*Epidemiology and Infection*

**www.cambridge.org/hyg**

# Mortality associated with Omicron and influenza infections in France before and during the COVID-19 pandemic

Edward Goldstein

Department of Ophthalmology, Harvard Medical School, Boston, MA, USA

**Original Paper**

**Cite this article:** Goldstein E (2023). Mortality associated with Omicron and influenza infections in France before and during the COVID-19 pandemic. *Epidemiology and Infection*, **151**, e148, 1–6
https://doi.org/10.1017/S0950268823001358

Received: 20 December 2022
Revised: 30 May 2023
Accepted: 25 July 2023

**Keywords:**
COVID-19; detection; influenza; mortality; Omicron

**Corresponding author:**
Edward Goldstein;
Email: edmigo3@gmail.com

## Abstract

For many deaths associated with influenza and Omicron infections, those viruses are not detected. We applied previously developed methodology to estimate the contribution of influenza and Omicron infections to all-cause mortality in France for the 2014–2015 through the 2018–2019 influenza seasons, and the period between week 33, 2022 and week 12, 2023. For the 2014–2015 through the 2018–2019 seasons, influenza was associated with annual average of 15,654 (95% CI (13,013, 18,340)) deaths, while between week 33, 2022 and week 12, 2023, we estimated 7,851 (5,213, 10,463) influenza-associated deaths and 32,607 (20,794, 44,496) SARS-CoV-2 associated deaths. For many Omicron-associated deaths for cardiac disease, mental&-behavioural disorders, and other causes, Omicron infections are not characterised as a contributing cause of death – for example, between weeks 33–52 in 2022, we estimated 23,983 (15,307, 32,620) SARS-CoV-2-associated deaths in France, compared with 12,811 deaths with COVID-19 listed on death certificate. Our results suggest the need for boosting influenza vaccination coverage in different population groups in France, and for wider detection of influenza infections in respiratory illness episodes (including pneumonia) in combination with the use of antiviral medications. For Omicron epidemics, wider detection of Omicron infections in persons with underlying health conditions is needed.

## Introduction

With the emergence of the Omicron variant of SARS-CoV-2, it became clear that the relative risk for severe outcomes of COVID-19 in adults is quite lower for the Omicron variant compared to the Delta variant [1, 2]. At the same time, the appearance of the Omicron variant led to an increase in the volume of severe outcomes (including hospitalisations and ICU admissions) in SARS-CoV-2-positive patients that were for a cause other than COVID-19 – see, for example, the data from France on hospitalisations and ICU admissions for a cause other than COVID-19 but with a SARS-CoV-2 infection versus admissions for COVID-19 [3]. This is related to differences in disease manifestation for Omicron infections versus Delta infections for both emergency department admissions [4], hospitalisations [5], and admissions to critical care [6]. In particular, Omicron epidemics make a substantial contribution to mortality for cardiac causes, cancer, Alzheimer's disease/neurological disorders, and other causes [7]. The number of deaths for different underlying causes that are triggered by an initial Omicron infection is expected to be quite higher compared with the number of deaths for COVID-19, though further work is needed to better characterise severe disease episodes for different principal causes for which the initial Omicron infection was not detected or treated (e.g. Omicron-associated acute myocardial infarction mortality in persons aged 25–44 years [8]).

In December 2022, high rates of all-cause mortality, not seen since April 2020, were recorded in France [9]. Those high rates of excess all-cause mortality were related to the Omicron and the influenza epidemics during that time. Those data provide an opportunity to estimate the volume of Omicron- and influenza-associated mortality and compare it with the number of deaths with COVID-19 or influenza listed on the death certificate. Studies suggest that only 23%–38% of influenza-associated deaths have an underlying respiratory cause of death [10–12], for which only a further fraction has influenza listed on the death certificate, with an additional significant contribution of influenza infections to mortality for circulatory and other non-respiratory causes [10, 12, 13]. Despite the high rates of influenza-associated mortality for different principal causes, frequency of testing for influenza and the related use of antiviral medications may be relatively low for various illness episodes (including pneumonia hospitalisations) during periods of active influenza circulation in the community. A U.S. study found that frequency of testing for influenza in cases of community-acquired pneumonia in the United States had increased significantly between 2010 and 2015, whereas oseltamivir use on the first day of hospitalisation in influenza-positive cases was associated with a relative risk of 0.75; 95% CI (0.59–0.96) for 14-day in-hospital mortality [14]. A French study of ICU patients with severe influenza illness showed a relatively low uptake of influenza

antiviral medications prior to ICU admission [15]. Another study of French patients with laboratory diagnosed influenza showed a higher influenza antiviral uptake [16] supporting the need for wider laboratory detection of influenza infections in France.

In addition to wider detection/treatment of Omicron and influenza infections, particularly in older individuals/persons with underlying health conditions, boosting vaccination coverage for both SARS-CoV-2 and influenza should help mitigate the spread of those infections in the community and the associated burden of severe outcomes, including deaths. Vaccination coverage for the second booster for COVID-19 in France is limited and largely restricted to persons aged over 60 years [17]. At the same time, there is evidence that vaccination reduces both the risk of acquisition of Omicron infections [18] and the risk of onward transmission of infection [19]. A French study of ICU patients with severe influenza illness found that 84.4% of those patients were eligible for influenza vaccination according to the vaccination recommendations in France, but only 52 out of 245 patients (21.2%) in whom this information was reported had been vaccinated [15]. Influenza vaccination coverage levels in different population groups in France are moderate-to-low [20], and significantly lower than influenza vaccination coverage levels in the corresponding population groups in the United States [21]. This pertains to both influenza vaccination coverage in risk groups for influenza-associated complications, and to population groups that play an important role in spreading influenza infections in the community. In particular, studies have found that children experience higher than average influenza infection rates [22] and play an important role in the spread of influenza infection in different countries [23], including France [24]. Finally, we note that during the winter of 2022–2023, the greatest relative increases in mortality in France took place in long-term care facilities for older individuals (EHPAD) [25]. Influenza vaccination rates for healthcare workers (HCWs) in EHPAD in France are quite low [26] despite evidence of a significant benefit of HCW vaccination against influenza for all-cause mortality in nursing home residents during influenza seasons [27].

In our earlier work [10, 12], we developed a method for combing data on syndromic surveillance with data on virologic surveillance to estimate rates of mortality associated with the major influenza subtypes in the United States. Subsequently, this method was applied to the estimation of influenza-associated mortality in other countries [28–30], including the EU population [30]. Here, we adopt this framework to evaluate the contribution of influenza infections to all-cause mortality for the 2014–2015 through the 2018–2019 influenza seasons, as well as the contribution of SARS-CoV-2 and influenza infections to all-cause mortality between week 33, 2022 and week 12, 2023. The reason for omitting the period between 2020 and August 2022 from the analyses is that patterns of non-COVID-19 mortality have changed during the pandemic due to lockdowns and other factors. For example, examination of mortality in England and Wales between March 2020 and June 2022 suggested that for deaths for which COVID-19 was not coded as the underlying cause of death, there was a reduction of 367,000 in the number of deaths for respiratory causes compared to averages during the previous 5 years [31]. Additionally, the heat wave in France resulted in significant levels of excess mortality in July 2022 [32]. However, starting mid-August 2023, baseline rates of mortality not associated with SARS-CoV-2 or influenza infections in France have returned to more regular patterns, which allowed for the inclusion of the period starting mid-August 2022 into the inference model in [10, 12]. The aim of this work is to help inform vaccination policies for SARS-CoV-2 and influenza, and policies for detecting/treating SARS-CoV-2 and influenza infections, particularly in persons with underlying health conditions (with Omicron-associated mortality for cardiac causes and for mental&behavioural disorders examined further in the Supplementary Material).

## Methods

### Data availability

This manuscript is based on aggregate, de-identified publicly available data. Data on weekly numbers of influenza-like illness (ILI) consultations in metropolitan France are available from the French sentinel surveillance [33]. Sentinel data on testing of respiratory specimens for the different influenza subtypes (A/H1N1, A/H3N2, B/Victoria, and B/Yamagata) are available from WHO FluNET [34]. Data on the daily number of deaths in France starting 2015 are available from [9]. Data on population in France are available from [35]. Electronic records for deaths with COVID-19 listed on the death certificate are available from [36]. We note that many SARS-CoV-2-associated deaths are not listed in [36], and weekly death rates in [36] are used as a covariate in the regression model rather than the estimate of the contribution of COVID-19, or SARS-CoV2 infections to mortality.

### Incidence indicators for the major influenza subtypes and for SARS-CoV-2-associated deaths

Not all ILI consultations in the sentinel data [33] correspond to influenza infections, and those that do, correspond to infection with different influenza subtypes. For each influenza subtype (e.g. A/H3N2), we define an indicator for the incidence of that subtype on week $t$ (e.g. $A/H3N2(t)$) as

$$A/H3N2(t) = \begin{array}{l}\text{Rate of ILI consultations per 100,000 persons on week } t \text{ in [33]} \\ \cdot \text{Percent of respiratory specimens on week } t \text{ in [34]} \\ \text{positive for influenza A/H3N2}\end{array} \quad (1)$$

To relate the incidence indicators for the major influenza subtypes to weekly levels of all-cause mortality per 100,000 persons in France [9], we note that age distribution of influenza cases changes with the appearance of antigenically novel influenza strains, and this changes the relation between rates of influenza-associated ILI (incidence indicators in equation (1)) and rates of influenza-associated mortality. The relevant antigenic changes for our study period were (a) the appearance of an antigenically/genetically novel A/H3N2 strain during the 2014–2015 influenza season [37]; (b) the appearance of the novel influenza B/Yamagata strain during the 2017–2018 season [30]; and (c) the 2018–2019 A/H3N2 epidemic strains belonging to several clades and exhibiting different immunity profiles for different birth cohorts [38]. Correspondingly, for the model relating A/H3N2 circulation to associated mortality, we split the A/H3N2 incidence indicator into three: $A/H3N2_1$, equalling the A/H3N2 incidence indicator for the period from January 2015 to September 2015, and equalling to 0 for later weeks; $A/H3N2_2$, equalling the A/H3N2 incidence indicator for the period from October 2015 to September 2018, and equalling to 0 for other weeks; and $A/H3N2_3$, equalling the A/H3N2 incidence indicator for the period starting October 2018, and equalling to 0 for other weeks. Similarly, we split the B/Yamagata incidence indicator into two, corresponding to the periods before and starting the 2017–2018 B/Yamagata epidemic. Finally, we note that it takes 1–2 weeks between influenza illness and influenza-associated mortality [10]. Correspondingly, we use a

https://doi.org/10.1017/S0950268823001358 Published online by Cambridge University Press

regression framework (equation (2))) to relate the mortality rate $M(t)$ on week $t$ to the *shifted* incidence indicators, e.g.

$$A/H3N2^s(t) = s \cdot A/H3N2(t-2) + (1-s) \cdot A/H3N2(t-1),$$

where the parameter $s$ (common for all incidence indicators) is chosen to minimise the $R^2$ for the model fit. For the estimation of the rates of SARS-CoV-2-associated deaths, we use the weekly rates $Cov_e(t)$ of deaths with COVID-19 listed on the electronic death certificate in [36] as an indicator (covariate in the regression model).

***Regression model:*** The regression model that we use is

$$\begin{aligned} M(t) = {} & \beta_1 \cdot A/H1N1^s(t) + \beta_2 \cdot A/H3N2_1^s(t) + \beta_3 \cdot A/H3N2_2^s(t) \\ & + \beta_4 \cdot A/H3N2_3^s(t) + \beta_5 \cdot B/Victoria^s(t) + \beta_6 \cdot B/Yamagata_1^s(t) \\ & + \beta_7 \cdot B/Yamagata_2^s(t) + \beta_8 \cdot Cov_e(t) + Baseline(t) \\ & + Trend(t) + Noise. \end{aligned} \tag{2}$$

The time period that we include in the analysis is week 3, 2015 through week 2, 2020, and week 33, 2022 through week 12, 2023. The baseline represents weekly rates of mortality not associated with influenza or SARS-CoV-2 circulation, and $Baseline(t)$ is modelled to have annual periodicity in week $t$. We use periodic cubic splines to model the baseline mortality rates whose shape is unknown [10, 12]. The trend $Trend(t)$ is modelled as a quadratic polynomial in week $t$. Finally, to account for the autocorrelation in the noise, we use a bootstrap procedure (resampling the noise on different weeks) to estimate the confidence bounds for various quantities evaluated in the model [10].

## Results

Figure 1 plots the results of the regression model in equation (2). The model fits in Figure 1 are generally temporally consistent, with baseline rates of non-influenza mortality + trend + the contribution of influenza infections to all-cause mortality (difference between the red and the green curves) explaining the patterns of mortality prior to the COVID-19 pandemic, while baseline + trend + contribution of influenza infections + contribution of SARS-CoV-2 infections to mortality explaining the patterns of mortality between week 33, 2022 and week 12, 2023 (with SARS-CoV-2 infections being responsible for most of excess mortality during that period).

Table 1 gives the estimates of the contribution of influenza infections to all-cause mortality for the 2014–2015 through the 2018–2019 influenza seasons, and the contribution of SARS-CoV-2 and influenza infections to all-cause mortality between week 33, 2022 and week 12, 2023. For the 2014–2015 through the 2018–2019 seasons, influenza was associated with an annual average of 15,654 (95% CI (13,013, 18,340)) deaths, whereas between week 33, 2022 and week 12, 2023, we estimated 7,851 (5,213, 10,463) influenza-associated deaths and 32,607 (20,794, 44,496) SARS-CoV-2-associated deaths.

Data on mortality with COVID-19 listed on the death certificate in France are available through the end of 2022 [36]. For the period between weeks 33–52 in 2022, we estimated 23,983 (15,307, 32,620) SARS-CoV-2-associated deaths in France, compared with 12,811 deaths with COVID-19 listed on the death certificate [36], and 8,639 in-hospital deaths with COVID-19 during the same period [39].

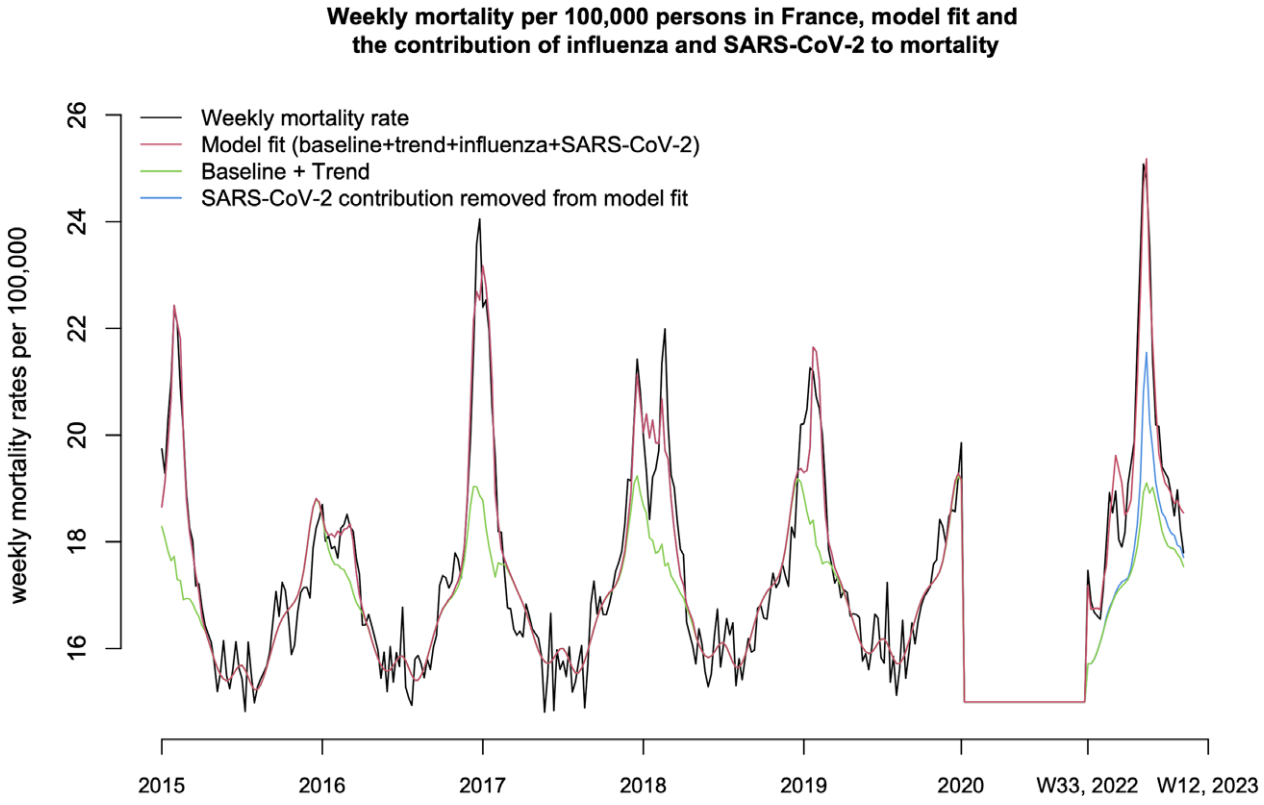


**Figure 1.** Weekly mortality rates for all causes between week 3, 2015 and week 2, 2020, and week 33, 2022 and week 12, 2023 (black curve), the baseline + trend for the rates of mortality not associated with influenza or SARS-CoV-2 infections in France (green curve), the model fit (baseline + trend + contribution of influenza infection +contribution of SARS-CoV-2 infection to mortality, red curve), and the model fit between week 33, 2022 and week 12, 2023 with the contribution of SARS-CoV-2 infection removed.

https://doi.org/10.1017/S0950268823001358 Published online by Cambridge University Press

**Table 1.** The contribution of influenza infection to all-cause mortality for the 2014–2015 through the 2018–2019 influenza seasons, and the contribution of SARS-CoV-2 and influenza infections to all-cause mortality between week 33, 2022 and week 12, 2023

| Season | Influenza-associated deaths | SARS-CoV-2-associated deaths |
|---|---|---|
| 2014–2015 | 19,779 (15,438, 24,122) | |
| 2015–2016 | 5,432 (902, 9,932) | |
| 2016–2017 | 21,997 (17,891, 26,067) | |
| 2017–2018 | 19,138 (13,599, 24,838) | |
| 2018–2019 | 11,925 (8,632, 15,245) | |
| Annual average, 2014–2015 to 2018–2019 seasons | 15,654 (13,013, 18,340) | |
| Week 33, 2022 to week 12, 2023 | 7,851 (5,213, 10,463) | 32,607 (20,794, 44,496) |

## Discussion

During the winter of 2022–2023, high levels of excess mortality (not seen since the first COVID-19 wave in April 2020) were recorded in France [9], with excess mortality being primarily associated with the Omicron epidemic [3], but also the influenza epidemic during that period [40]. The emergence of the Omicron variant saw a higher proportion of ICU admissions and deaths with a SARS-CoV-2 infection which were for causes other than COVID-19 compared to the earlier SARS-CoV-2 variants [3]. Additionally, most influenza-associated deaths do not have influenza listed on the death certificate [10, 12]. A better understanding is required of the contribution of SARS-CoV-2 and influenza infections to hospitalisations and mortality for different principal causes to inform vaccination policies for SARS-CoV-2 and influenza, and policies for detecting/treating SARS-CoV-2 and influenza infections, particularly in persons with underlying health conditions.

We have estimated (15,307, 32,620) SARS-CoV-2-associated deaths in France between weeks 32–52 in 2022, compared with 12,811 deaths with COVID-19 listed on the death certificate during the same period. In the Supplementary Material, we show a significant contribution of Omicron infections to mortality for cardiac disease and for mental&behavioural disorders without COVID-19 being listed on the death certificate. A significant contribution of Omicron infections to mortality for cardiac causes, cancer, Alzheimer's disease/neurological disorders, and other causes was also found in [7]. Those findings suggest the need to widen the detection/treatment of Omicrons infections, particularly in individuals with underlying health conditions, as well as the need to increase COVID-19 booster vaccination coverage in the whole population to mitigate SARS-CoV-2 transmission in the community. We have also estimated that influenza was responsible for high levels of associated mortality prior to the pandemic, with an average of 15,654 (95% CI (13,013, 18,340)) annual deaths associated with influenza infections during the 2014–2015 through the 2018–2019 seasons, as well as 7,851 (5,213, 10,463) influenza-associated deaths between week 33, 2022 and week 12, 2023. Influenza vaccination coverage in non-elderly adults and in children in France is quite lower compared with the United States [20, 21], with children known to play a significant role in influenza transmission in the community [22–24]. Residents of establishments for dependent elderly persons (EHPAD) in France represent a sizeable share of all-cause mortality [41] and influenza-associated mortality in the French population. Rates of influenza vaccination for HCWs in EHPAD in France are quite low [26], while HCW vaccination against influenza has a significant effect on all-cause mortality in nursing home residents during influenza seasons [27]. Additionally, influenza vaccine effectiveness in older individuals can be quite low [42], and types of influenza vaccines administered to older individuals play a role in preventing adverse outcomes associated with influenza infections. In the United States, recent Advisory Committee on Immunization Practices recommendations stipulate that adults aged ≥65 years should preferentially receive any one of the following higher dose or adjuvanted influenza vaccines: quadrivalent high-dose inactivated influenza vaccine (HD-IIV4), quadrivalent recombinant influenza vaccine (RIV4), or quadrivalent adjuvanted inactivated influenza vaccine (aIIV4) [43]. Finally, antiviral medications for influenza are prescribed quite frequently in France when an influenza infection is laboratory-detected [16], while antiviral treatment of influenza infection in hospitalisations for respiratory causes, including pneumonia, was found to have benefits in terms of reducing mortality rates in hospitalised patients [14].

Our results have some limitations. Influenza surveillance data in France pertain to mainland France [33], whereas we have used data on mortality for the whole of France. Additionally, sentinel data on testing for viral specimens [34] have a moderate sample size and may not represent all of France. We note that influenza epidemics exhibit a great deal of temporal synchrony [44, 45] which should help address the above limitations. Finally, despite the fact that we split some of the influenza subtype incidence indicators into several time periods, where might still be temporal variability in the relation between the incidence indicators used in this paper and rates of associated mortality? For example, while model fits are generally temporally consistent (Figure 1), the model fit for the mortality data for the 2017–2018 season is worse compared with other influenza seasons, which might be related to the fact that the influenza subtypes that circulated during that season (A/H1N1 and B/Yamagata) have different age distributions feeding into one ILI data stream.

### *Conclusions*

Our findings about the high rates of influenza-associated mortality in France, the very high rates of influenza-associated mortality in individuals aged over 75 years during certain influenza seasons in France [46], and the low influenza vaccination rates in HCWs in France [26] suggest the need for (a) boosting influenza vaccination rates for HCWs and other population groups, possibly including children; and (b) wider testing for influenza infection in respiratory illness episodes with different principal diagnoses (including pneumonia) during periods of active influenza circulation in combination with the use of antiviral medications [14]. In the event of the recrudescence of Omicron circulation in France, efforts should be undertaken to administer booster vaccination for COVID-19 to HCWs, with coverage levels for booster vaccines containing the Omicron component in HCWs in France being relatively low [3]. Wider detection and treatment of Omicron infections, particularly in older individuals/persons with underlying health conditions such as cardiac disease and mental/behavioural disorders (Supplementary Material) should help mitigate the mortality burden of future Omicron epidemic waves.

**Supplementary material.** The supplementary material for this article can be found at http://doi.org/10.1017/S0950268823001358.

https://doi.org/10.1017/S0950268823001358 Published online by Cambridge University Press

**Data availability statement.** This manuscript is based on aggregate, de-identified publicly available data that can be accessed through the links in references [9, 33–36].

**Author contribution.** Conceptualization: E.G.; Formal analysis: E.G.; Investigation: E.G.; Methodology: E.G.; Software: E.G.; Writing – original draft: E.G.; Writing – review & editing: E.G.

**Financial support.** This work received no specific grant from any funding agency, commercial, or not-for-profit sectors.

**Competing interest.** The author declares no competing interests exist.

## References

[1] **Nyberg T, Ferguson NM, Nash SG, Webster HH, Flaxman S, Andrews N, Hinsley W, Bernal JL, Kall M, Bhatt S, Blomquist P, Zaidi A, Volz E, Aziz NA, Harman K, Funk S, Abbott S, Hope R, Charlett A, Chand M, Ghani AC, Seaman SR, Dabrera G, de Angelis D, Presanis AM, Thelwall S, Nyberg T, Ferguson NM, Nash SG, Webster HH, Flaxman S, Andrews N, Hinsley W, Lopez Bernal J, Kall M, Bhatt S, Blomquist P, Zaidi A, Volz E, Abdul Aziz N, Harman K, Funk S, Abbott S, Hope R, Charlett A, Chand M, Ghani AC, Seaman SR, Dabrera G, de Angelis D, Presanis AM and Thelwall S** (2022) Comparative analysis of the risks of hospitalization and death associated with SARS-CoV-2 Omicron (B.1.1.529) and Delta (B.1.617.2) variants in England: A cohort study. *The Lancet* **399** (10332), 1303–1312.

[2] **Auvigne V, Vaux S, Strat YL, Schaeffer J, Fournier L, Tamandjou C, Montagnat C, Coignard B, Levy-Bruhl D and Parent du Châtelet I** (2022) Severe hospital events following symptomatic infection with Sars-CoV-2 Omicron and Delta variants in France, December 2021–January 2022: A retrospective, population-based, matched cohort study. *eClinicalMedicine* **48**, 101455.

[3] **Santé publique France** (2022) Santé publique France. InfoCovidFrance: Chiffres clés et évolution de la COVID-19 en France et dans le Monde. Available at https://www.santepubliquefrance.fr/dossiers/coronavirus-covid-19/coronavirus-chiffres-cles-et-evolution-de-la-covid-19-en-france-et-dans-le-monde (accessed 10 April 2023).

[4] **Bouzid D, Visseaux B, Kassasseya C, Daoud A, Fémy F, Hermand C, Truchot J, Beaune S, Javaud N, Peyrony O, Chauvin A, Vaittinada Ayar P, Bourg A, Riou B, Marot S, Bloom B, Cachanado M, Simon T, Freund Y, IMProving Emergency Care (IMPEC) FHU Collaborators Group, Salmona M, le Goff J, Veyer D, Chocron R, Augustin C, Rozenberg F, Meritet JF, Schnuriger A, Fourati S, Khellaf M, Coulomb A, Gindre F, Aloui K, Jacquier H, Eyer X, Choquet C, Ing V, Pavlovsky T, Houhou-Fidouh N, Ferré V, Landraud L, Goulet H, Yordanov Y, Berard L, Rousseau A, Morel T, Vieux T, Cahen S, Saib M, Salmona M, le Goff J, Veyer D, Chocron R, Augustin C, Rozenberg F, Meritet JF, Schnuriger A, Fourati S, Khellaf M, Coulomb A, Gindre F, Aloui K, Jacquier H, Eyer X, Choquet C, Ing V, Pavlovsky T, Houhou-Fidouh N, Ferré V, Landraud L, Goulet H, Yordanov Y, Berard L, Rousseau A, Morel T, Vieux T, Cahen S and Saib M** (2022) Comparison of patients infected with Delta versus Omicron COVID-19 variants presenting to Paris emergency departments: A retrospective cohort study. *Annals of Internal Medicine* **175**(6), 831–837.

[5] **Leiner J, Pellissier V, Hohenstein S, König S, Schuler E, Möller R, Nachtigall I, Bonsignore M, Hindricks G, Kuhlen R and Bollmann A** (2022) Characteristics and outcomes of COVID-19 patients during B.1.1.529 (Omicron) dominance compared to B.1.617.2 (Delta) in 89 German hospitals. *BMC Infectious Diseases* **22**(1), 802.

[6] **de Prost N, Audureau E, Heming N, Gault E, Pham T, Chaghouri A, de Montmollin N, Voiriot G, Morand-Joubert L, Joseph A, Chaix ML, Préau S, Favory R, Guigon A, Luyt CE, Burrel S, Mayaux J, Marot S, Roux D, Descamps D, Meireles S, Pène F, Rozenberg F, Contou D, Henry A, Gaudry S, Brichler S, Timsit JF, Kimmoun A, Hartard C, Jandeaux LM, Fafi-Kremer S, Gabarre P, Emery M, Garcia-Sanchez C, Jochmans S, Pitsch A, Annane D, Azoulay E, Mekontso Dessap A, Rodriguez C, Pawlotsky JM and Fourati S** (2022) Clinical phenotypes and outcomes associated with SARS-CoV-2 variant Omicron in critically ill French patients with COVID-19. *Nature Communications* **13**, 6025.

[7] **Australian Bureau of Statistics** (2023). COVID-19 mortality by wave. Available at https://www.abs.gov.au/articles/covid-19-mortality-wave (accessed 10 April 2023).

[8] **Yeo YH, Wang M, He X, Lv F, Zhang Y, Zu J, Li M, Jiao Y, Ebinger JE, Patel JK, Cheng S and Ji F** (2023) Excess risk for acute myocardial infarction mortality during the COVID-19 pandemic. *Journal of Medical Virology* **95**(1), e28187.

[9] **Institut national de la statistique et des études économiques (INSEE)** (2023) Nombre de décès quotidiens France, régions et départements. Available at https://www.insee.fr/fr/statistiques/4931039?sommaire=4487854#tableau-figure1 (accessed 10 April 2023).

[10] **Goldstein E, Viboud C, Charu V and Lipsitch M** (2012) Improving the estimation of influenza-related mortality over a seasonal baseline. *Epidemiology* **23**(6), 829–838.

[11] **Hansen CL, Chaves SS, Demont C and Viboud C** (2022) Mortality associated with influenza and respiratory syncytial virus in the US, 1999–2018. *JAMA Network Open* **5**(2), e220527.

[12] **Quandelacy TM, Viboud C, Charu V, Lipsitch M and Goldstein E** (2014) Age- and sex-related risk factors for influenza-associated mortality in the United States between 1997–2007. *American Journal of Epidemiology* **179** (2), 156–167.

[13] **Kwong JC, Schwartz KL, Campitelli MA, Chung H, Crowcroft NS, Karnauchow T, Katz K, Ko DT, McGeer AJ, McNally D, Richardson DC, Rosella LC, Simor A, Smieja M, Zahariadis G and Gubbay JB** (2018) Acute myocardial infarction after laboratory-confirmed influenza infection. *The New England Journal of Medicine* **378**(4), 345–353.

[14] **Deshpande A, Klompas M, Yu PC, Imrey PB, Pallotta AM, Higgins T, Haessler S, Zilberberg MD, Lindenauer PK and Rothberg MB** (2022) Influenza testing and treatment among patients hospitalized with community-acquired pneumonia. *Chest* **162**(3), 543–555.

[15] **Fartoukh M, Voiriot G, Guérin L, Ricard JD, Combes A, Faure M, Benghanem S, de Montmollin E, Tandjaoui-Lambiotte Y, Vieillard-Baron A, Maury E, Diehl JL, Razazi K, Lemiale V, Trouiller P, Planquette B, Savale L, Heming N, Marey J, AP-HP Clinical Data Warehouse, Carrat F, Lapidus N, The EPIcuFLU_APHP Group, Djibré M, Teboul JL, Messika J, Demoule A, Mira JP, Timsit JF, Cohen Y, Page B, Mekontso Dessap A, Azoulay E, Sanchez O, Humbert M, Annane D and Roche N** (2021) Seasonal burden of severe influenza virus infection in the critically ill patients, using the assistance Publique-Hôpitaux de Paris clinical data warehouse: A pilot study. *Annals of Intensive Care* **11**, 117.

[16] **Cizeron A, Saunier F, Gagneux-Brunon A, Pillet S, Cantais A and Botelho-Nevers E** (2021) Low rate of oseltamivir prescription among adults and children with confirmed influenza illness in France during the 2018–19 influenza season. *Journal of Antimicrobial Chemotherapy* **76** (4), 1057–1062.

[17] **Gouvernement de la République française** (2023). Vaccins (COVID-19). Available at https://www.gouvernement.fr/info-coronavirus/vaccins (accessed 10 April 2023).

[18] **Chin ET, Leidner D, Lamson L, Lucas K, Studdert DM, Goldhaber-Fiebert JD, Andrews JR and Salomon JA** (2022) Protection against Omicron from vaccination and previous infection in a prison system. *The New England Journal of Medicine* **387**(19), 1770–1782.

[19] **Tan ST, Kwan AT, Rodríguez-Barraquer I, Singer BJ, Park HJ, Lewnard JA, Sears D and Lo NC** (2023) Infectiousness of SARS-CoV-2 breakthrough infections and reinfections during the Omicron wave. *Nature Medicine* **29**, 358–365.

[20] **Robert J, Detournay B, Levant MC, Uhart M, Gourmelen J and Cohen JM** (2020) Flu vaccine coverage for recommended populations in France. *Médecine et Maladies Infectieuses* **50**(8), 670–675.

[21] **US Centers for Disease Control and Prevention** (2022) Flu Vaccination Coverage, United States, 2019–20 Influenza Season. Available at https://www.cdc.gov/flu/fluvaxview/coverage-1920estimates.htm (accessed 10 April 2023).

[22] **Monto A, Koopman J and Longini IM** (1985) Tecumseh study of illness. XIII. Influenza infection and disease, 1976–1981. *American Journal of Epidemiology* **102**, 553–563.

[23] **Worby CJ**, **Chaves SS**, **Wallinga J**, **Lipsitch M**, **Finelli L and Goldstein E** (2015) On the relative role of different age groups in influenza epidemics. *Epidemics* **13**, 10–16.

[24] **Cauchemez S**, **Valleron AJ**, **Boëlle PY**, **Flahault A and Ferguson NM** (2008) Estimating the impact of school closure on influenza transmission from sentinel data. *Nature* **452**, 750–754.

[25] **Institut national de la statistique et des études économiques (INSEE)** (2023) Daily deaths files broken down by sex, age and place of death. Available at https://www.insee.fr/en/statistiques/4493808?sommaire=4493845 (accessed 10 April 2023).

[26] **Santé Publique France** (2023) Quelle est la couverture vaccinale contre la grippe des résidents et des professionnels en établissements médico-sociaux?. Available at https://www.santepubliquefrance.fr/maladies-et-traumatismes/maladies-et-infections-respiratoires/grippe/documents/enquetes-etudes/quelle-est-la-couverture-vaccinale-contre-la-grippe-des-residents-et-des-professionnels-en-etablissements-medico-sociaux-point-au-3-juillet-2023 (accessed 3 juillet 2023).

[27] **Goldstein E** (2023) Benefits of influenza vaccination of healthcare workers. *Cochrane Reviews/Commentary*. Available at https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD005187.pub5/detailed-comment/en?messageId=409503002# (accessed 30 July 2023).

[28] **Pebody RG**, **Green HK**, **Warburton F**, **Sinnathamby M**, **Ellis J**, **Mølbak K**, **Nielsen J**, **de Lusignan S and Andrews N** (2018) Significant spike in excess mortality in England in winter 2014/15 – Influenza the likely culprit. *Epidemiology and Infection* **146**(9), 1106–1113.

[29] **Rosano A**, **Bella A**, **Gesualdo F**, **Acampora A**, **Pezzotti P**, **Marchetti S**, **Ricciardi W and Rizzo C** (2019) Investigating the impact of influenza on excess mortality in all ages in Italy during recent seasons (2013/14–2016/17 seasons). *International Journal of Infectious Diseases* **88**, 127–134.

[30] **Nielsen J**, **Vestergaard LS**, **Richter L**, **Schmid D**, **Bustos N**, **Asikainen T**, **Trebbien R**, **Denissov G**, **Innos K**, **Virtanen MJ**, **Fouillet A**, **Lytras T**, **Gkolfinopoulou K**, **Heiden M**, **Grabenhenrich L**, **Uphoff H**, **Paldy A**, **Bobvos J**, **Domegan L**, **O'Donnell J**, **Scortichini M**, **de Martino A**, **Mossong J**, **England K**, **Melillo J**, **van Asten L**, **de Lange MMA**, **Tønnessen R**, **White RA**, **da Silva SP**, **Rodrigues AP**, **Larrauri A**, **Mazagatos C**, **Farah A**, **Carnahan AD**, **Junker C**, **Sinnathamby M**, **Pebody RG**, **Andrews N**, **Reynolds A**, **McMenamin J**, **Brown CS**, **Adlhoch C**, **Penttinen P**, **Mølbak K and Krause TG** (2019) European all-cause excess and influenza-attributable mortality in the 2017/18 season: Should the burden of influenza B be reconsidered? *Clinical Microbiology and Infection* **25**(10), 1266–1276.

[31] **Office for National Statistics, UK** (2022) Excess deaths in England and Wales: March 2020 to June 2022. Available at https://www.santepubliquefrance.fr/dossiers/coronavirus-covid-19/coronavirus-chiffres-cles-et-evolution-de-la-covid-19-en-france-et-dans-le-monde (accessed 10 April 2023).

[32] **Santé Publique France** (2022) Bulletin de santé publique canicule. Bilan été 2022. Available at https://www.santepubliquefrance.fr/determinants-de-sante/climat/fortes-chaleurs-canicule/documents/bulletin-national/bulletin-de-sante-publique-canicule.-bilan-ete-2022 (accessed 10 April 2023).

[33] **Réseau Sentinelles, France** (2022) Surveillance continue. Available at https://www.sentiweb.fr/france/fr/?page=table (accessed 10 April 2023).

[34] **World Health Organization** (2022) Influenza virus detections reported to FluNET. Available at https://app.powerbi.com/view?r=eyJrIjoiNjViM2Y4NjktMjJmMC00Y2NjLWFmOWQtODQ0NjZkNWM1YzNmIiwidCI6ImY2MTBjMGI3LWJkMjQtNGIzOS04MTBiLTNkYzI4MGFmYjU5MCIsImMiOjh9 (accessed 10 April 2023).

[35] **Institut national de la statistique et des études économiques (INSEE)** (2022) Évolution et structure de la population. Available at https://www.insee.fr/fr/statistiques?debut=0&theme=1 (accessed 10 April 2023).

[36] **The Institut national de la santé et de la recherche médicale (INSERM)** (2022) Données sur la Covid-19 du centre d'épidémiologie sur les causes médicales de décès de l'Inserm. Available at https://opendata.idf.inserm.fr/cepidc/covid-19/telechargements (accessed 10 April 2023).

[37] **Skowronski DM**, **Chambers C**, **Sabaiduc S**, **de Serres G**, **Winter AL**, **Dickinson JA**, **Krajden M**, **Gubbay JB**, **Drews SJ**, **Martineau C**, **Eshaghi A**, **Kwindt TL**, **Bastien N and Li Y** (2016) A perfect storm: Impact of genomic variation and serial vaccination on low influenza vaccine effectiveness during the 2014–2015 season. *Clinical Infectious Diseases* **63**(1), 21–32.

[38] **Kissling E**, **Pozo F**, **Buda S**, **Vilcu AM**, **Gherasim A**, **Brytting M**, **Domegan L**, **Gómez V**, **Meijer A**, **Lazar M**, **Vučina VV**, **Dürrwald R**, **van der Werf S**, **Larrauri A**, **Enkirch T**, **O'Donnell J**, **Guiomar R**, **Hooiveld M**, **Petrović G**, **Stoian E**, **Penttinen P and Valenciano M**, **I-MOVE primary care study team** (2019) Low 2018/19 vaccine effectiveness against influenza a(H3N2) among 15–64-year-olds in Europe: Exploration by birth cohort. *Euro Surveillance* **24**(48), 1900604.

[39] **Santé publique France** (2023) Données hospitalières relatives à l'épidémie de COVID-19. Available at https://www.data.gouv.fr/fr/datasets/donnees-hospitalieres-relatives-a-lepidemie-de-covid-19/ (accessed 10 April 2023).

[40] **Santé publique France** (2023) Bulletin épidémiologique grippe, semaine 15. Saison 2022–2023. Available at https://www.santepubliquefrance.fr/maladies-et-traumatismes/maladies-et-infections-respiratoires/grippe/documents/bulletin-national/bulletin-epidemiologique-grippe-semaine-15.-saison-2022-2023 (accessed 10 April 2023).

[41] **Botton J**, **Drouin J**, **Bertrand M**, **Jabagi MJ**, **Weill A**, **Zureik M and Dray-Spira R** (2021) Fréquence des décès et des hospitalisations chez les résidents des établissements d'hébergement pour personnes âgées dépendantes (EHPAD) et des unités de soin longue durée (USLD) en France au cours des années 2018 et 2019. EPI-PHARE – Groupement d'intérêt scientifique (GIS). Available at https://www.epi-phare.fr/app/uploads/2021/02/epi-phare_rapport_deces_hospit_hors-ehpad_20210205.pdf (accessed 30 July 2023).

[42] **US Centers for Disease Control and Prevention** (2023) Past seasons vaccine effectiveness estimates. Available at https://www.cdc.gov/flu/vaccines-work/past-seasons-estimates.html (accessed 10 April 2023).

[43] **US Centers for Disease Control and Prevention. Morbidity and Mortality Weekly Report (MMWR)** (2022) Prevention and Control of Seasonal Influenza with Vaccines: Recommendations of the Advisory Committee on Immunization Practices – United States, 2022–23 Influenza Season. Available at https://www.cdc.gov/mmwr/volumes/71/rr/rr7101a1.htm?s_cid=rr7101a1_w (accessed 10 April 2023).

[44] **Schanzer DL**, **Langley JM**, **Dummer T and Aziz S** (2011) The geographic synchrony of seasonal influenza a waves across Canada and the United States. *PLoS One* **6**(6), e21471.

[45] **Morris SE**, **Freiesleben de Blasio B**, **Viboud C**, **Wesolowski A**, **Bjørnstad ON and Grenfell BT** (2018) Analysis of multi-level spatial data reveals strong synchrony in seasonal influenza epidemics across Norway, Sweden, and Denmark. *PLoS One* **13**(5), e0197519.

[46] **Santé publique France** (2019) Bulletin épidémiologique hebdomadaire. Available at http://beh.santepubliquefrance.fr/beh/2019/28/pdf/2019_28_1.pdf (accessed 10 April 2023).

https://doi.org/10.1017/S0950268823001358 Published online by Cambridge University Press