among COVID-19 patients in both hospital and community settings, some include deaths that occur in the hospital setting only or apply a time limit from diagnosis for a death to have been considered attributable to COVID-19.(15)

Hospitalisations with COVID-19 and ICU admissions with COVID-19

Hospitalisation and ICU data for European countries in OWID's COVID-19 repository are mainly collated from those published by the ECDC,(16) but some of these data are based on official national sources. The full list of country sources is available from GitHub. Reporting differences may exist between countries as well as between points in time within a country. For example, some countries include hospitalisation data for those that test positive for SARS-CoV-2 on admission (that is, admissions with COVID-19) and others include only admissions due to COVID-19.

Excess mortality

Aggregate European-level data, comprising absolute estimates of excess mortality, and country-level data in the form of 'z-scores' (see below) are published by EuroMOMO. In order to examine absolute estimates of excess mortality for Ireland, the HPSC performed this analysis, using the methods set out by EuroMOMO, and provided these results to HIQA.

Ireland-specific data

Data on excess mortality in Ireland were provided by the HPSC. Excess mortality, here, is the difference between the registered number of deaths in Ireland and the expected number of deaths, as estimated using the standardised European EuroMOMO algorithm.[17] This algorithm derives the expected number of deaths using a time-series Poisson regression model, adjusted for a linear or nonlinear trend and for seasonal variation across a maximum of a five-year historical period.[17] For the HPSC analysis, only deaths in Ireland that occurred between 1 January 2020 and 28 November 2021, and which were formally registered with General Register Office, were included. Deaths in Ireland can be registered up to three months following death, as per the Civil Registration Act, 2004, with evidence to suggest that only approximately 90% of deaths are registered within this time.[18] A delay adjustment is built into the EuroMOMO model, correcting registered deaths data for reporting delays.

Country-level data for all countries in Europe

Excess mortality data for the remaining countries in this report were obtained from the publicly available EuroMOMO dataset.[7] The EuroMOMO monitoring system is based on national mortality data registered in the 27 countries participating in the EuroMOMO network. While the dataset covers the full national population mortality for most countries, the percentage of total mortality covered is reduced for France (77%), Italy (14%), Spain (93%) and Ukraine (95%).[19] The methods used to calculate the expected number of deaths are available on the EuroMOMO website.

The data obtained from EuroMOMO for this report comprised country-level z-scores, as reported by EuroMOMO relative to the baseline (that is, the expected number of deaths) for that country. The z-score is the excess mortality expressed as the number of standard deviations from the expected number of deaths; if the number of deaths does not differ from expected, then the z-score is zero. A positive z-score indicates an excess of deaths, while a negative z-score indicates mortality below that expected. A z-score of up to +/- two standard deviations from the expected number of deaths is considered to be within normal variability (that is, such variability is not considered an unusual level of mortality).

Typically, z-scores are used to assess within-country variation (for example, the extent to which a particular winter demonstrated excess mortality relative to previous winters). Cross-country comparisons of z-scores are problematic in part due to the difficulties in comparing excess mortality values for countries of different population sizes. Countries with smaller populations will have fewer deaths than countries with larger populations and thereby demonstrate greater variability in weekly death counts relative to the normal expected value; this can lead to an understatement of their relative excess mortality, or, conversely, an apparent exaggeration of excess mortality for larger countries in comparison with smaller countries.[20] To partly mitigate this limitation, five countries (Cyprus, Estonia, Luxembourg, Malta and Northern Ireland) were excluded from these analyses due to their very small population size. Furthermore, direct comparisons were not made between Ireland and any one country in this report, and numerical comparisons of z-scores were not performed. The present analysis focuses on visually depicting Ireland's temporal trend alongside those European countries included within this analysis in order to illustrate where periods of mortality were above or below expected values, and to allow for some comparison of patterns.

2.4 Contextual factors

The report describes seven contextual factors that have an individual and collective impact on the COVID-19 epidemiological indicators. These contextual factors comprised the following four baseline factors:

- population age
- population density
- household size
- hospital and ICU capacity.

Population age (that is, median age and the proportion of people aged 65 or older and 70 years or older), population density (that is, the number of people per square kilometre) and hospital capacity (that is, the number of acute hospital beds per 1,000 population) were accessed from the OWID COVID-19 data repository. These data were based on the most recent years available for that country (range: 2015 to 2020). Data on ICU capacity were accessed from the OECD, which were based on the most recent years available for that country (range: 2014 to 2020). Data on household size, based on the most recent year available (range: 2018 to 2020), were accessed from Eurostat.

The contextual factors also considered three public health measures introduced in response to the pandemic:

- test positivity rate
- COVID-19 vaccination coverage
- extent of public health restrictions.

The test positivity rate represents the proportion of COVID-19 test results officially recorded within national data that were reported as positive for SARS-CoV-2 on a given day. When the test positivity rate is high, it is likely that there is under-ascertainment of cases (that is, a larger proportion of cases are going undetected); if positivity rates are increasing, this suggests that the virus is spreading faster than the growth in confirmed cases. A high test positivity rate can indicate where a system is close to capacity and that testing has been prioritised for confirmation of cases (for example, where testing is mainly used for symptomatic cases). Conversely, when the positivity rate is low, it is likely that a higher proportion of infected individuals are being detected and that there is sufficient testing capacity for contact tracing and testing of asymptomatic individuals.

Each of these contextual factors were accessed from the OWID COVID-19 data repository. COVID-19 vaccination coverage is reported here as completion of the primary vaccine course. This is defined by OWID as the total number of people who received all doses prescribed by the initial vaccination protocol. Coverage is also reported with respect to those who received a booster or additional dose, that is, the percentage of the population who were administered doses beyond the number prescribed by the initial vaccination protocol.[21] As vaccine eligibility varied between countries and over time, coverage is reported as a percentage of the total population. Vaccination coverage is presented for the whole population as well as for those aged 70-79 years and those aged over 80 years. These data are from official national sources, the full list of which can be found on the GitHub repository.

The Stringency Index, developed by the Oxford Covid-19 Government Response Tracker project, is used to track how strict a country's pandemic response was at a given time.[22, 23] The index is a composite measure of nine response metrics, namely: school closures; workplace closures; cancellation of public events; restrictions on public gatherings; closures of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls. The index is expressed from less to more strict on a scale of 0-100.

2.5 Data analysis and presentation

The data and graphical analyses were undertaken in Microsoft Excel 2013. Country-level data for COVID-19 cases, hospitalisations, ICU admissions, and deaths are presented per million population. Fourteen-day rolling daily averages (that is, the daily average over the previous 14 days) were calculated for numbers of cases, patients in hospital and ICU, and deaths. Averages, weighted by country population, for 27 EU member state countries (EU-27), were calculated for cumulative epidemiological indicators and contextual factors (other than for the stringency index and test positivity rate). Complete data were not available for all countries for all outcomes; the countries included in analyses are named for each outcome.

Data on COVID-19 cases and deaths published by OWID are collected by date reported (as opposed to the date of the test or death). Therefore, due to the long reporting chain that exists between a new case or death and its inclusion in national statistics, the number of new COVID-19 cases or deaths on a given day does not necessarily represent the actual number that occurred on that date. These reporting lags can result in negative values (that is, retrospective corrections) in the dataset. These negative values were excluded from graphics presenting incidence over time, but were included in graphics presenting cumulative figures over time. Some daily or weekly figures may represent over-estimates of actual cases or deaths on that date, however, the magnitude of the effect is likely to be small and is corrected for in the estimates of cumulative cases.

The data for the epidemiological indicators were verified for consistency by cross-referencing with data available from the ECDC.[24] The transcription of all data, coding, and graphical depiction, were checked by a second analyst.

Ratios of the indicators (for example, the case hospital rate or hospitalisation fatality rate) were not calculated as this was not considered appropriate given the limitations of the available data, for example, time lags between the epidemiological indicators and differences in how the data were calculated and reported.

3 Results

Timing of COVID-19 waves in Ireland and associated SARS-CoV-2 variants of concern

The COVID-19 pandemic has been characterised by a series of waves, that is, periods where there were surges in new cases followed by periods where cases declined. The number and timing of these COVID-19 waves varied by country. The first case in Ireland was detected on 29 February 2020.[25, 26] During the period from 1 January 2020 to 30 November 2021, Ireland experienced four distinct waves:

- March 2020 to August 2020
- August 2020 to November 2020
- November 2020 to June 2021
- June 2021 to November 2021.[27]

The initial wild-type SARS-CoV-2 strain of the virus was first detected within Europe in France in January 2020.[1] Since then, new variants have been detected through strain surveillance with the dominant variant in circulation changing over time. As of 9 March 2022, five variants of concern have been identified in Ireland:

- B.1.1.7 (Alpha)
- B.1.351 (Beta)
- P.1 (Gamma)
- B.1.617.2 (Delta)
- B.1.1.529 (Omicron).[2]

The first case of the Alpha variant was detected in week 51 (14-20 December) 2020; it became the dominant strain for the period from January 2021 to June 2021.[2] Retrospective testing has since revealed that cases of the Alpha strain occurred as early as September 2020.[2] The first case of the Delta variant was detected in week 13 (29 March to 4 April) 2021, with Delta becoming the dominant strain in circulation for the period from June 2021 to November 2021.[2] First detection of the Omicron variant in Ireland was announced on 1 December 2021,[28] with retrospective testing confirming specimen dates for Omicron cases as early as 25 November 2021.[2] As noted, a data cut-point of 30 November 2021 was used to avoid the inclusion of the Omicron wave, which is still evolving.

SARS-CoV-2 variants of concern across Europe

The variants of SARS-CoV-2 in circulation in Europe changed throughout the COVID-19 pandemic. Table 2 summarises the timing of the reporting of the first case of each variant of concern detected in Ireland and Europe. The table also summarises the transmissibility, immune escape and severity associated with each variant, compared with that of the previously prevailing strain of SARS-CoV-2. As evident from Table 2, each of the variants of concern were reported in at least one other European country prior to being first identified in Ireland.

Table 2: Summary of SARS-CoV-2 variants of concern

Variants of concern	Timing of first reported case in Ireland	Timing of first reported case in Europe	Transmissibility, immune escape and severity
SARS-CoV-2 (Initial virus)	Week 9 (24 February to 1 March) 2020	24 January 2020 (France)	Not applicable
B.1.1.7 (Alpha)	Week 51 (13 to 19 December) 2020 Dominant strain (January – June 2021)	Week 40 (28 September to 4 October) 2020 Finland, Italy, Slovakia, Spain	Evidence for increased transmissibility
B.1.351 (Beta)	Week 52 (20 to 26 December) 2020	Week 51 (14 to 20 December) 2020 Belgium, Finland	Evidence for increased transmissibility, immune escape and increased severity
P.1 (Gamma)	Week 5 (31 January to 6 February) 2021	Week 1 (4 to 10 January) 2021 Italy	Evidence for increased transmissibility, immune escape and increased severity
B.1.617.2 (Delta)	Week 13 (29 March to 3 April) 2021 Dominant strain (July – November 2021)	Week 9 2021 (1 to 7 March) 2021 Finland	Evidence for increased transmissibility, immune escape and increased severity
B.1.1.529 (Omicron)	Week 47 (22 to 28 November) 2021 Dominant strain (December 2021 - present)	Week 42 (18 to 24 October) 2021 Belgium, Italy	Evidence for increased transmissibility and immune escape

Sources: Health Protection Surveillance Centre,[2, 25, 26] Government of Ireland,[28] Finnish Institute for Health and Welfare,[29] and the European Centre for Disease Prevention and Control.[30]

3.1 Epidemiological indicators

3.1.1 Confirmed cases of COVID-19

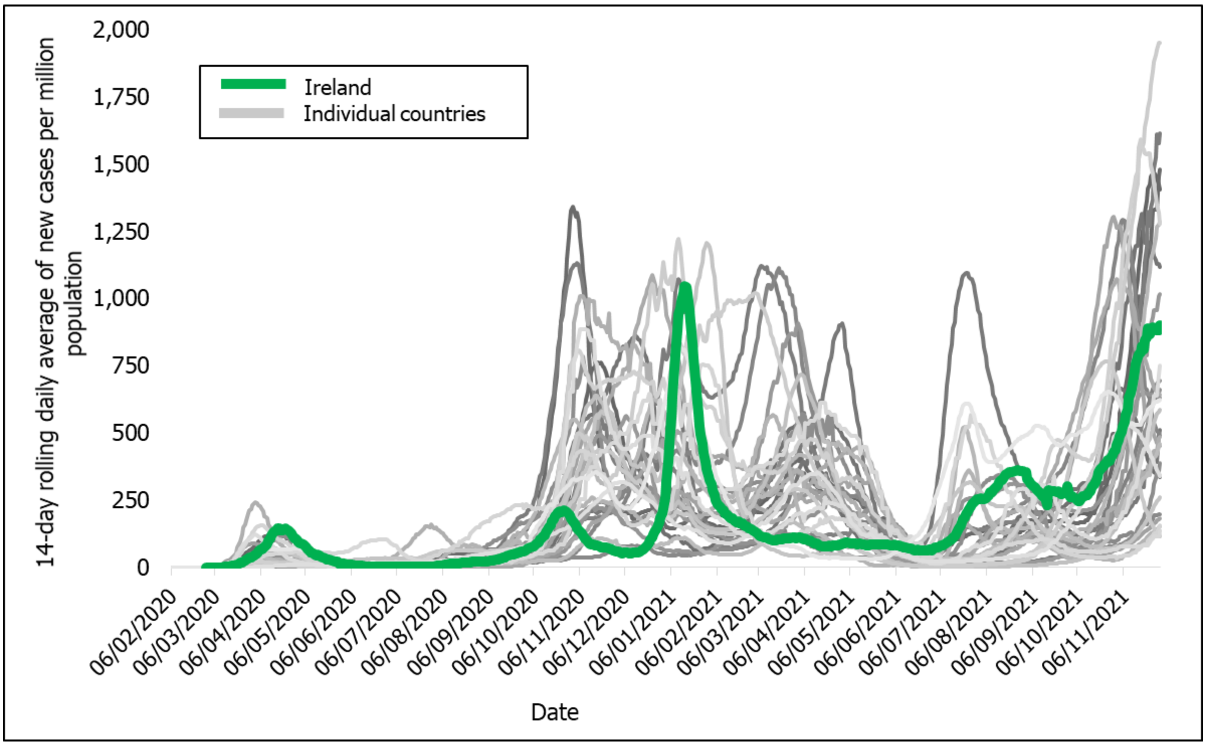
Figure 1 presents the 14-day rolling daily average of new cases of COVID-19 per million population across Europe during the COVID-19 pandemic. Cross-country comparisons are limited by variation in country-specific factors including testing policy, definitions and reporting of confirmed COVID-19 cases, the specific strains of SARS-CoV-2 in circulation and the implementation of public health restrictions. As noted, the timing and impact of COVID-19 waves varied across countries, leading to marked differences for the period between October 2020 and May 2021 when the rates of new COVID-19 cases peaked sharply and then fell again in many European countries.

From Figure 1 it is evident that five distinct peaks in confirmed COVID-19 cases in Ireland occurred:

- April 2020 (145 cases per million population)
- October 2020 (210 cases per million population)
- January 2021 (1,047 cases per million population)
- August 2021 (362 cases per million population)
- November 2021 (894 cases per million population; cases continued to rise throughout November, and had not peaked when the final data were included at the end of November 2021).

The initial peak experienced in Ireland in April 2020 occurred later than in the rest of Europe. From July 2020, confirmed COVID-19 cases in Ireland gradually increased until late–October 2020. There was a steady decrease in confirmed COVID-19 cases from the end of October 2020 until the start of December 2020; this coincided with a period when national Level 5 COVID restrictions were in place.[31] There was a sharp increase in confirmed COVID-19 cases towards the end of December 2020, which peaked in January 2021. This peak, likely attributable to increased socialisation over the December 2020 period, combined with increased circulation of the Alpha variant., was one of the sharpest peaks experienced in Europe during January 2021. From February 2021 until the end of July 2021 the rate of COVID-19 cases was stable. Between August 2021 and November 2021 there was a sharp rise in COVID-19 cases which was likely attributable to the significantly increased transmissibility of Delta, which became the dominant strain in Ireland during this time.

Figure 1. Fourteen-day rolling daily average of new cases of COVID-19 per million population



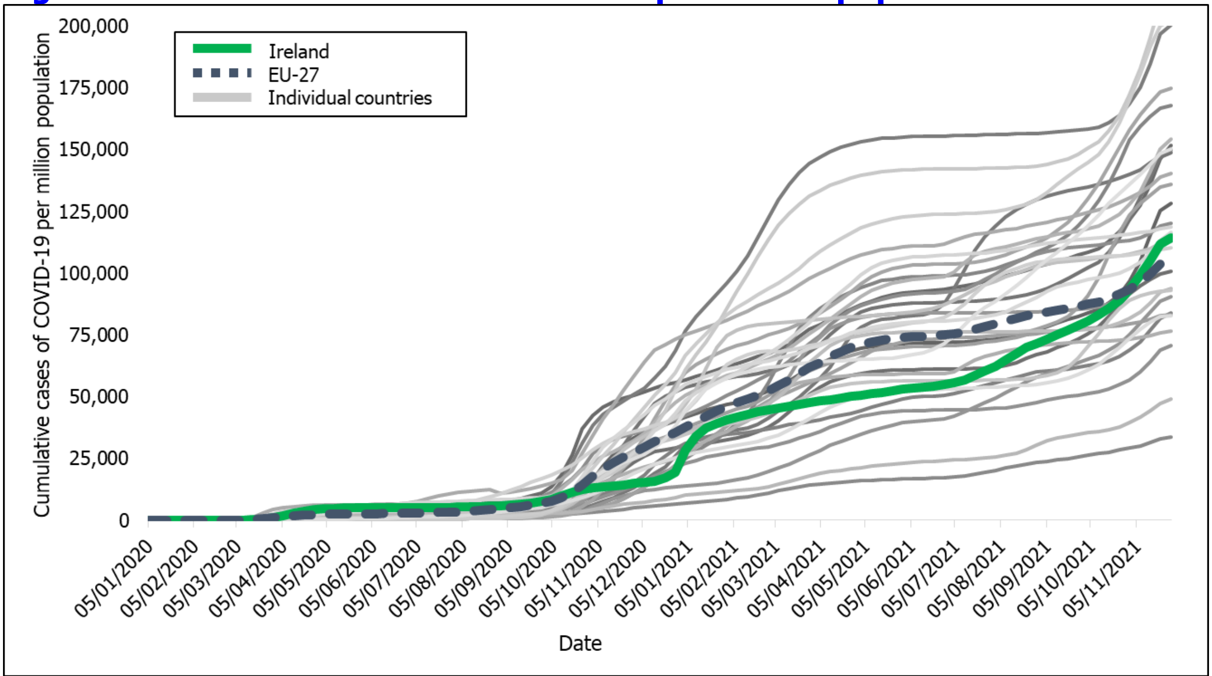
Source: Our World in Data (OWID) COVID-19 data repository[(3)]

Note(s):

1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, UK.
2. As 14 days of data are required to calculate the 14-day rolling daily average, lines in this figure begin 14 days after the first reported cases.
3. Occasionally, reporting lags result in negative values (retrospective corrections) in the OWID repository (see Section 2.5). These adjustments accounted for 0.5% of all COVID-19 cases reported in Ireland. The maximum adjustment across Europe was 1.6% for Spain.
4. Confirmed cases of COVID-19 occurring in Ireland from 1 March to 30 April 2020 were extracted from the HPSC's Computerised Infectious Disease Reporting (CIDR) database. Confirmed cases are based on the date of notification in the CIDR database. Due to validation steps, the date of notification may be a few days after the date of diagnosis. Ninety percent of notifications are within two days of the date of diagnosis.

Figure 2 presents the cumulative number of cases of COVID-19 per million population across Europe up to 30 November 2021. During this period there was substantial variation across countries. A total of 570,115 confirmed COVID-19 cases (114,414 per million population) were reported in Ireland by the end of November 2021, with cases ranging from 33,620 to 214,744 per million population across all included European countries. The cumulative figure for Ireland was in line with the EU-27 average up until the end of November 2020, but subsequently grew at a slower rate until the end of October 2021, with COVID-19 case numbers increasing more rapidly thereafter.

Figure 2. Cumulative cases of COVID-19 per million population



Source: Our World in Data (OWID) COVID-19 data repository(3)

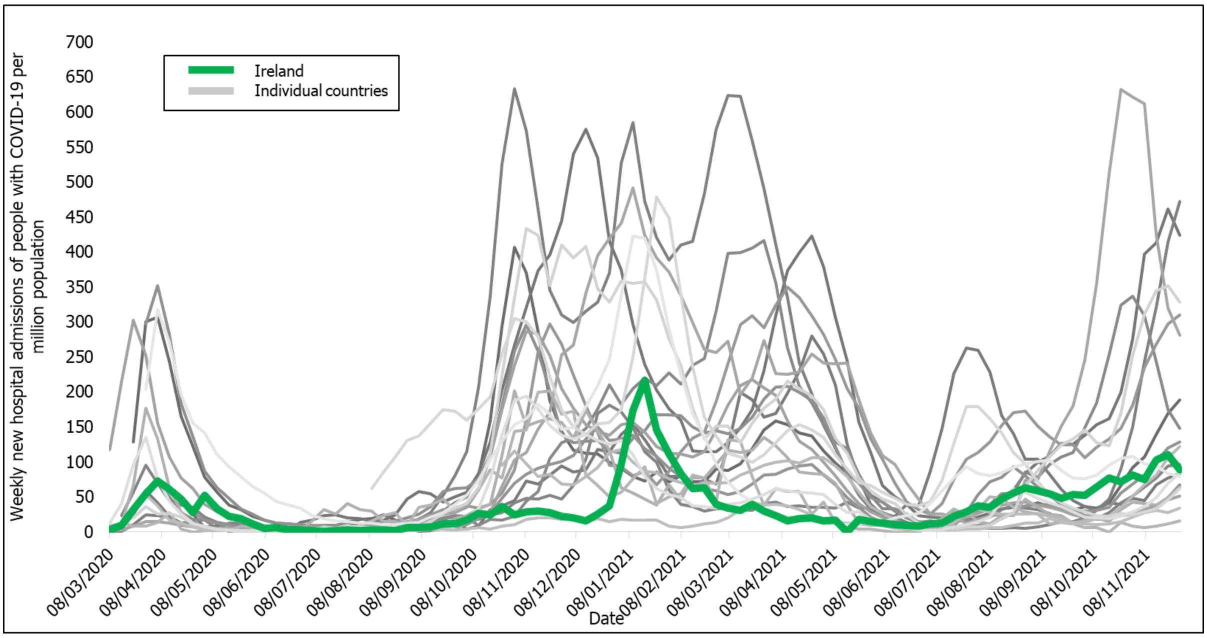
Note(s):

1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, UK.
2. Confirmed cases of COVID-19 occurring in Ireland from 1 March to 30 April 2020 were extracted from the HPSC's Computerised Infectious Disease Reporting (CIDR) database. Confirmed cases are based on the date of notification in the CIDR database. Due to validation steps, the date of notification may be a few days after the date of diagnosis. Ninety percent of notifications are within two days of the date of diagnosis.

3.1.2 COVID-19 hospital admissions

Figure 3 presents the weekly number of new hospital admissions of people with COVID-19 per million population from March 2020 to November 2021. These data represent all hospital admissions where the patient was recorded as having COVID-19 and do not distinguish between people admitted to hospital due to COVID-19 from those that tested positive for SARS-CoV-2 on or subsequent to their admission (for example, due to routine screening). Regardless of whether or not the reason for hospital admission was related to COVID-19, the detection of SARS-CoV-2 in a hospitalised patient has implications for hospital systems due to the need to isolate patients with COVID-19 and the potential complications of patient care and treatment associated with a COVID-19 diagnosis.

Figure 3. Weekly new hospital admissions of people with COVID-19 per million population



Source: Our World in Data (OWID) COVID-19 data repository[(3)]
Note(s):

1. Countries represented in this figure: Belgium, Croatia, Cyprus, Czechia, Denmark, Estonia, France, Germany, Greece, Ireland, Italy, Latvia, Luxembourg, Malta, Netherlands, Norway, Slovenia, Spain, Switzerland, and the UK.
2. Data for hospital admissions occurring in Ireland from 1 March to 30 April 2020 were extracted from the HPSC's Computerised Infectious Disease Reporting (CIDR) database. Hospitalisation figures in the CIDR database are based on date of hospitalisation unless that precedes date of notification, in which case it is date of notification.
3. Gaps in individual country lines indicate missing data at that time point.
4. This figure presents data reported on the seventh day of each week. Therefore, the slope of the curve does not reflect the daily change in new hospitalisations.

As demonstrated in Figure 3, substantial variation in the rates of new hospital admissions of people with COVID-19 was observed during the COVID-19 pandemic both within Ireland and between countries. During the first wave in Ireland, the majority of COVID-19 cases were in older people.[32] As the severity of COVID-19 is strongly associated with age, rates of hospitalisation may have been partly explained by the distribution of disease within the population. During the second wave, a higher proportion of cases were seen in younger cohorts who had a lower likelihood of requiring hospital admission. Similar patterns may have been observed across other countries, but such trends would be subject to substantial heterogeneity.

In Ireland, notable peaks in new weekly hospitalisations were experienced in:

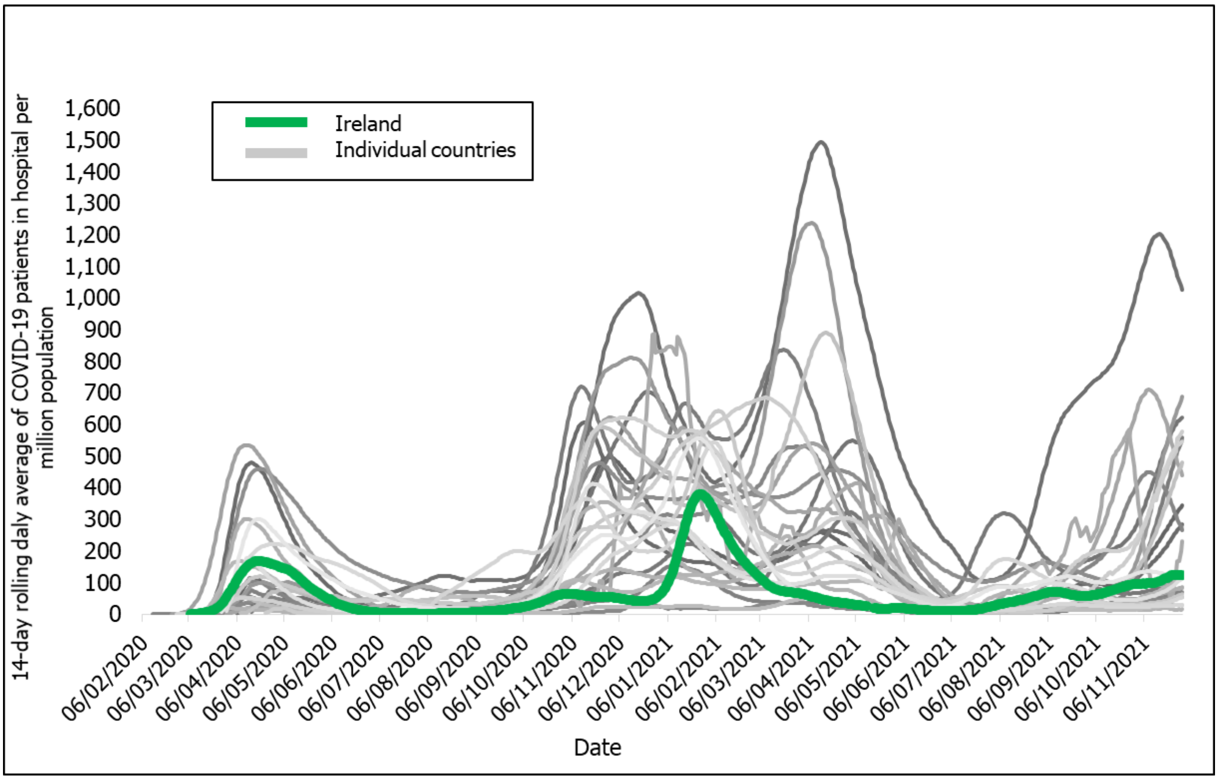
- April 2020
- January 2021.

Other countries experienced significant increases in hospitalisations around these times; however, the surges in hospitalisations experienced in Ireland were lower and of shorter duration than those experienced by other European countries. The variation across countries may in part have been due to differences in admission policies arising from differences in hospital capacity (presented in Section 3.2.4) as well as differences in their demographic characteristics such as the proportion of the population aged 65 years or older (presented in Section 3.2.1) or vaccination coverage over time (presented in Section 3.2.6).

Figure 4 illustrates the 14-day rolling daily average of the total number of patients in hospital with COVID-19 per million population on a given day. The total number reflects both the number of new hospital admissions and the length of stay of those already admitted. Across countries, there was substantial variation in the 14-day rolling daily average throughout the COVID-19 pandemic. This was likely influenced by several factors, including the severity of COVID-19 cases and hospital policies regarding admission and discharge. For example, admissions may have been restricted or discharges accelerated (that is, shorter length of stay) in countries where capacity was limited, especially during times of higher case numbers (see Section 3.2.4 for an overview of country-specific hospital capacity). As per the number of new hospitalisations (Figure 3), Ireland experienced two notable peaks in the 14-day rolling daily average of the total number of patients in hospital with COVID-19:

- May 2020
- January 2021.

Figure 4. Fourteen-day rolling daily average of COVID-19 patients in hospital per million population



Source: Our World in Data (OWID) COVID-19 data repository(3)

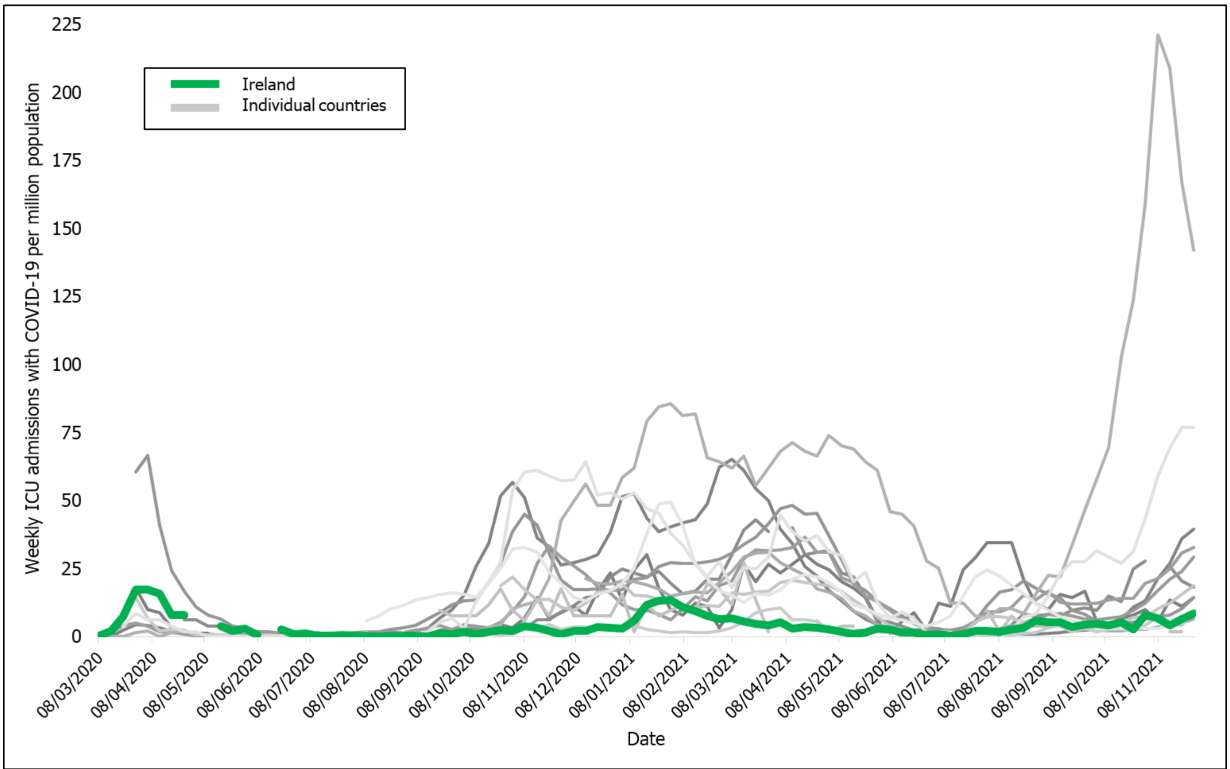
Note(s):

1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK.
2. Gaps in individual country lines indicate missing data at that time point.

3.1.3 ICU admissions with COVID-19

Figure 5 presents the weekly number of new ICU admissions of people with COVID-19 per million population from March 2020 to November 2021. As with the hospitalisation data, these represent all ICU admissions where the patient was recorded as having COVID-19, and do not distinguish between people admitted to the ICU due to COVID-19 from those that tested positive for SARS-CoV-2 prior to or subsequent to their admission to ICU (for example, due to routine screening).

Figure 5. Weekly new ICU admissions with COVID-19 per million population



Source: Our World in Data (OWID) COVID-19 data repository[3]
Note(s):
1. Countries represented in this figure: Cyprus, Czechia, Estonia, France, Germany, Greece, Ireland, Italy, Latvia, Malta, Netherlands, Norway, Slovenia, and Spain.
2. Data for ICU admissions occurring in Ireland from 1 March to 30 April 2020 were based on an extract from the HPSC's Computerised Infectious Disease Reporting (CIDR) database. Date of ICU admission was unavailable. For this analysis the date of hospital admission was used unless that preceded the date of notification, in which case date of notification was used.
3. Gaps in individual country lines indicate missing data at that time point.

Across all countries, large variation was observed over time in both the magnitude and duration of peaks of new weekly admissions to the ICU of patients with COVID-19. This was particularly evident during the period from October 2020 to May 2021 in which many countries experienced sustained peaks in the rate of new ICU admissions. Ireland experienced two peaks in the rate of new weekly ICU admissions:

- April 2020
- January 2021.

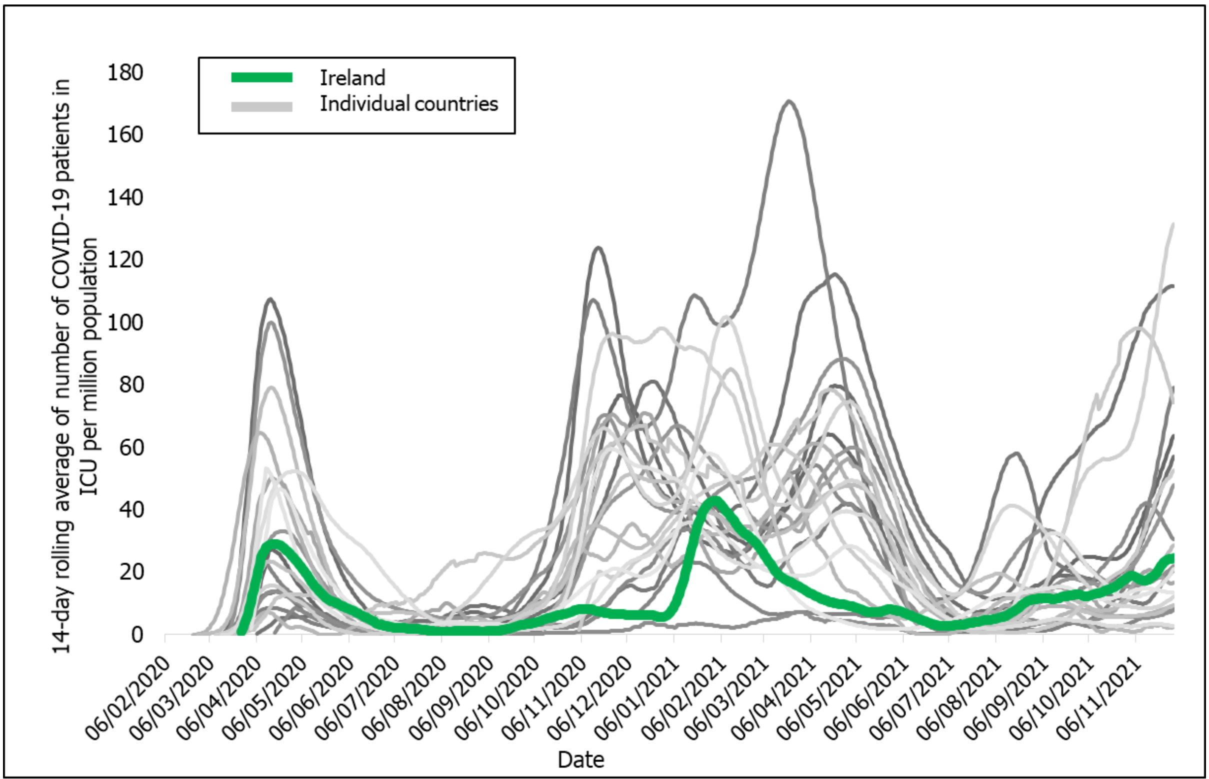
There is an intrinsic link between hospital and ICU admissions, with ICU admissions representing a subset of hospital admissions. The pattern observed over time for ICU admissions was similar to that observed for hospital admissions which, as noted, in Section 3.1.2, peaked in April 2020 and January 2021. The risk of ICU admission generally increases with age given the strong association between age and the severity of COVID-19. In the first wave the majority of COVID-19 cases were in older people, which may explain the higher hospitalisation and ICU admission rates observed. As the COVID-19 pandemic progressed, the majority of cases began to occur in younger cohorts who were at lower risk of severe disease with reduced ICU admission rates occurring. Similar patterns may have been observed across other countries, but such trends would likely be subject to substantial variability.

Figure 6 presents the 14-day rolling daily average of the total number of patients with COVID-19 in ICU per million population on a given day. The total number of patients in the ICU on a given day reflects both the rate of new ICU admissions and the length of stay of those already admitted. Across countries, there was substantial variation in the 14-day rolling daily average during the COVID-19 pandemic. This was likely influenced by several factors, including the proportion of people infected with COVID-19 that experienced severe disease, vaccine rollout (see Section 3.2.6), and hospital policies regarding admission and discharge to the ICU (see Section 3.2.4 for an overview of ICU capacity). As per the number of new ICU admissions (Figure 5), Ireland experienced two notable peaks in the 14-day rolling daily average of the total number of patients in ICU with COVID-19 on a given day:

- April 2020
- February 2021.

It can be seen from Figure 6 that the 14-day rolling daily average gradually increased from September 2021 to the end of the reporting period for this report, coinciding with the rise in COVID-19 cases in Ireland following increased circulation of the more transmissible Delta variant. While peaks in the 14-day rolling daily average were also observed in other European countries prior to and during April 2020, the timing and duration of subsequent peaks varied, especially between October 2020 and April 2021.

Figure 6. Fourteen-day rolling daily average of number of COVID-19 patients in ICU per million population



Source: Our World in Data (OWID) COVID-19 data repository[3]

Note(s):

1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK.
2. Gaps in individual country lines indicate missing data at that time point.

3.1.4 Reported COVID-19 deaths

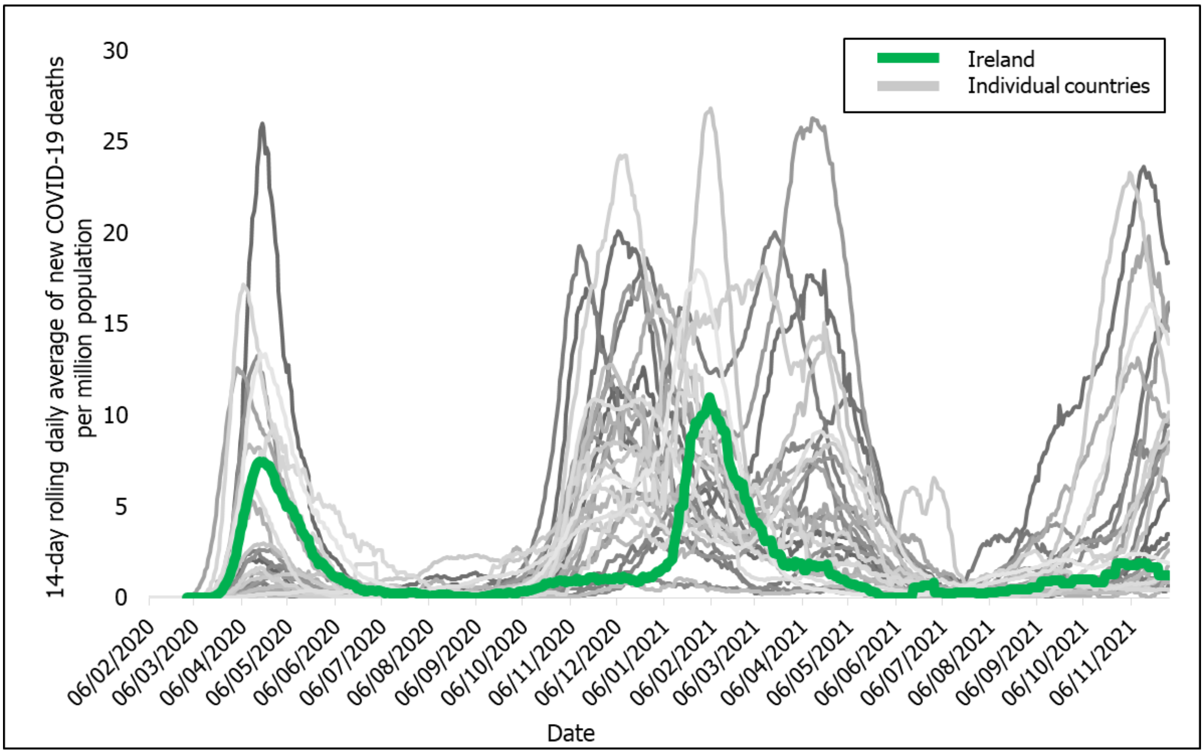
Figure 7 presents the 14-day rolling daily average of recorded COVID-19 deaths per million population across Europe over the course of the COVID-19 pandemic. As noted at the beginning of Section 3, the timing and impact of COVID-19 waves varied across countries. This variation was particularly evident for the period between October 2020 and June 2021 in which COVID-19 death rates peaked sharply in many European countries. The variation between countries may have been influenced by a number of factors, including the rollout and uptake of vaccination, specific country demographics, and national practices in the recording and reporting of deaths relating to COVID-19. As noted in Section 2.3, some countries include only laboratory-confirmed cases among death totals, while others also include probable cases. Similarly, while the majority include deaths among COVID-19 patients in both hospital and community settings, some include deaths that occur in the hospital setting only or apply a time limit from diagnosis for the death to be considered attributable to COVID-19.

In Ireland, there were two clear peaks in the rate of reported COVID-19 deaths:

- April 2020 (7.4 deaths per million population)
- February 2021 (11.0 deaths per million population).

These peaks were narrower (that is, shorter in duration) than those seen in many other European countries, with many other countries observing a third peak between September and November 2021. The variation between countries was likely influenced by variation in the rollout of COVID-19 vaccination between countries. Vaccines became available from December 2020, but there was substantial variation in the rate of rollout, timing in which those most at risk of severe disease were vaccinated, and overall coverage obtained. The potential impact of differences in vaccination coverage is discussed further in Section 3.2.6.

Figure 7. Fourteen-day rolling daily average of new COVID-19 deaths per million population



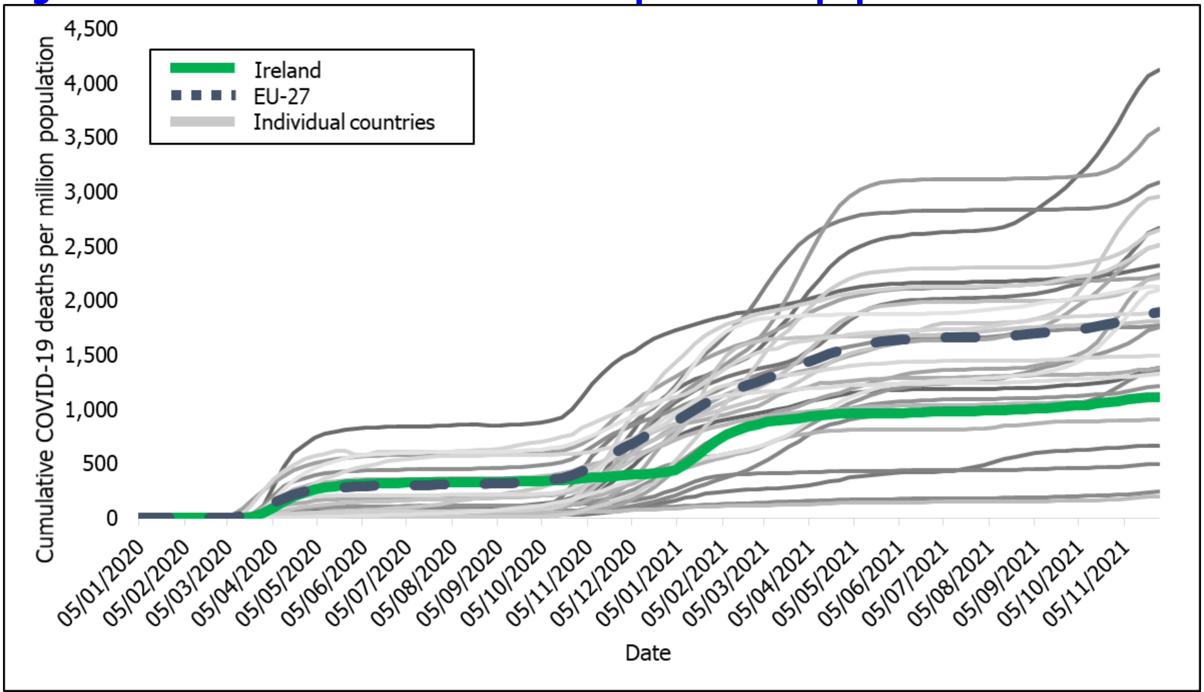
Source: Our World in Data (OWID) COVID-19 data repository[3]

Note(s):

1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, UK.
2. Occasionally, reporting lags result in negative values (retrospective corrections) in the OWID repository (see Section 2.5). These adjustments accounted for 0.3% of all COVID-19 deaths reported for Ireland. The maximum adjustment across Europe was 2.1% for Spain.
3. Reported COVID-19 deaths in Ireland from 1 March to 30 April 2020 were extracted from the HPSC's Computerised Infectious Disease Reporting (CIDR) database. Date of death in the CIDR database refers to the reported date of death rather than date of COVID-19 notification.

Figure 8 presents the cumulative number of reported COVID-19 deaths per million population across Europe throughout the COVID-19 pandemic. Over the full time period (1 January 2020 to 30 November 2021), there were a total of 5,514 reported COVID-19 deaths (1,107 per million population) in Ireland. The cumulative number of reported COVID-19 deaths per million population in Ireland remained consistently lower than the EU-27 average throughout. However, as noted previously, there are numerous issues that limit direct comparisons between countries. These include differences in recording and reporting of deaths relating to COVID-19, and differences in population age between countries. Specifically, the proportion of the population aged 65 (or 70) years or older (see Section 3.2.1) likely influenced the differences in total cumulative mortality observed, given the association between older age and COVID-19-related mortality. Other factors that potentially influenced COVID-19 death rates across countries included the timing and uptake of vaccination, vaccination coverage in older age groups, and the use of public health restrictions (each of which are described in Section 3.2).

Figure 8. Cumulative COVID-19 deaths per million population



Source: Our World in Data (OWID) COVID-19 data repository(3)
Note(s):

1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, UK.
2. Reported COVID-19 deaths in Ireland from 1 March to 30 April 2020 were extracted from the HPSC's Computerised Infectious Disease Reporting (CIDR) database. Date of death in the CIDR database refers to the reported date of death rather than date of COVID-19 notification.

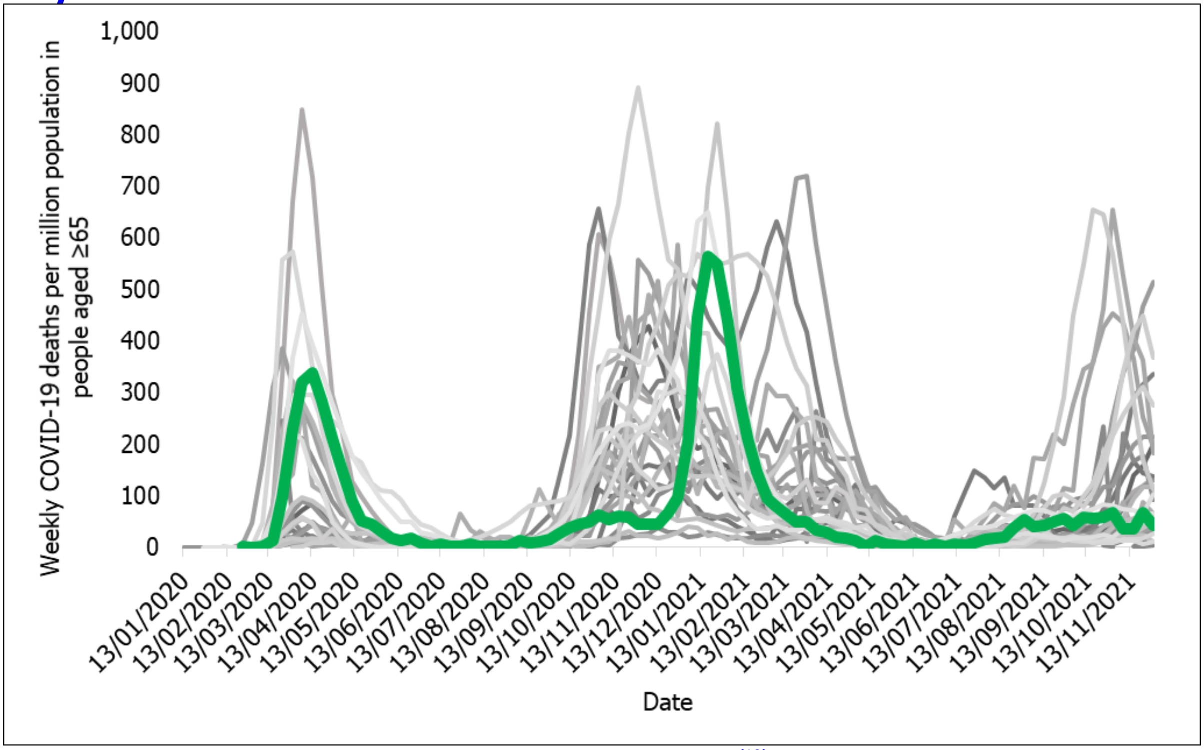
COVID-19 deaths within the population aged 65 years or older

Figure 9 presents the weekly number of recorded COVID-19 deaths that occurred in people aged 65 or older, per million population, based on data reported by the WHO. In Ireland, there were two clear peaks in the rate of reported COVID-19 deaths among people aged 65 or older:

- April 2020 (337.4 deaths per million population)
- January 2021 (563.8 deaths per million population).

Ninety-one percent of recorded COVID-19 deaths in Ireland occurred among those aged 65 years or older. Although there was substantial variation in the duration and magnitude of peaks across countries (with a number of countries observing a third peak towards the end of 2021), the trend of increased mortality in older age groups observed in Ireland was mirrored throughout Europe. At least 80% of deaths occurred in the population aged 65 years or older in 24 of the 31 European countries.

Figure 9. Weekly COVID-19 deaths per million population in people aged 65 years or older



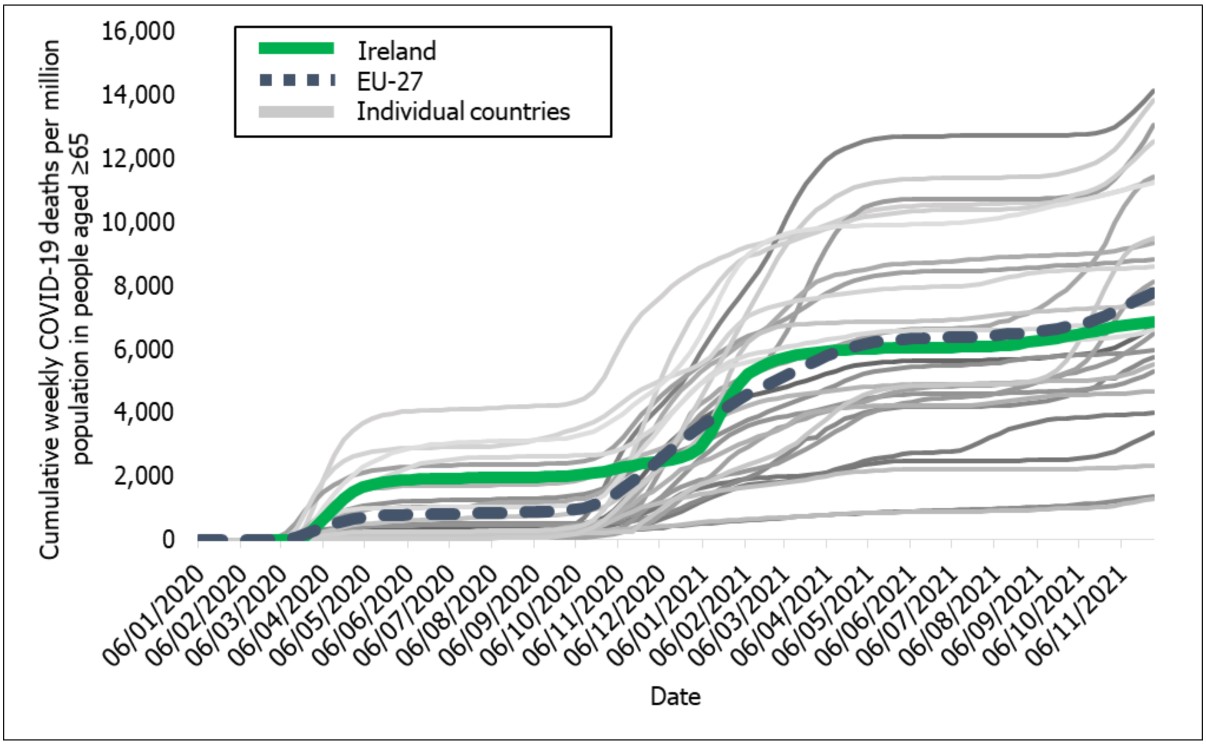
Source: World Health Organization (WHO) COVID-19 data repository,[10] Organisation for Economic Co-operation and Development (OECD)[33]

Note(s):

1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK.
2. Gaps in individual country lines indicate missing data at that time point.

Figure 10 presents the cumulative reported COVID-19 deaths per million population in those aged 65 or older across Europe from 1 January 2020 to 30 November 2021. In Ireland, there were 5,001 reported deaths (or 6,879 per million population) in this age group. Between April and December 2020, there was a consistently higher rate of deaths in Ireland in people aged 65 or older compared with the EU-27 average. During January 2021, there was a sharp rise in the death rate, which broadly coincided with the peak in cases observed in January 2021. The cumulative death rate stabilised following this period and by November 2021 was lower than the EU-27 average. It should be noted that countries used different definitions to report COVID-19 deaths, which could influence the cross-country differences observed in Figure 10; some countries (such as Ireland) included probable COVID-19 deaths while most included strictly laboratory-confirmed COVID-19 deaths.

Figure 10. Cumulative COVID-19 deaths per million population in people aged 65 years or older



Source: World Health Organization (WHO) COVID-19 data repository[(10)]
Note(s):

1. Countries represented in this figure: Austria, Belgium, Croatia, Cyprus, Czechia, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK.

3.1.5 Excess mortality

Excess all-cause mortality in Ireland

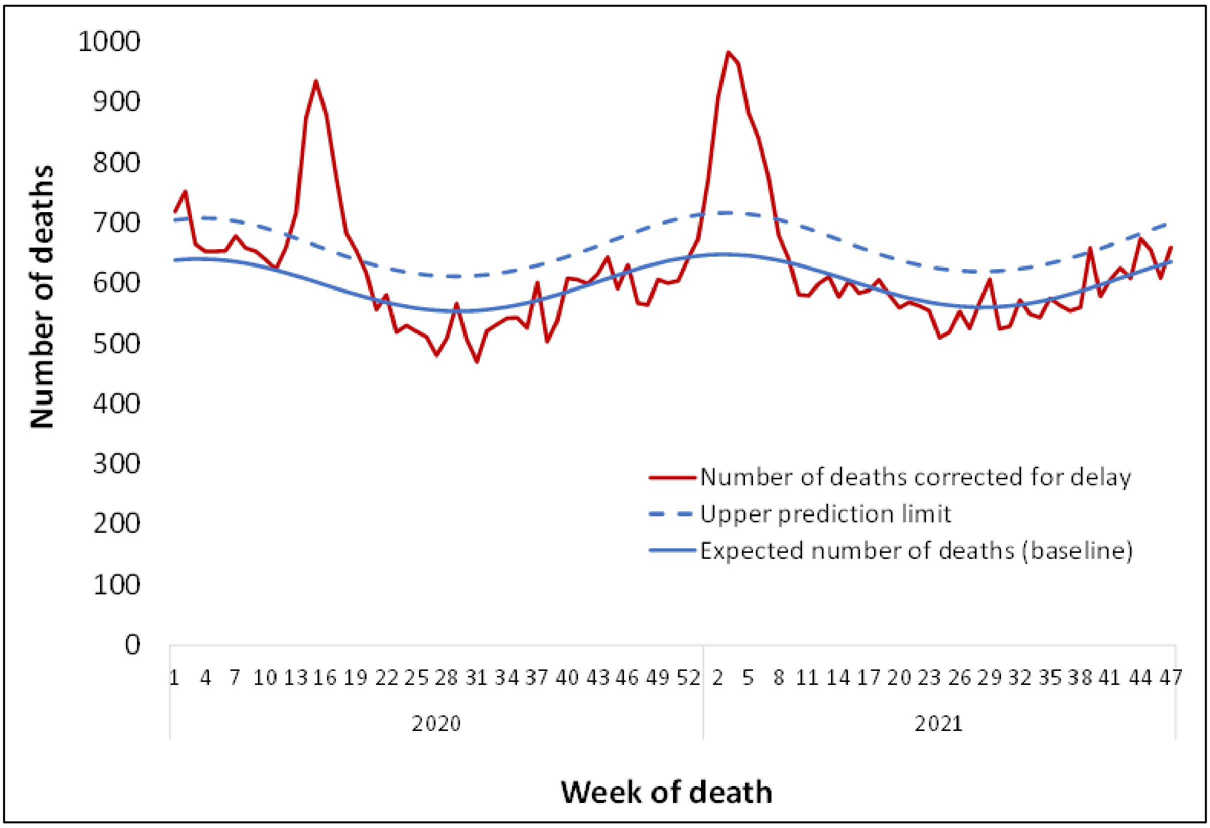
The analysis of excess mortality, described below, was provided by the HPSC and conducted in line with the standardised EuroMOMO algorithm. It was estimated that a total of 2,019 excess deaths occurred in Ireland between 2 March 2020 and 28 November 2021.

From Figure 11, it can be seen that the majority of these excess deaths occurred during two distinct peaks in which the number of excess deaths was above the upper prediction limit (and therefore significantly above predicted variation):

- a seven-week period between late-March 2020 and mid-May 2020
- an eight-week period between early January 2021 and the end of February 2021.

No consecutive weeks of excess mortality occurred outside of these periods. A total of 352 excess deaths were estimated to have occurred during January and February 2020. As this period of excess all-cause mortality coincided with high levels of influenza virus circulation and influenza-associated morbidity and mortality, the excess mortality was not attributed to the COVID-19 pandemic.

Figure 11. Excess all-cause mortality in Ireland (all age groups)

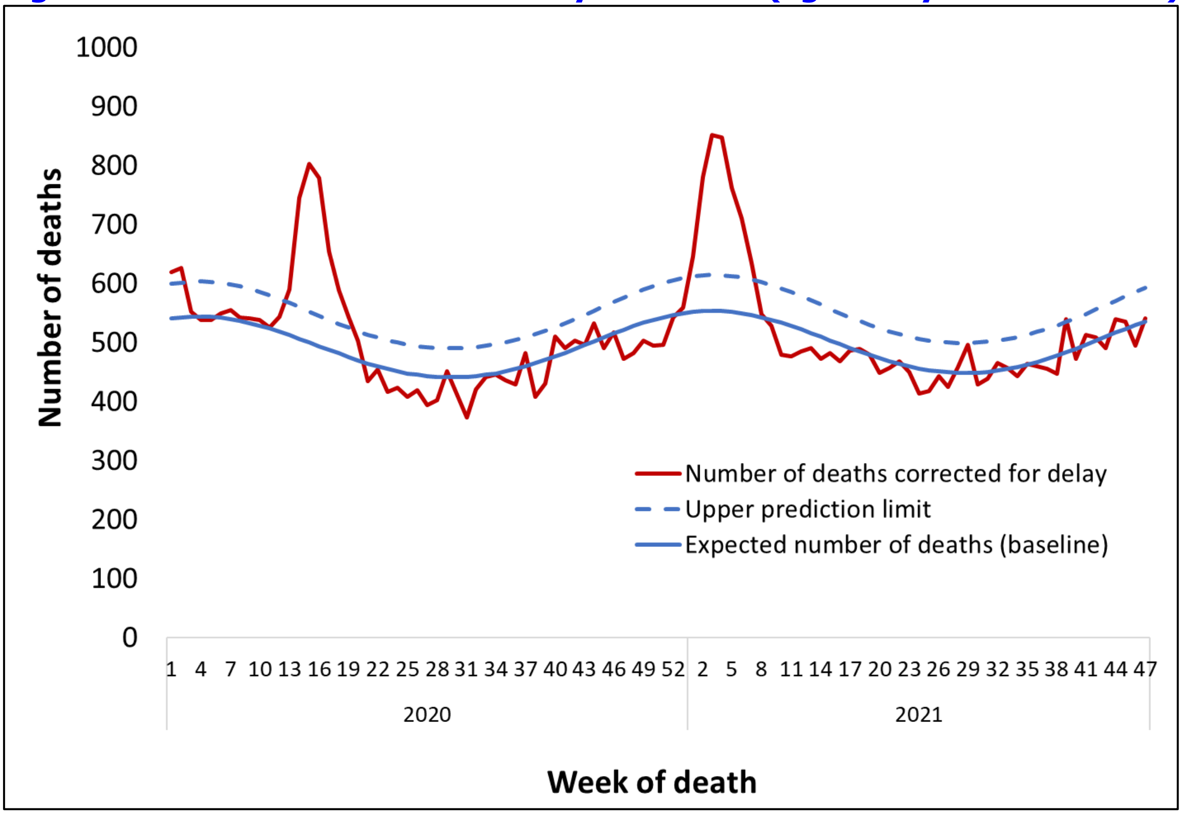


Source: Analysis of excess mortality in Ireland provided by the Health Protection Surveillance Centre (HPSC).

Estimates of excess deaths will vary according to age group and the period of time chosen to estimate the excess all-cause deaths. Excess all-cause mortality in Ireland in those aged 65 years and older is presented in Figure 12, while excess all-cause mortality in Ireland in those aged 85 years and older is presented in Figure 13. The majority (82%) of excess deaths in Ireland occurred among those aged 65 years and older (n=1,665), with 22% of all-cause excess deaths in Ireland occurring in those aged 85 years and older (n=451).

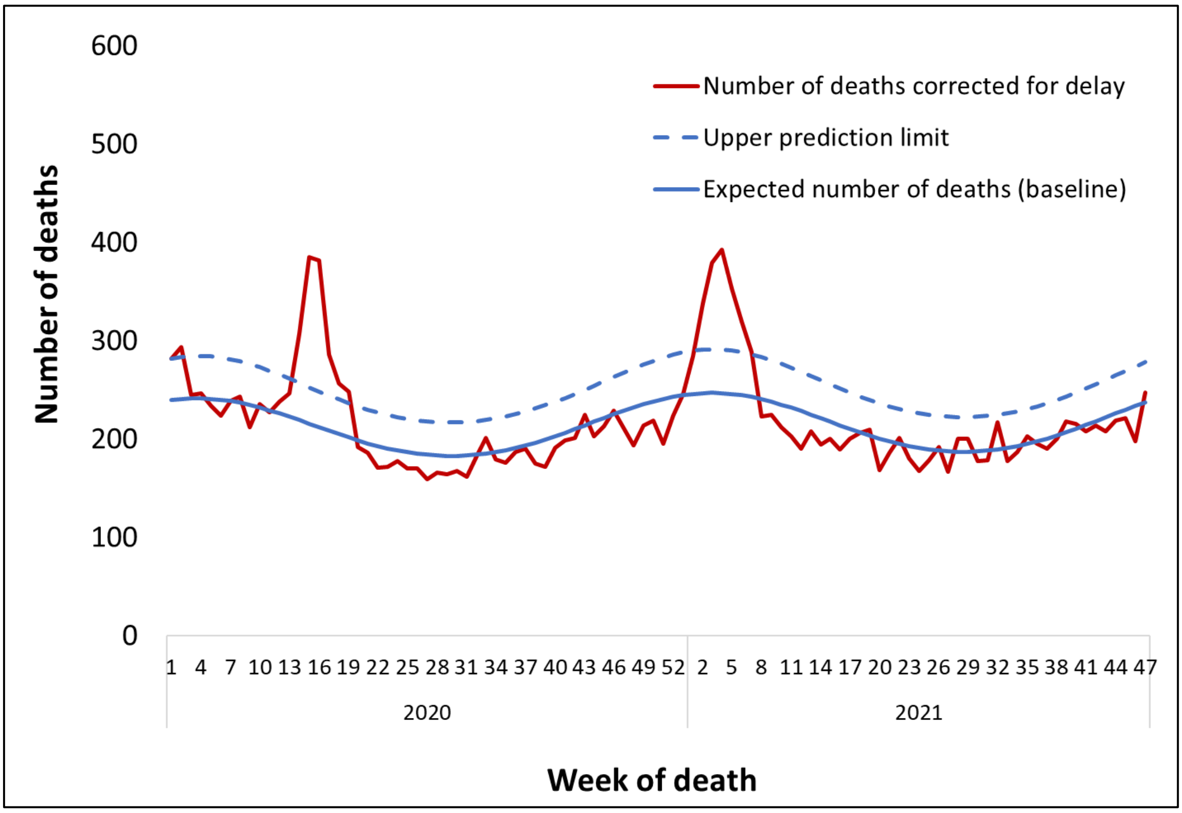
Similar to that of the total population, these excess deaths occurred during two distinct peaks in which the number of excess deaths were above the upper prediction limit (and therefore significantly above predicted variation). Although more all-cause deaths occurred in Ireland during the time of the third COVID-19 wave in early 2021, the expected number of deaths is also greater at that time of year. As a result, excess mortality was similar across the two waves for both age groups.

Figure 12. Excess all-cause mortality in Ireland (aged 65 years and older)



Source: Analysis of excess mortality in Ireland provided by the Health Protection Surveillance Centre (HPSC).

Figure 13. Excess all-cause mortality in Ireland (aged 85 years and older)



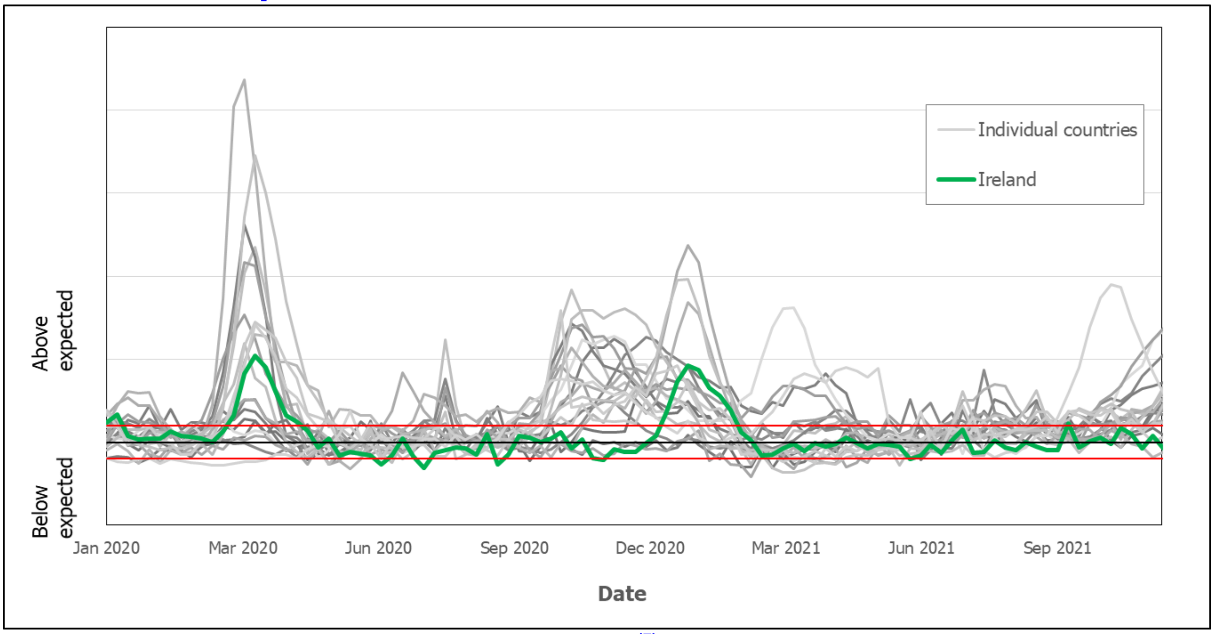
Source: Analysis of excess mortality in Ireland provided by the Health Protection Surveillance Centre (HPSC).

Excess mortality in countries in Europe

Figure 14 presents z-scores for excess mortality in Ireland and across countries in Europe. The dotted red lines represents ±2 z-scores, indicating the region of normal expected variation in mortality rates. This graph serves to illustrate trends in excess mortality for Ireland, and for individual countries, over the time period of the analysis. As discussed in Section 2.3, direct comparison of z-scores for countries of different sizes, and particularly numerical comparison of z-scores, is limited in its validity. As such, comparisons are not made in this report between Ireland and any one country. Rather, Figure 14 presents Ireland alongside other individual country trends to permit visualisation of common patterns (for example, the common peak observed in March 2020, though with varying magnitudes across countries).

The Irish-specific excess mortality data presented in Figure 11 is part of the EuroMOMO dataset and thus presented again in Figure 14 in the form of a z-score. There was substantial variability in the magnitude and duration of peaks in excess mortality across European countries throughout the study period. Considering the timing of the waves of excess mortality, the peaks across European countries were largely coincident during the early phase of the pandemic. However, subsequent to the first wave, peaks were no longer synchronised across European countries. Between mid- and late-2021, some countries experienced a peak in excess mortality while Ireland did not. During this time, the excess mortality in Ireland was observed to be amongst the lowest in Europe.

Figure 14. Z-scores indicating excess mortality relative to pre-pandemic baseline in European countries



Source: European Mortality Monitoring (EuroMOMO) project[7]

Note(s):

1. Countries represented in this figure: Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Ukraine, England, Scotland, Wales.
2. The black line is the baseline and represents the expected number deaths, the red lines represent ±2 z-scores, indicating the region of expected variation in mortality rates.

3.2 Contextual factors

This report describes seven contextual factors that have an individual and collective impact on the COVID-19 epidemiological indicators. These contextual factors comprised the following four baseline factors:

- population age
- population density
- household size
- hospital and ICU capacity.

The contextual factors also included the following three public health measures introduced in response to the pandemic:

- COVID-19 vaccination coverage
- test positivity rate
- strictness of public health restrictions.

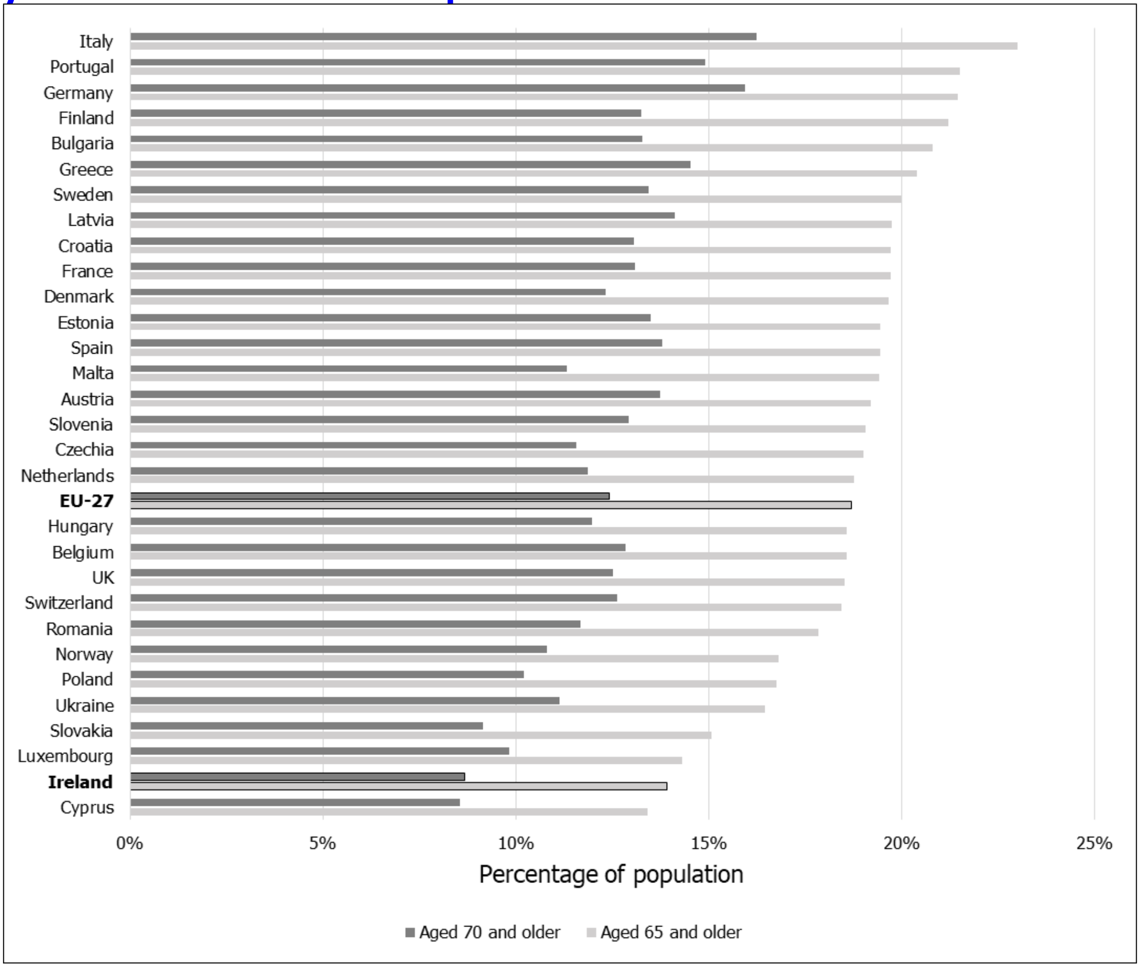
Key findings in relation to these contextual factors are described in Section 3.2.1 to 3.2.7.

3.2.1 Population age

The age-distribution of a country is important to consider when seeking to understand the variation in epidemiological indicators presented in Section 3.1. The burden of severe COVID-19 disproportionately impacted older populations (for example, the majority of deaths in Ireland occurred among those aged 65 years or older). Given the association between age and disease severity and mortality, countries with a lower proportion of older adults and with a lower median age would be anticipated to have a lower burden of severe disease.

Figure 15 presents the proportion of the total population who were aged 65 years or older and 70 years or older across Europe in 2015. Across countries, the proportion of the population aged 65 years or older and the proportion aged 70 years or older ranged from 13% to 23% and from 9% to 16%, respectively. Ireland has a smaller proportion of older adults relative to most countries within Europe, with 13.9% of the population aged 65 years or older (EU-27 average: 18.7%) and 8.7% of the population aged 70 years or older (EU-27 average: 12.4%).

Figure 15. Percentage of the population aged 65 years and older and 70 years and older within European countries



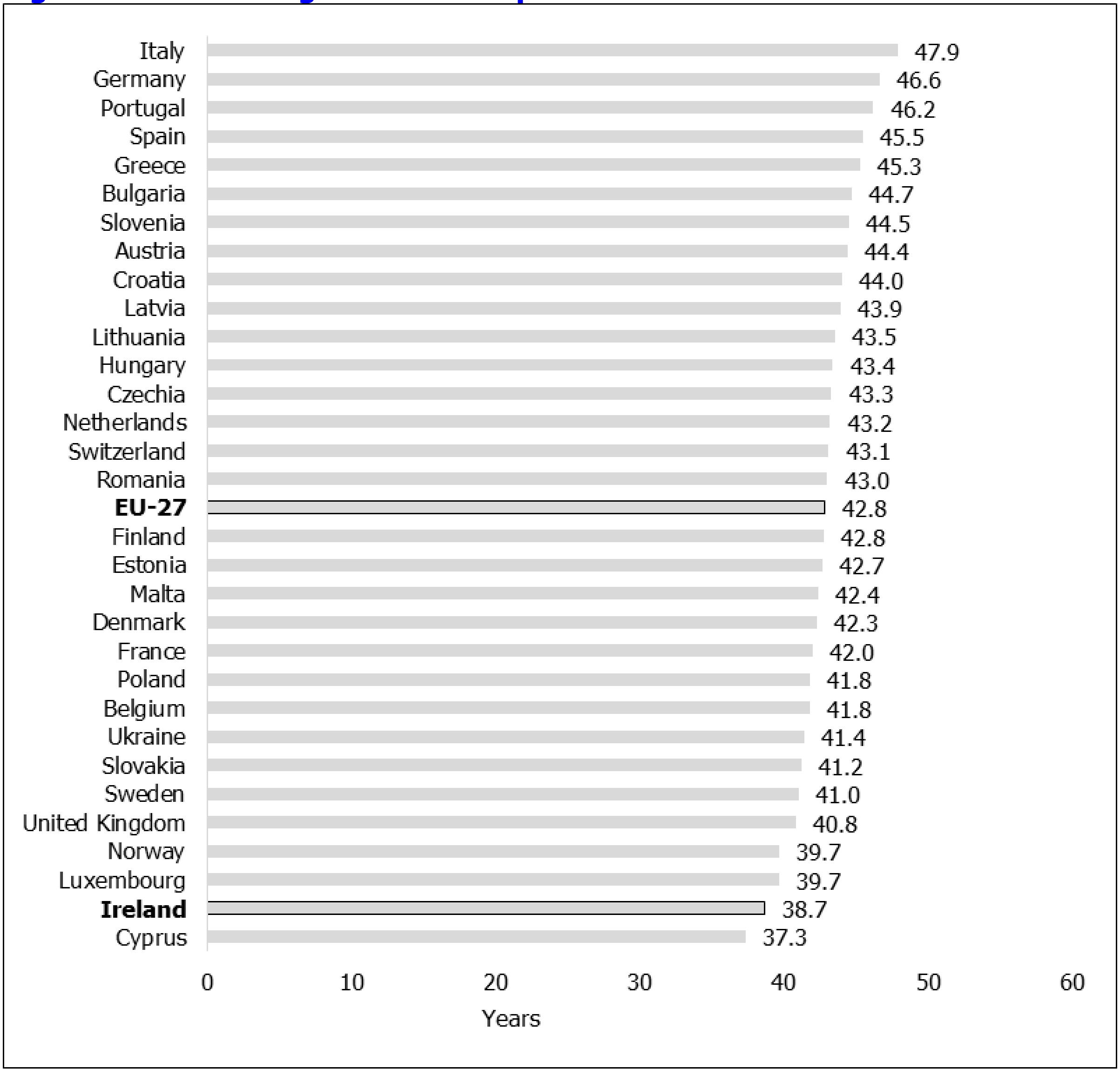
Source: Our World in Data (OWID) COVID-19 data repository[3]

Note(s):

1. Data are from year 2015 or most recent year available.

Figure 16 shows the median age across Europe in 2015. The median age ranged from 37 to 48 years; average median age for the EU-27 was 43 years. Consistent with the lower proportion of older adults presented in Figure 15, Ireland had a comparatively young median age of 39 years.

Figure 16. Median age across European countries



Source: Our World in Data (OWID) COVID-19 data repository[3]

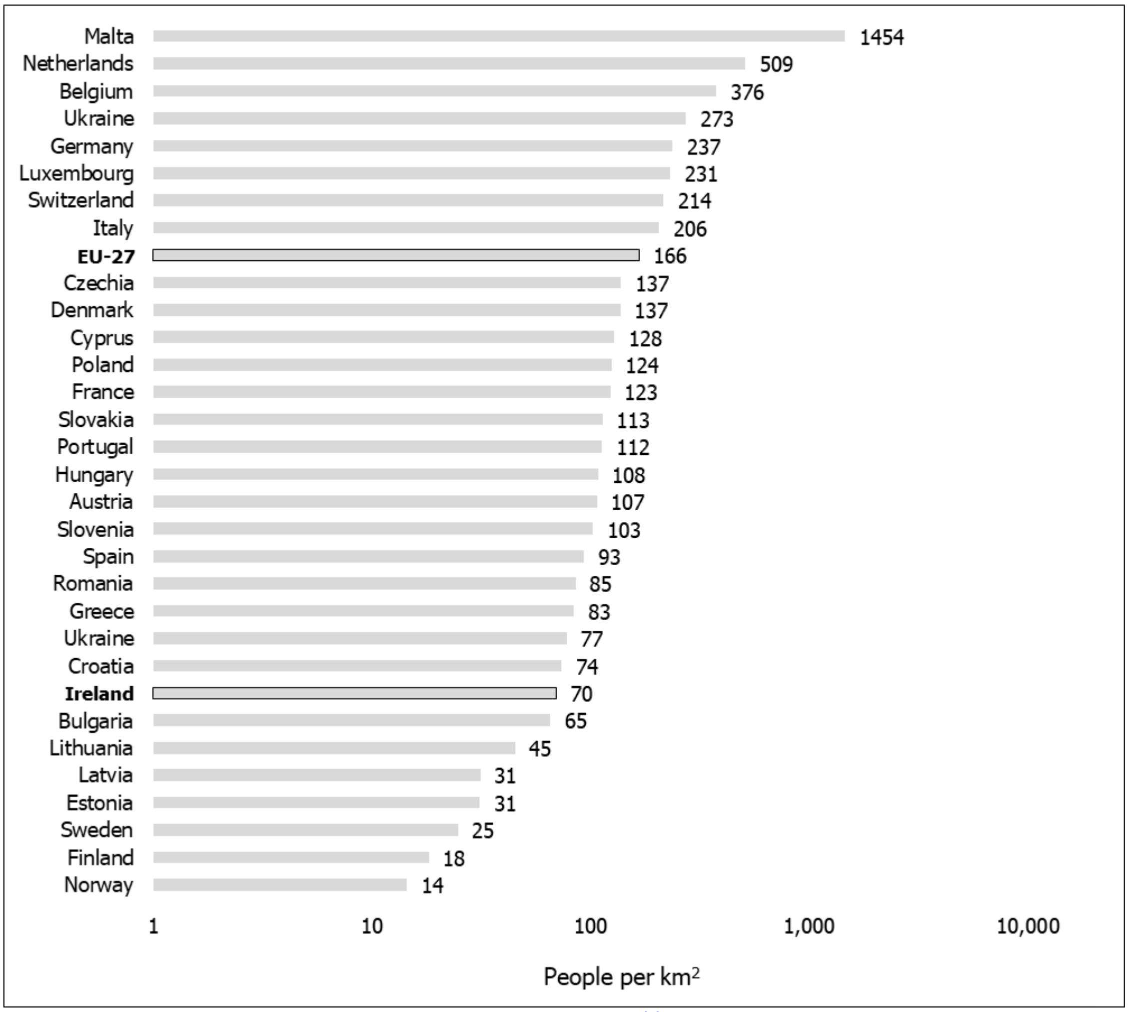
Note(s):

1. Data are from year 2015 or most recent year available.

3.2.2 Population density

Population density is an important contextual factor as lower population densities may lead to reduced SARS-CoV-2 transmission due to the fact that it may be less challenging to follow the public health advice, such as physical distancing. There may also be fewer people in public places in areas with low population density than places with high population density, further reducing transmission opportunities. However, population density can vary significantly within countries, as it does not reflect the different patterns of population dispersion (for example, between urban and rural areas). As shown in Figure 17, Ireland has a low population density relative to the majority of European countries.

Figure 17. Population density measured as the number of people per square kilometre



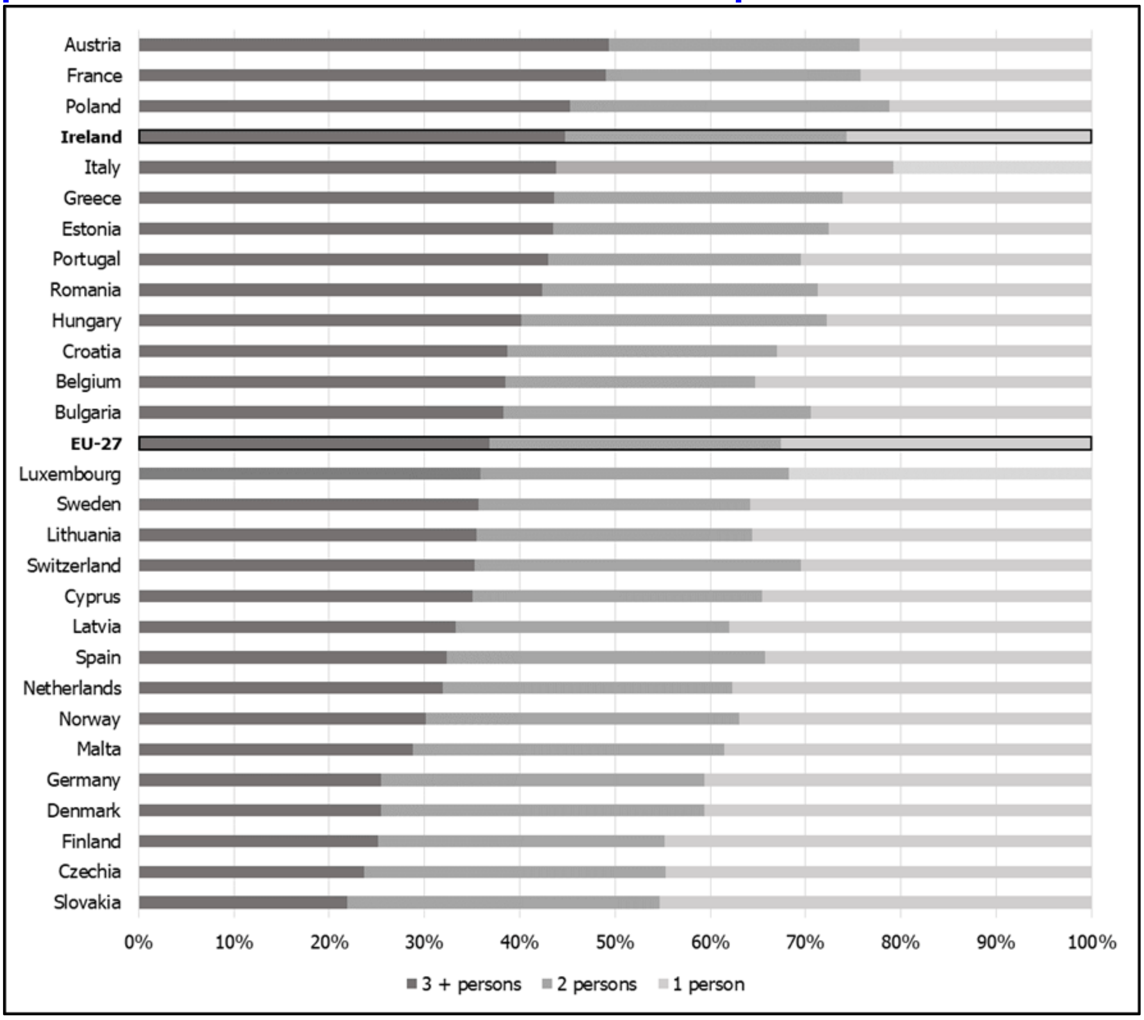
Source: Our World in Data (OWID) COVID-19 data repository[3]
Note(s):
1. Data are from year 2020 or most recent year available.
2. Data bars are presented based on logarithmic scale.

3.2.3 Household size

Similar to population density, household size may be an important contextual factor as a larger household may constrain an individual's ability to follow public health advice, particularly to socially distance from fellow household members. Household transmission rates were high throughout the pandemic.[(34)] Along with the household size the composition of the household may also be important; for example, a greater number of multi-generational households could lead to an increased transmission risk to older adults.

Figure 18 presents variation in household sizes across Europe. Relative to most other countries and the EU-27 weighted average, Ireland has a high proportion of people living in households of three or more persons (44.8%) and a low proportion of people living in one-person households (25.7%).

Figure 18. Proportions of people living in one, two, or three or more person households in Ireland and across Europe



Source: Distribution of households by household size European Union Statistics or Income and Living Conditions survey, Eurostat[35]

Note(s):

1. Data are from the year 2020 or most recent year available.

3.2.4 Hospital capacity

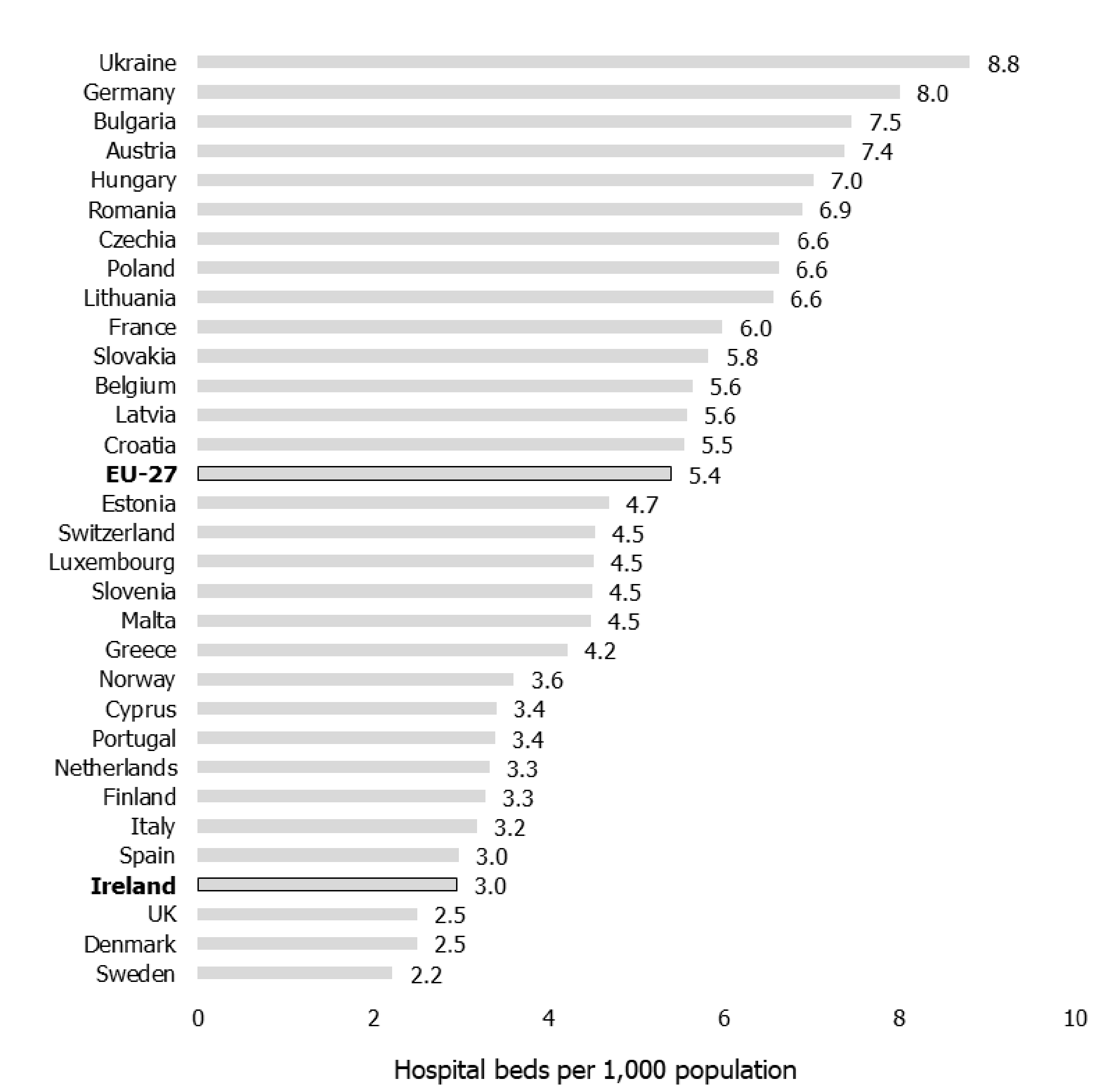
Hospital capacity is an important contextual factor, particularly when comparing hospital and ICU admission rates across countries, as capacity may influence admission and discharge policies. For example, differing discharge policies could lead to a shorter length of stay in countries where hospital and ICU bed capacity is limited, especially during times when case numbers are high. It also has consequences for the extent to which other activity was displaced during the pandemic.

Figure 19 displays hospital capacity across European countries, expressed as the number of hospital beds (public and private) per 1,000 population as measured in 2019. Hospital capacity ranged from 2.2 to 8.8 per 1,000 population across Europe, with a weighted EU-27 average of 5.4 beds per 1,000 population. This compared with 3.0 per 1,000 population in Ireland. It should be noted that many countries, including Ireland, increased their hospital bed capacity during the pandemic, but this increase is not reflected in the data presented in Figure 19.

Data on the number of ICU beds across many European countries can be difficult to obtain. However, a report published by the OECD in 2020 highlighted the range in intensive care bed capacity across 14 selected OECD European countries. The ICU bed capacity of the 14 European countries reported ranged from 5.1 (Ireland, 2020 data) to 33.9 (Germany, 2017 data) per 100,000 population.(36) As with many other countries, surge capacity was temporarily provided in Ireland to manage the sudden, unexpected increase in patient volume that would otherwise have severely challenged or exceeded the existing capacity. During the pandemic, surge capacity in Ireland peaked in January 2021 at 348 ICU beds (equating to 7.0 beds per 100,000 population).(37)

Ireland had relatively lower hospital capacity and critical care capacity prior to the COVID-19 pandemic compared with the majority of other European countries.

Figure 19. The number of hospital beds per 1,000 population



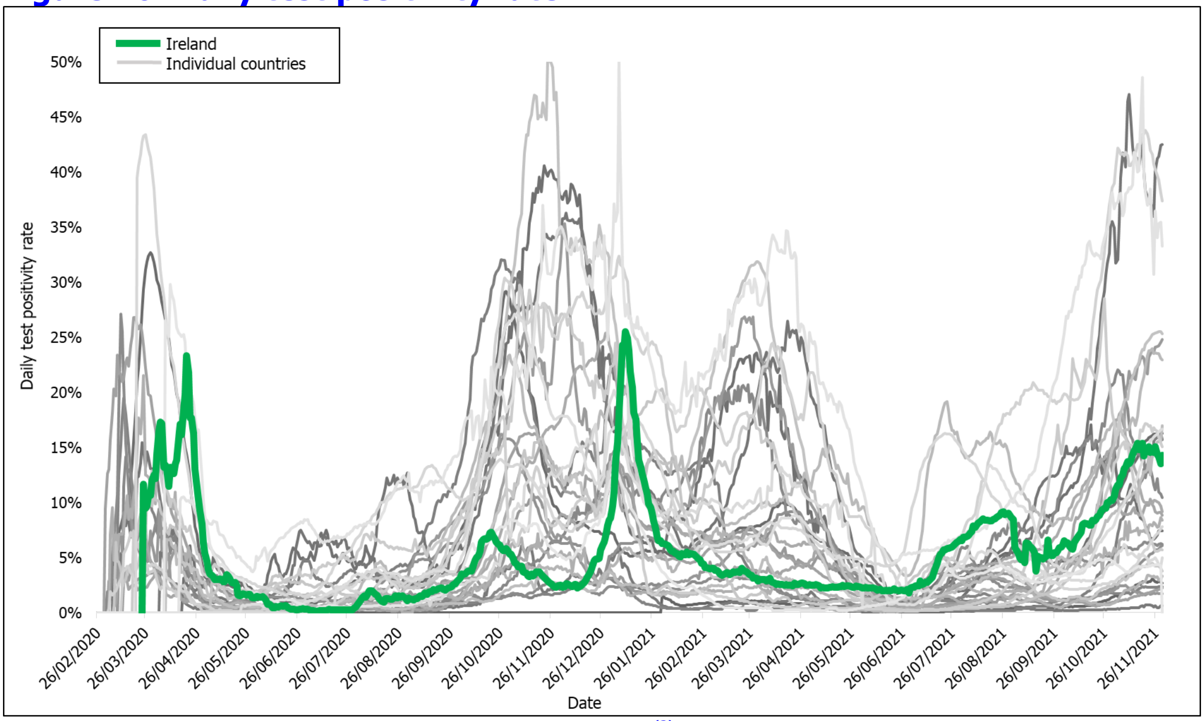
Source: Our World in Data (OWID) COVID-19 data repository[3]
Note(s):
1. Data are from 2019 or the next most recently available year.

3.2.5 Test positivity rate

The test positivity rate is an important contextual factor when interpreting variation in case numbers over time and between countries. High test positivity reflects likely under-ascertainment of cases; if positivity rates are increasing, this suggests that the virus is spreading faster than the growth in confirmed cases. Figure 20 illustrates the daily test positivity rate over the course of the COVID-19 pandemic. Substantial variation was observed between and within countries over time. In Ireland, peaks in test positivity rates broadly coincided with the timing of the five COVID-19 peaks experienced in April 2020, October 2020, January 2021, August 2021 and November 2021 (see Section 3.1.1). The highest test positivity rates in Ireland occurred in April 2020 and January 2021, at 23% and 26%, respectively.

A policy of only testing symptomatic individuals in the context of very limited test capacity may have contributed to the high test positivity rates in the early stages of the pandemic, potentially leading to under-ascertainment of cases compared with later in the pandemic when there were fewer barriers to testing. When the test positivity rate is low, it is likely that a higher proportion of infected individuals are being detected and that there is sufficient capacity for contact tracing and testing of asymptomatic individuals.

Figure 20. Daily test positivity rate



Source: Our World in Data (OWID) COVID-19 data repository[3]
Note(s):
1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, UK.

3.2.6 Vaccination coverage

Vaccination against COVID-19 is an important public health intervention introduced to reduce morbidity and mortality associated with COVID-19. Vaccination rollout began in late 2020, with approximately 60,000 vaccine doses administered across 17 countries in Europe by the end of 2020.(38)

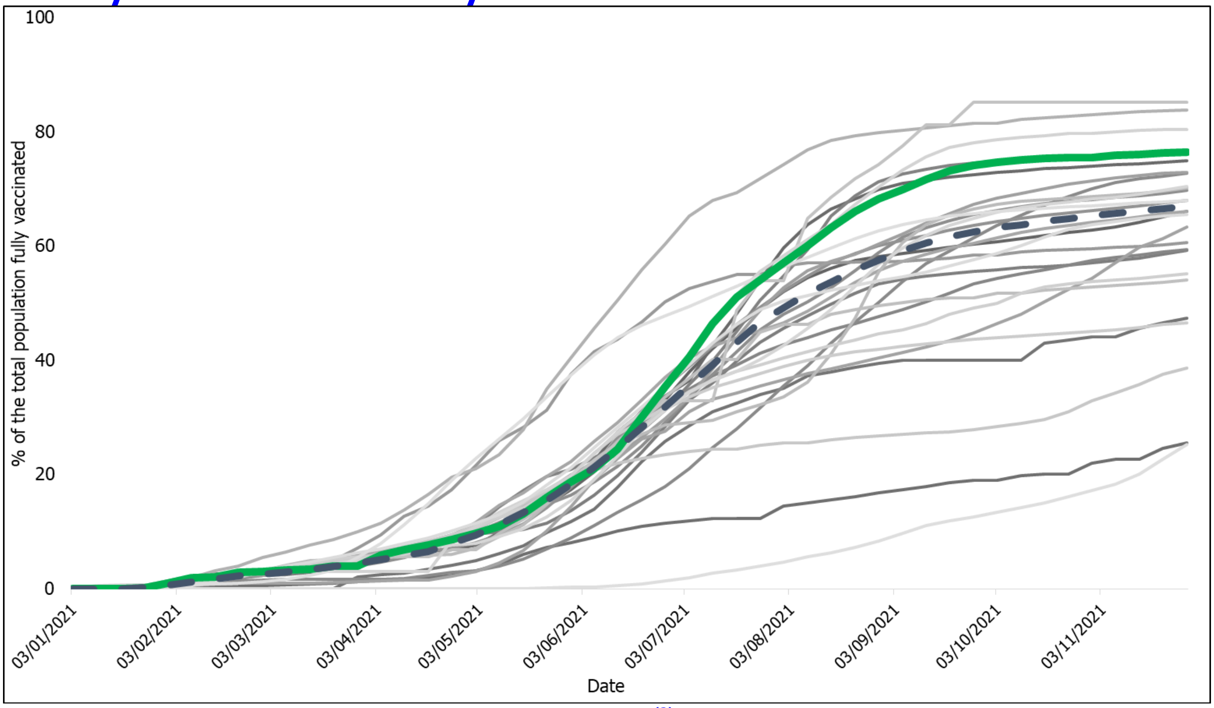
Data are available in terms of the percentage of the population who are fully vaccinated and who have received booster or additional doses. Vaccination coverage is reported here on the basis of completion of the primary vaccine course. This is defined by OWID as the total number of people who received all doses prescribed by the initial vaccination protocol.(21) Coverage is also reported with respect to those who received a booster or additional dose, that is, the percentage of the population having received doses administered beyond the number prescribed by the initial vaccination protocol. As vaccine eligibility varied between countries and over time, coverage is reported as a percentage of the total population.

Figure 21 presents the percentage of the total population that was considered to be fully vaccinated over the period from January 2021 to November 2021. Ireland had a strict policy of prioritising full vaccination for those at highest risk of exposure (that is, healthcare workers) or severe disease. By the end of June 2021, 38% of the total Irish population was fully vaccinated, increasing to 76% by the end of November 2021. This compared with a range of 26-86% fully vaccinated across the European countries included by the end of November 2021.

Policies regarding the rollout of vaccination differed by country. For example, Ireland prioritised vaccinating those at highest risk of severe disease or exposure first, as opposed to offering a general population-wide rollout. Figures 22 and 23 present vaccine coverage in those aged 70-79 years and 80 years or older, respectively. While coverage in Ireland was below the EU-27 average for the total population until the end of June 2021, coverage in those aged 80 years or older and 70-79 years exceeded the EU-27 average by the end of April 2021. By the end of June 2021, six months after the vaccination rollout began, approximately 100% of Irish adults aged 70 years or older were fully vaccinated, greatly exceeding the EU-27 averages (EU-27 average in those aged 70-79 years: 73%; EU-27 average in those aged 80 years or older: 81%).

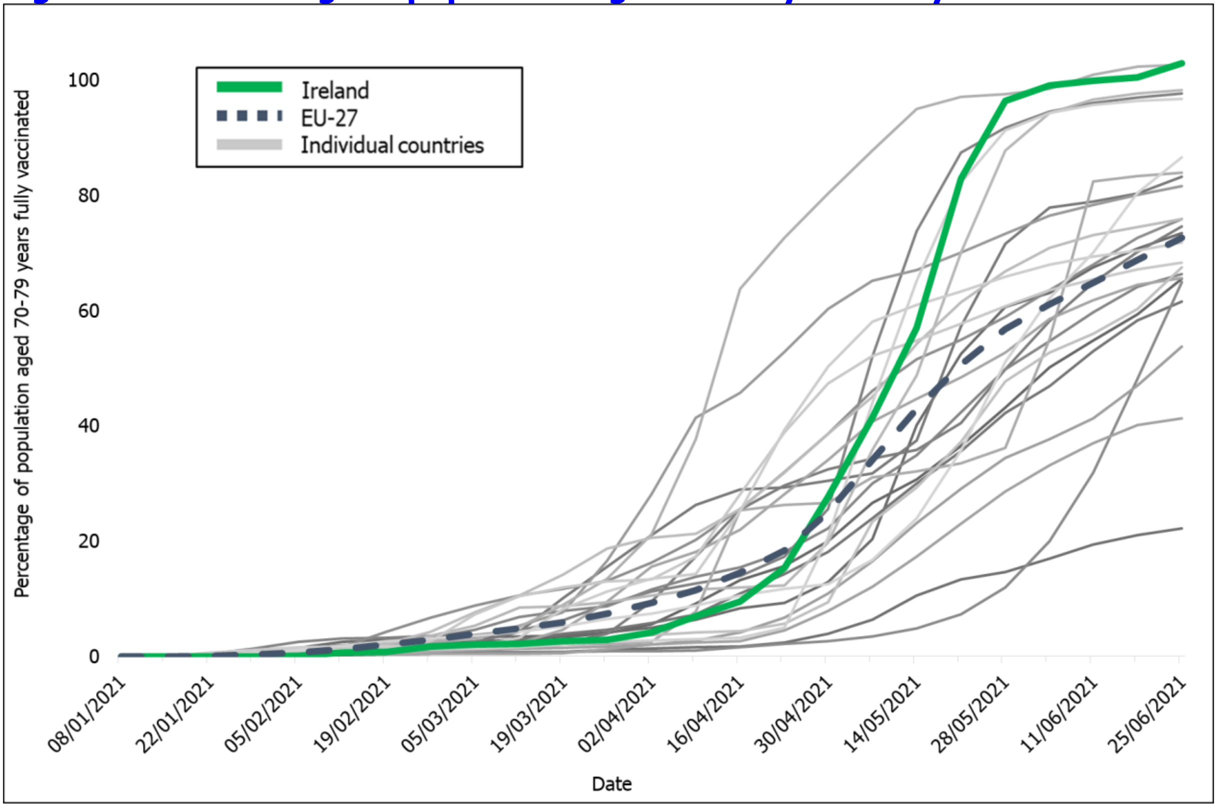
Differences in vaccination coverage in European countries, both in terms of the timing in which the majority of the population were considered fully vaccinated, and or had received booster doses, and in terms of the timing and extent to which coverage was achieved in those most at risk of severe disease, likely contributed to observed differences in the morbidity (hospitalisations and ICU admissions) and mortality from COVID-19. This is discussed in greater detail in Section 4.

Figure 21. The percentage of the total population in each European country considered to be fully vaccinated



Source: Our World in Data (OWID) COVID-19 data repository[3]
Note(s):
1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, UK.
2. When data were partially incomplete (that is, days with missing values) the last observation was carried forward.

Figure 22. Percentage of population aged 70-79 years fully vaccinated

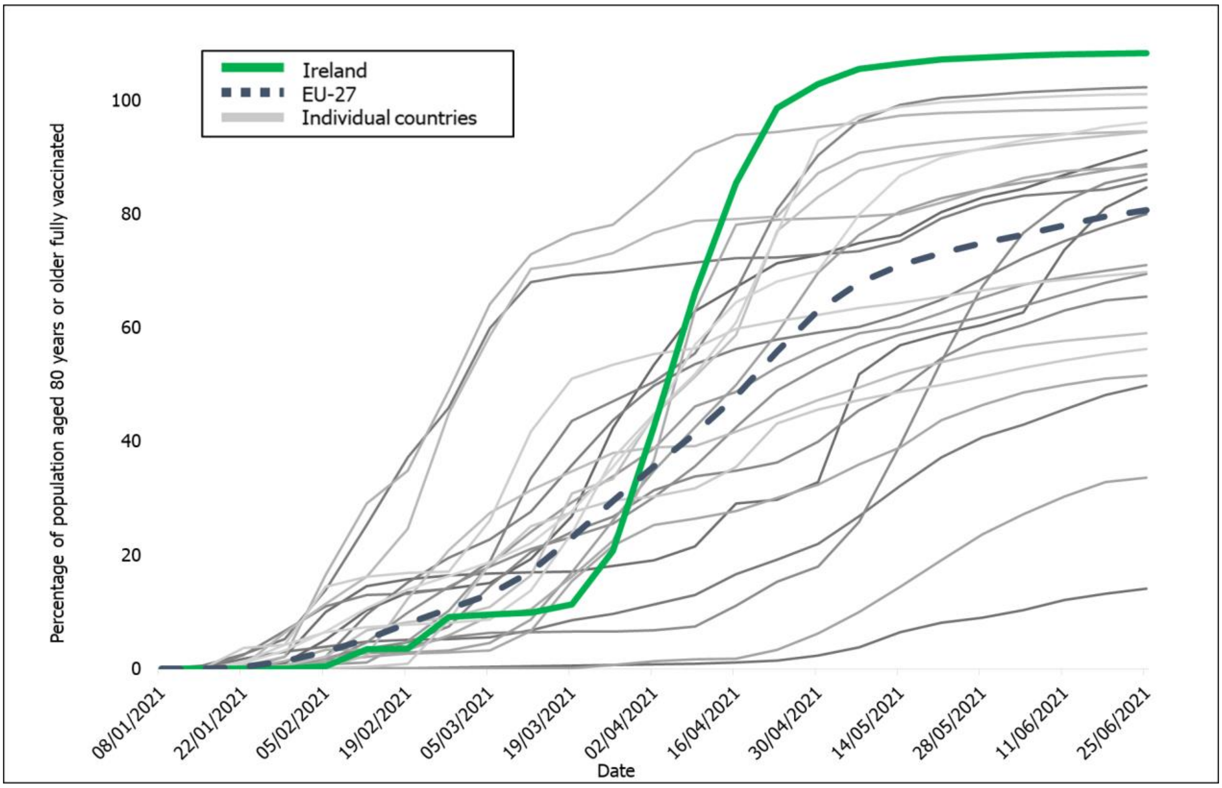


Source: Our World in Data (OWID) COVID-19 data repository[3] and Organisation for Economic Co-operation and Development (OECD)[11]

Note(s):

1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.
2. Values greater than 100% are attributable to the presence of a small number of duplicate registrations/records in the national vaccination database, people not registered in the population who are registered as being vaccinated, inaccuracies in population estimates, and the dynamic nature of the numerator (that is, number of people vaccinated) and denominator (that is, population size).

Figure 23. Percentage of population aged 80 years or older fully vaccinated



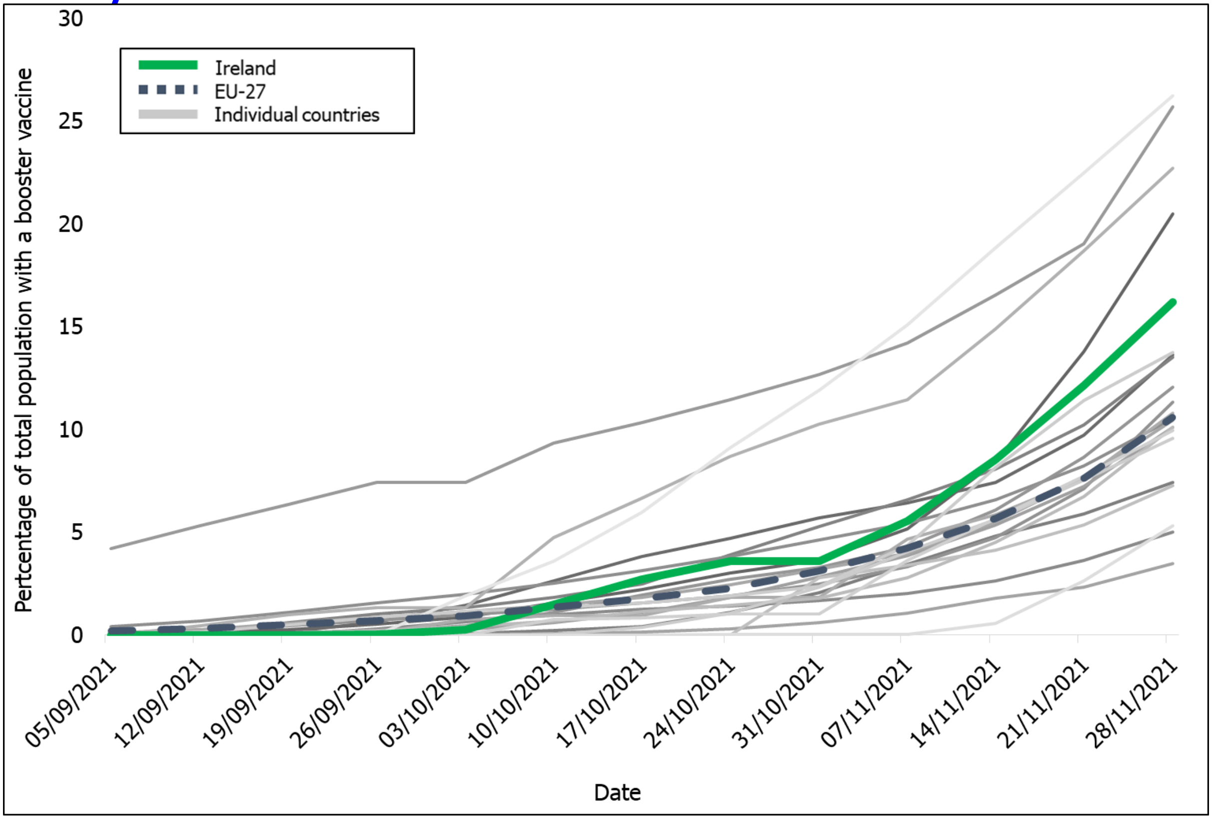
Source: Our World in Data (OWID)[39] and Organisation for Economic Co-operation and Development (OECD)[11]
Note(s):

1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.
2. Values greater than 100% are attributable to the presence of a small number of duplicate registrations/records in the national vaccination database, people not registered in the population who are registered as being vaccinated, inaccuracies in population estimates, and the dynamic nature of the numerator (that is, number of people vaccinated) and denominator (that is, population size).

Figure 24 presents the percentage of the population that had received a booster dose from September 2021 to November 2021. Here, the term 'booster' represents doses administered beyond the number prescribed by the initial vaccination protocol, and thus includes 'additional doses' received by those who are immunocompromised. As booster eligibility varied between countries, Figure 24 represents the percentage of the total population, not necessarily the population that was eligible for a booster at any given time.

Widespread rollout of booster or additional vaccine doses was underway by October 2021. By the end of November 2021, 17.4% of the total Irish population had received a booster or additional vaccine dose, which was higher than the EU-27 average (14.2%). The age breakdown of those who received booster or additional doses was not available from the accessed data sources.

Figure 24. The percentage of the total population in each European country that have received a booster or additional dose



Source: Our World in Data (OWID) COVID-19 data repository(3)

Notes:

1. Countries represented in this figure: Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Norway, Poland, Slovakia, Slovenia, Spain, Switzerland, UK.
2. Partially incomplete data (that is, days with missing values) were carried forward using the last observation.

3.2.7 Stringency index

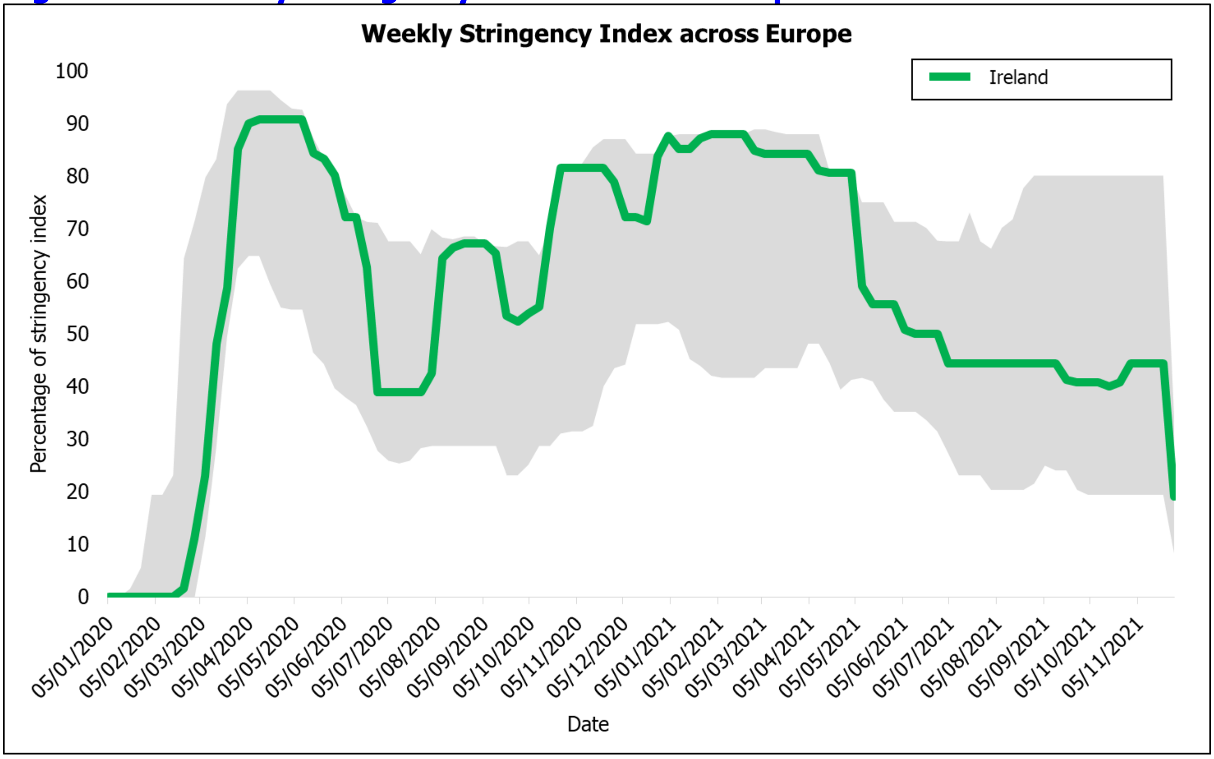
The Stringency Index, developed by the Oxford Covid-19 Government Response Tracker project, is used to track how strict a country's pandemic response was at a given time.[22, 23] The index is a composite measure of nine response metrics, namely:

- school closures
- workplace closures
- cancellation of public events
- restrictions on public gatherings
- closures of public transport
- stay-at-home requirements
- public information campaigns
- restrictions on internal movements
- international travel controls.

These measures were introduced with the aim of reducing the transmission of SARS-CoV-2, with high values often reflecting measures introduced in response to periods of stress or risk of stress on the health system. The index is expressed from less to more strict on a scale of 0-100.

Figure 25 presents the weekly Stringency Index across Europe from January 2020 to November 2021. During a number of periods, Ireland's Stringency Index values were among the highest in Europe. These periods included April/May 2020, August/September 2020, November 2020, and January to May 2021. Ireland's stringency index reduced in May 2021, coincident with the achievement of high vaccination coverage in those aged over 70 years.

Figure 25. Weekly Stringency Index across Europe



Source: Our World in Data (OWID) COVID-19 data repository[3]
Note(s):
1. Countries represented in this figure: Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden Switzerland, Ukraine, UK.
2. The grey shaded area represents the maximum and minimum of the stringency index for all of the countries examined at any given time point.

4 Discussion

4.1 Summary

The purpose of this report was to provide a high-level summary of key epidemiological indicators relating to the burden of COVID-19, and some of the associated contextual factors, over the course of the COVID-19 pandemic prior to the emergence of the Omicron variant in Ireland (from January 2020 up to November 2021). Trends in these indicators and factors were highlighted for Ireland, and presented for individual countries throughout Europe (that is, each of the 27 EU member states together with Norway, Switzerland, Ukraine and the UK). Additionally, European averages of cumulative data were highlighted for the 27 EU member state countries (EU-27). While direct cross-country comparisons are challenging, as discussed below and throughout this report, trends over the timeline are shown to allow for a depiction of Ireland's situation relative to other European countries.

Epidemiological indicators

The COVID-19 pandemic has been characterised by a series of COVID-19 waves, that is, periods where there were surges in new cases followed by periods where cases declined. Across Europe, the number and timing of these COVID-19 waves varied by country, leading to differences between Ireland and other European countries in terms of the burden of confirmed cases, hospital admissions, ICU admissions, and reported deaths over time. For example, the peak of the initial wave of COVID-19 in Ireland (April 2020) occurred later than peaks observed in other European countries. This may reflect a later emergence of the virus in Ireland in addition to differences in testing capacity and policies across countries in the early stages of the pandemic, which would have impacted patterns in cases reported during the first wave.

Cases of COVID-19 in Ireland peaked in April 2020, October 2020 and January 2021 (the peak of greatest magnitude). Following a significant period of relatively low case numbers from March 2021 to July 2021, there was a rise in cases with a peak in August 2021. This was followed by a moderate decline prior to a steady rise in cases during November 2021. Two of these peaks corresponded with the emergence of new variants of concern; the rise in cases in January 2021 was likely attributable to increased socialisation over the December 2020 period, combined with the emergence of the more transmissible Alpha variant, while the peak that occurred in late 2021 was associated with the predominance of the Delta variant, under conditions conducive to higher transmission (that is, indoor gatherings over autumn and winter 2021). Across Europe, the timing and impact of COVID-19 waves varied, with marked differences in case numbers particularly evident for the period between October 2020 and May 2021, when the rates of new COVID-19 cases peaked sharply and then fell again in many European countries. Up until the end of November 2020 the cumulative rate of cases in Ireland was in line with the EU-27 average, but then grew at a slower rate until the end of October 2021, with COVID-19 case numbers increasing more rapidly thereafter. While it is noted that there were differences in how cases were measured in the various countries due to differences in testing and reporting policies, differences across countries may be attributable to a variety of other factors. These include, but are not limited to, differences in the timing of the emergence of variants of concern across Europe, policy differences in restrictive measures adopted, and differing approaches to vaccination rollout.

The timing of the peaks of new hospital admissions with COVID-19 and the total number of people treated in hospital with COVID-19 in Ireland broadly corresponded with peaks observed in the incidence of cases during April 2020 and January 2021. A recent report from the Central Statistics Office (CSO) of Ireland found that people aged 65 years and older accounted for 50% of all those hospitalised with COVID-19 between March 2020 and 10 December 2021.[40] Given the intrinsic link between hospital and ICU admissions (that is, ICU admissions represent a subset of hospital admissions), a broadly similar pattern was observed for ICU admissions and the number of people with COVID-19 treated in ICU beds during the study period. Across Europe, large variation was observed over time in both the size and duration of peaks of hospital and ICU admissions, particularly during the period from October 2020 to May 2021. However, the surges experienced in Ireland were lower and of shorter duration than those experienced by other European countries.

The peaks experienced in recorded deaths with COVID-19 coincided with the peaks in hospital and ICU admissions, occurring in late April 2020 and February 2021. Notably, these two peaks in reported COVID-19 mortality were similar in magnitude, despite the number of cases recorded being substantially higher in February 2021 than in April 2020. COVID-19 death rates peaked sharply between October 2020 and June 2021 in many European countries. The peaks in Ireland were shorter in duration than those seen in many other European countries, with many other countries observing a third peak in the period after September 2021. Throughout the study period, the cumulative total rate of reported COVID-19 deaths in Ireland remained consistently lower than the EU-27 average. However, differences were observed when the cumulative data were disaggregated by age. The majority of recorded COVID-19 deaths in Ireland and in most European countries occurred in those aged 65 years and older. In this older population, the cumulative rate of reported COVID-19 deaths in Ireland exceeded that of the EU-27 average in 2020.

In 2021 this death rate slowed in Ireland, so that for the period from January 2021 to November 2021 the cumulative death rate in people aged 65 years and older was slightly lower than that of the EU-27 average. While noting that there were differences in how deaths were measured in the various countries, differences in recorded deaths across countries may be attributable to a variety of other factors. These include differences in the timing of the emergence of variants of concern across Europe, differences across countries in the proportion of the population at higher risk of severe disease (due to differences in demographics or the burden of comorbidity), policy differences in restrictive measures adopted, and differing approaches to vaccination rollout and prioritisation of vulnerable groups.

Excess (all-cause) mortality identifies the number of deaths occurring above what would be expected under normal circumstances. The majority (82%) of excess deaths in Ireland occurred among those aged 65 years and older, with 22% occurring in those aged 85 years and older. Ireland experienced two distinct peaks in excess mortality which broadly corresponded with the peaks observed for recorded COVID-19 deaths. The first was a seven-week period between late March and mid-May 2020, and the second was an eight-week period between early January and late February 2021. There was substantial variability in the magnitude and duration of peaks in excess mortality across European countries throughout the study period. Between mid- and late-2021, some countries experienced a peak in excess mortality while Ireland did not. During this time, the excess mortality in Ireland was observed to be amongst the lowest in Europe. A number of factors may have contributed to this; for example, this peak could be a result of environmental conditions that impacted public health in other European countries which were not experienced in Ireland (for example, heat waves). The absence of a third peak in Ireland could alternatively have been a consequence of Ireland's vaccination policy; this focused on an accelerated rollout in those at highest risk of exposure or severe disease and achieved high rates of coverage by June 2021, as demonstrated by the vaccination coverage data presented within this report for those aged 70 years and older.

Following the first wave, the peaks observed in Ireland in the epidemiological indicators generally appeared to be lower and shorter in duration compared with those observed in other European countries. The possible exception is the peak in reported cases in January 2021, where incidence in Ireland was one of the highest experienced in Europe that winter. This peak in cases in January 2021, and the correspondingly high COVID-19 mortality in February 2021, followed increased socialisation over the December 2020 period, combined with increased circulation of the Alpha variant. Test positivity rates were also at their highest in Ireland during January 2021, indicating that there was likely to have been under-ascertainment of cases during that time. The reduction in the stringency of public health measures, and increased social interaction and intergenerational mixing during the festive period, may have added to the intensity of this wave.

Differences in the impact of particular variants of concern were also observed between countries. For example, the Delta variant (associated with higher transmissibility, immune escape and increased disease severity) was dominant from July to November 2021 in Ireland and the rest of Europe. The numbers of new cases, and new hospital and ICU admissions, increased to a peak around the end of July 2021 in some European countries, while Ireland experienced a later and slower increase in new cases, a smaller rise in hospital admissions, and almost no apparent spikes in ICU admissions during that period. Following the reintroduction of strict restrictions in early 2021, the reopening of society (for example, reopening of the hospitality sector) progressed in Ireland through May and June 2021, thereby providing conditions for increased transmission. However, Ireland had achieved significant vaccination coverage by this time, particularly in those at highest risk of severe disease, and this likely influenced the relatively lower numbers of hospitalisations.

Contextual factors

The contextual factors included within this report help to provide an understanding of some of the factors which may have influenced the trajectory of disease burden during the COVID-19 pandemic. These contextual factors comprised baseline conditions in place prior to the pandemic and public health measures that were introduced in response to the COVID-19 pandemic.

Given the association between older age and an increased risk of COVID-19 severity,[41-43] it could be expected that countries with a younger population would have a lower burden of severe disease. The proportion of the total population in Ireland aged 65 years or older is lower than that of most other countries in Europe. Correspondingly, Ireland has a younger median age than most European countries. This age distribution may have influenced the cumulative rates of recorded COVID-19 deaths experienced, with this figure remaining consistently below the EU-27 average up until the end of November 2021. However, similar to most other European countries, the majority of COVID-19 deaths in Ireland occurred in people aged 65 years and older. As with Ireland, the high burden of mortality in older adults is likely to have influenced the vaccine rollout and public health restrictions across other European countries described within this report. As demonstrated by the data presented in Section 3.2.7, strict public restrictions were in place in Ireland up to May 2021, at which point Ireland's vaccination programme had been rolled out to the populations at highest risk of exposure or severe disease outcomes from COVID-19.[44]

While data specific to long-term residential care facilities (LTRCFs) were not examined within the present report, the rate of COVID-19 mortality in such facilities also reflects the impact of the COVID-19 pandemic on vulnerable populations. Large outbreaks have been reported in LTRCFs for older adults worldwide, with particularly high mortality reported during the first wave, and analyses have attempted to understand the impact of various contributory factors to these outbreaks and mortality figures.[45, 46] A report by the International Long-term Care Policy Network, which examined data available during the first wave of COVID-19 across 16 countries, estimated the percentage of all COVID-19 related deaths (up to 3 May 2020) that occurred in residents in LTRCFs; results ranged from 24% (Hungary) to 82% (Canada), with the estimate for Ireland standing at 62%.[47] The report concluded that the proportion of COVID-19 deaths in residents of LTRCFs tended to be lower in countries that had fewer deaths in the total population. A more recent report by the same group, considering 21 countries, found that the proportion of deaths in residents of LTRCFs decreased in most countries from June 2021, likely reflecting enhanced measures in care homes and the prioritisation of COVID-19 vaccination for older populations.[48] Supporting this, a recent study examining mortality in nursing homes across 13 European countries and the US, with data up to October 2021, reported a lower proportion of COVID-19 deaths occurring among nursing home residents per occupied nursing home bed than was reported for the first wave.[49] Mortality rates in LTRCFs will be affected by a range of factors, including population age distribution and burden of comorbidities, long-term care policies, infection prevention and control in care homes, and pandemic preparedness of the long term care sector. As described in a separate analysis by HIQA which examined factors associated with outbreaks in LTRCFs, in Ireland, the probability of an outbreak was found to increase with rising community incidence in the locality of the facility, the size of the facility in terms of the number of beds, and if there was a high density of other LTRCFs for older adults in the area.[50]

Population density can also influence the incidence and burden of COVID-19, particularly in the absence of policy measures aimed at reducing transmission through limiting interactions within the population.[51-54] In Ireland, it was demonstrated that COVID-19 transmission was reduced in areas of low population density, where it may have been less challenging to follow specific public health advice (such as implementation of physical distancing in public places), compared with areas of high population density.[55] National population density, however, does not capture the substantial variation between cities and rural areas which varies markedly within and across countries. It is also important to note that national and regional customs of interaction between individuals, and other culturally-specific behaviours, which are not captured by population density, may impact rates of COVID-19 transmission. Household size has also been shown to influence COVID-19 transmission dynamics,(56-59) and is an important risk factor for both severe and non-severe COVID-19 (even after adjustment for potential confounding by deprivation, prior morbidity and age).(57) Ireland has relatively larger households, which can make it difficult for people living together to follow public health advice in relation to self-isolation and restriction of movements, and thereby may increase COVID-19 transmission rates. Other related factors which are likely to impact transmission rates include the relative contribution of within-household transmission to disease spread and household composition. Each of these factors is in itself nuanced; for example, multigenerational households are expected to pose an increased risk of transmission to older generations. However, older adults in single-occupancy households may have been more likely to be exposed to frequent contacts with people from different households when receiving help from formal or informal carers during periods of lockdown.(60)

Hospital and ICU capacity is an important measure of the ability of a country's healthcare system to cope with a large disease burden. In Ireland, the per capita rates of both hospital beds and ICU beds are lower than those in other European countries. However, emergency provision of additional (surge) capacity was achieved in a number of countries, including Ireland, during the COVID-19 pandemic.(41, 61) Therefore, the ICU capacity reported across European countries may not fully reflect the available capacity during the COVID-19 pandemic. In Ireland, to alleviate pressure on the public system, capacity from private hospitals was leveraged and coupled with additional temporary ICU capacity in the public system.(62) Based on data provided by the National Office of Clinical Audit, surge capacity in Ireland peaked at 348 ICU beds in January 2021 compared with a baseline of 256 ICU beds in 2020.(37) National bed occupancy in ICU or high dependency units in Ireland peaked at 95% (n=330 patients) during January 2021, compared with a typical pre-pandemic occupancy rate of 90%.(8, 37) The lower numbers of admissions to hospital and critical care in Ireland, as compared with those observed in other European countries, may partly reflect the relatively young population in Ireland and the swift enactment of societal restrictions to prevent surges on health system capacity. Additionally, it is plausible that countries' hospital and ICU capacities may have impacted hospital discharge and vaccination policies with a view to managing the number of patients in hospital.

Vaccine coverage is an important contextual factor given that the protective immunity following COVID-19 vaccination can impact on disease severity and mortality rates. In this report, vaccine coverage was reported in terms of the percentage of the total population and also the percentage of people aged 70 or older that completed the primary vaccine course. Across Europe, vaccine eligibility varied between countries and over time. In Ireland, a policy of prioritising rollout to people at highest risk of COVID-19 exposure (that is, healthcare workers) or severe disease (including older adults) was implemented. This prioritisation of older adults led to higher vaccination rates being achieved earlier in those aged over 70 in Ireland compared to the EU-27 average. While providing lower levels of protection against severe disease, partial vaccination (that is, incomplete courses) also provides protective immunity. Rates of partial vaccination were not specifically considered in this report, but would have differed within these populations and across countries. The trajectory of the pandemic was also likely impacted by differences in the uptake of booster or additional vaccine doses, widespread rollout of which was underway across Europe by October 2021. By the end of November 2021, 17.4% of the total Irish population had received a booster or additional vaccine dose, which was higher than the EU-27 average (14.2%).

Considering test positivity, the number of COVID-19 cases in a country can be influenced by the testing strategy adopted and the case definition used, which can vary over time, causing fluctuations in the number of new cases recorded. The test positivity rate provides an indication of the ascertainment rate of cases of COVID-19, with increases in test positivity generally indicating lower case ascertainment.(63) This report found that there was substantial variation in test positivity both within and across countries, often indicating where testing capacity came under pressure during peaks of COVID-19 incidence. When incidence increased, there may have been a tendency for countries to focus resources on confirming symptomatic cases rather than diagnosing asymptomatic cases.

This descriptive analysis of COVID-19 epidemiological indicators and associated contextual factors across European countries, was facilitated by timely and readily available data through open sources, in particular the Our World in Data (OWID) COVID-19 data repository. The availability of publicly accessible, accurate and robust epidemiological, clinical and laboratory data is an important tool for guiding policy and public health decision-making during an epidemic.(3, 5, 39) The increasing availability of these data, which also provide opportunities for public health response evaluation and other research activities, has been supported and accelerated by the wider open-access community during the COVID-19 pandemic.(64, 65) The availability of these data across countries throughout the COVID-19 pandemic has represented an important achievement, having facilitated and accelerated research critical to understanding and responding to the COVID-19 pandemic.(66-68)

4.2 Limitations

Comparisons between countries

Cross-country comparisons made within this descriptive analysis are limited by a lack of availability of truly comparable data, and by the unit of comparison chosen (for example, comparison of individual countries, cross-country averages and the time points chosen).

Firstly, recording and reporting practices for key epidemiological data varied considerably between countries, as detailed throughout this report and discussed further detail below. As well as differences in recording and reporting, there are substantial differences across countries in factors which underlie the epidemiological data reported. These include differences in testing strategies, healthcare system capacity and structure, age distribution, vaccination coverage, social behaviour patterns and implementation of and adherence to public health guidance and restrictions. The variation in these factors necessitates caution when comparing trends between countries, while difficulty in obtaining complete data on all relevant factors limits the ability to relate individual factors to the epidemiological findings. To appropriately understand the course and burden of COVID-19 within a country it would be necessary to consider the epidemiological findings in light of the totality of that country's public health responses and in the context of the full range of relevant contextual factors.

In order to present Irish data in the context of countries that experienced COVID-19 waves and variants somewhat comparable to Ireland, this report focused on providing data for European countries only. In this sense, comparisons were also made between Ireland and the EU-27 average. The EU-27, which comprises a defined list of countries, shared some common policy responses during the pandemic, such as EU-level vaccine purchasing agreements and common travel restrictions. However, it is important to note that the EU-27 average does not reflect the experience of any one country as the experiences across European countries differed vastly at any given time point. Comparing epidemiological indicators across countries during a common wave of COVID-19 might be more appropriate than comparisons of countries at particular points in time. However, direct comparisons based on the impact of individual COVID-19 waves is problematic to undertake without a clear universal way to define when one wave ends and another begins.(69, 70)

Furthermore, there are important nuances to consider which may be overlooked in simple comparisons of waves over time. For example, it is plausible that periods with high infection rates in a particular country would be followed by reduced case numbers due to higher levels of natural immunity. However, based on the cumulative numbers of confirmed cases, the proportion of people across countries who had a confirmed case of COVID-19 was relatively low, meaning each country was still likely to have had large populations at risk (that is, non-immune) at any given time point. Additionally, other factors such as the increased transmissibility and or a lack of cross-protection between different variants may reduce the protective impact of prior infections on future case numbers at a population level.[(2)]

COVID-19 specific indicators; differences affecting data recording and reporting

In terms of incidence, the number of COVID-19 cases recorded in a country at any one time is heavily influenced by the testing strategy adopted, the capacity available in the testing system, and the case definition used. These can vary over time, causing fluctuations in the number of new cases recorded each day, which may be more pronounced where sudden policy changes occur (for example, widespread use of self-testing using rapid antigen detection tests, and the reporting, or lack of reporting, of results thereof). The number of new cases on a given day can also be affected by the return of awaited or delayed test results due to, for example, reduced testing on weekends or during holiday periods, and or the outsourcing of testing. The extent to which reporting lags differed throughout the pandemic within countries (for example, due to staff redeployment) or to which reporting lags differ between countries is not known, but may have impacted the perceived occurrence or timing of peaks. However, expression of case rates in terms of a 14-day average is expected to mitigate some of this effect.

Comparisons of hospital and ICU admissions between countries are limited by variations across countries in terms of case definitions used for reporting admissions related to COVID-19. For example, within the UK, the individual countries of England, Scotland and Northern Ireland only include confirmed COVID-19 cases in their hospitalisation counts, whereas Wales additionally includes suspected COVID-19 cases.[(71)] Similarly, Ireland measures ICU occupancy for COVID-19 confirmed patients whereas the UK measures the daily count of COVID-19 patients in mechanical ventilation beds.[(71, 72)]

Recording of COVID-19 deaths also differs substantially between countries. The actual mortality from COVID-19 internationally may be higher than the number of reported deaths, due to limited testing and different approaches in the attribution of the cause of death between countries.[(3)] In particular, the definition of a COVID-19 death used by EU countries varies considerably. As per a briefing published by the European Parliament, Ireland is one of only six EU countries that followed the ECDC definition of death due to COVID-19, which includes both laboratory confirmed COVID-19 deaths and probable COVID-19 deaths that meet clinical criteria where no virus is identified.[73-75] This broader definition will result in higher estimates of the number of COVID-19 deaths within these six countries. As highlighted in Section 2.2, some countries do not record all COVID-19 deaths (for example, Hungary only includes deaths in hospitals and deaths recorded in Spain are primarily from hospitals),[76] while others may only report deaths confirmed as due to COVID-19, as opposed to also including deaths suspected to be due to COVID-19.[77] These inconsistencies could lead to differences in country-level outcomes and limit cross-country comparisons. It is also important to note that the death figures on a given date are not necessarily the number of new deaths on that day, but comprise the deaths reported on that day, which is subject to a time lag. As previously noted, such lags may have impacted the perceived occurrence or timing of peaks, though expression of death rates in terms of a 14-day average should mitigate some of this effect.

Due to missing data in the OWID dataset for hospital admissions, data relating to the time period between 1 March and 30 April 2020 for ICU admissions and COVID-19 deaths reported in Ireland were extracted from the HPSC's Computerised Infectious Disease Reporting (CIDR) database. For consistency with the other epidemiological indicators, confirmed cases of COVID-19 reported by CIDR were also extracted for this period. There are several caveats relevant to the CIDR data. Specifically, cases are based on the date of notification, which for some cases was delayed when samples were sent to Germany for testing in March and April 2020 as demand exceeded national testing capacity at that time.[78] The hospitalisation and ICU admission figures were based on date of hospitalisation unless that preceded the date of notification, in which case it is reported according to date of notification. Additionally, the date of a COVID-19-related death is the reported date of death, not the date of notification of a COVID-19 death. Although the CIDR data present the Irish epidemiological data during March and April 2020, which was missing from the OWID, there is potential for inconsistencies between data reported in the CIDR and OWID databases arising from retrospective adjustments. It is also possible that the OWID database could be missing data for other European countries during the early stages of the pandemic.

In addition to variability in how measures were reported, missing data were also a concern regarding various indicators for many of the included countries, either during particular time periods or over the full time period of the analysis. This was particularly evident for hospital and ICU admissions data, with the data reported for these indicators in the data repositories accessed missing for over half of the included countries; this precluded the presentation of data from these countries and restricted interpretation.

Due in part to the above-described differences in recording and reporting of epidemiological indicators, this report does not formally consider the interrelationships between these indicators. For example, one epidemiological indicator that could be of interest, but that is not presented here, is the case fatality rate. The case fatality rate is the proportion of people diagnosed with COVID-19 at a given time point who subsequently died from COVID-19. Meaningful cross-country comparisons of estimates of the case fatality rate using the COVID-19 cases and deaths presented in this report would not be possible, due to an inability to accurately link individual cases and subsequent deaths, as well as due to the number and dynamic nature of external factors that would influence the estimates. These include changes in testing policies, the true number of people infected (that is, including those who are asymptomatic and undiagnosed), changes in public health mitigation measures, and COVID-19 treatment approaches.[79]

Excess mortality; differences in approach to measurement

Excess mortality can provide a more complete understanding of deaths that occurred during the pandemic as this indicator includes deaths from all causes; this avoids certain limitations of the COVID-19 death indicator, such as under-reporting of COVID-19 deaths. Excess deaths include those which may have indirectly resulted from COVID-19 (for example, where non-COVID-19 deaths may have occurred as a result of delayed treatment due to hospital capacity becoming overwhelmed or at risk of being overwhelmed in instances of high volumes of COVID-19 cases). Excess mortality also takes into account the potential for fewer deaths from other causes during the pandemic, such as lower transmission rates of other diseases and lower incidences of road deaths. As such, this measure can offer a more complete examination of the impact of the COVID-19 pandemic on mortality within a country.

The present analysis of excess mortality is based on the data and approaches of EuroMOMO; this project represents a long-standing and robust approach to the measurement of excess mortality and includes data for the majority of the countries of interest included within this analysis. As such, the excess mortality presented in this report was calculated (by HPSC and by EuroMOMO) using EuroMOMO's standardised algorithm for prediction of expected deaths. One specific limitation of the choice to use EuroMOMO data for the European countries within this report is that, as country-level excess mortality estimates are published by EuroMOMO in the form of z-scores, cross country comparisons are limited.

However, the estimate of excess deaths depends on several factors and subjective decisions. Firstly, the typical variation in mortality rates of a specific population will impact the excess mortality estimate. For example, in younger populations the number of deaths is low and, consequently, the expected variation in the number of deaths is high. As a result, a greater proportional increase in deaths among younger populations is required to exceed limits of normal variation than for older populations where mortality rates are higher. Secondly, the decisions underlying the model used to estimate expected deaths are fundamentally important. Such decisions include the historical timeframe examined and whether deaths from events, such as influenza or natural disasters, are defined as "expected." The different estimates of expected mortality underlie the different excess mortalities seen in different models. Also an 'excess' of mortality is specified according to the bounds of expected variation in excess mortality, which in turn are estimated based on a model. Therefore, mortality due to a crisis or unexpected events can potentially lie within the bounds of expected variation, due to natural variation in mortality rates between years, and thereby not be recorded as excess mortality. Conversely, normal variation could exceed what is expected and be recorded as excess mortality. It is also important to note that the calculated excess deaths indicator does not take into account the ages of those who died; age at death may be considered important as a measure of the societal impact as people lose more years of remaining life when they die at a younger age. To address this, some studies have attempted to estimate years of life lost, though, this estimate has its own assumptions and limitations.

Alternative approaches to modelling expected deaths, which involve varying degrees of complexity, have been described and discussed elsewhere.(20) As analyses of excess mortality during the COVID-19 pandemic emerge, it can be expected that different estimates of excess mortality will be produced, based on different modelling approaches adopted.(80) For example, a recently published analysis estimated fewer excess deaths in Ireland between 1 January 2020 and 31 December 2021 than reported in this present analysis.(80) As noted, the present analysis is based on the data and approaches of EuroMOMO which provides a long-standing and robust approach to the measurement of excess mortality. The relevance of results from other models will need to be considered in the context of the data sources underpinning them and the appropriateness of any cross-country comparisons that have been made.

Contextual factors

While data are provided within this report for some contextual factors which are expected to have interactions with the epidemiological indicators presented, any apparent association between contextual factors and epidemiological measures should be interpreted with caution. Furthermore, this report does not seek to provide an exhaustive description of all contextual factors and risk factors that might contribute to differences in the morbidity and mortality burden across countries. Instead, the included data are presented to indicate the heterogeneity across a small sample of factors that may be expected to influence outcomes at a national level. Other potentially important contextual factors, such as ethnicity and socioeconomic status,[81, 82] comorbidities such as obesity,[83] levels of pandemic preparedness across countries, adherence to public restrictions, and cultural factors relating to risks of exposure and transmission, are not covered in the current report.

Furthermore, the contextual factors reported here are subject to limitations, in part because they do not capture all considerations relating to the individual factors. For example, the stringency index provides a broad overview of how strict a country's pandemic response was at a given time, largely in terms of restrictive measures (for example, school and workplace closures), but does not focus on public health responses generally. As such, the stringency index does not capture policies relating to, for example, face mask use, or guidance on ventilation of buildings.

Similarly, the measure of hospital capacity presented within this report, expressed in terms of hospital beds per capita, does not capture many of the nuances associated with the efficient use of hospital beds across the wider health system. For example, the number of isolation rooms per hospital, corresponding personnel capacity, and effective transfer of patients between hospitals will all impact upon the available hospital capacity. As such, several of the contextual factors described in this report represent simplifications of wider system characteristics. Nonetheless, the presentation of these contextual factors, and the associated patterns observed, illustrates to some extent the substantial variation between countries, and indicates the complexity of the relationships between these variables and the epidemiological indicators.

5 Conclusion

This descriptive analysis demonstrated how all of the included countries across Europe, for which data were available, experienced peaks in five epidemiological indicators relating to the burden of COVID-19. The timing, magnitude and duration of those peaks varied across individual countries. Due to differences in how the outcomes were measured and reported, and given differences in demography, and in the suite of public health measures implemented across countries, it is not appropriate to directly compare these epidemiological indicators across countries.

Between March 2020 and November 2021, Ireland experienced five peaks in the incidence of COVID-19. In comparison, several European countries were observed to have a higher incidence of cases during their peaks, which may reflect true differences in incidence or that a higher proportion of cases were recorded (that is, under-ascertainment of cases was lower in those countries) due to differences in testing capacity and policy. Ireland experienced two clear peaks in hospital and ICU admissions; these occurred during April 2020 and January 2021. The peaks experienced in Ireland were substantially lower than those observed in some of the other European countries, which may reflect differences in COVID-19 incidence, in risk factors for severe disease, and or in hospital admission criteria.

Ireland also experienced two peaks in COVID-19 mortality, corresponding to the two peaks in hospitalisation and ICU admission. The first peak occurred during April 2020, and was similar in magnitude to that experienced by other European countries, while the second peak occurred during February 2021. Several European countries experienced a further peak in reported COVID-19 deaths during the period from October to November 2021.

Similar to the pattern observed in COVID-19 mortality, two distinct periods of excess mortality (all-cause deaths) were experienced in Ireland. The first occurred during a seven week period between late-March 2020 and mid-May 2020. The second occurred during an eight week period between early January 2021 and the end of February 2021. With the exception of these two periods, excess mortality in Ireland was within the bounds of normal variation between January 2020 and November 2021. Throughout the study period, it was noted that there was substantial variability in the magnitude and duration of peaks in excess mortality across European countries. Between mid- and late-2021, the excess mortality in Ireland was observed to be amongst the lowest in Europe.

A range of contextual factors that may influence the burden of disease in a country were also considered in this descriptive analysis; these include aspects of demography, healthcare capacity, and the implementation of a range of public health measures used to control the pandemic. There was substantial variation across countries in these contextual factors, thus serving to highlight the challenges in understanding the burden of disease and making comparisons across countries.

Between January 2020 and November 2021, COVID-19 resulted in a substantial burden of disease across European countries. This descriptive analysis demonstrated that the timing, magnitude and duration of peaks in the included epidemiological indicators of the burden of COVID-19 varied across individual countries in Europe. Differences in how outcomes were measured and reported, and differences in demography and in the suite of public health measures implemented, were noted. The lack of directly comparable data and the methodological challenges in determining cause and effect strongly limit direct comparisons of these epidemiological indicators, and the reasons behind their patterns, across countries.

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