Canadian Studies in Population (2021) 48:139–164
https://doi.org/10.1007/s42650-021-00053-z

ORIGINAL ARTICLE

Counting the Dead: COVID-19 and Mortality in Quebec and British Columbia During the First Wave

Yann Décarie[1] **· Pierre-Carl Michaud**[1,2]

Received: 11 November 2020 / Accepted: 9 August 2021 / Published online: 17 September 2021

Abstract

The first wave of the COVID-19 pandemic has led to excess mortality across the globe, and Canada has been no exception. Nonetheless, the pandemic experience has been very different across provinces, and the objective of this paper is to investigate these differences focusing on two extreme cases. We contrast the mortality experience of British Columbia with that of Québec to understand how large differences in mortality during the first wave of the pandemic emerged across these two provinces. We find that most of the differences can be found in excess mortality in institutions (nursing homes) and that travel restrictions, differences in how deaths are recorded, differences in the seasonality of the flu, or differences in how the pandemic spread across different economic segments of the population are unlikely explain these large differences. We document that the reported death toll from COVID-19 is about 30% larger than excess mortality in Quebec due to lower mortality from other causes of death, in particular malignant tumors, heart disease, and respiratory problems. We do not find evidence of an income gradient (measured by postal code level income) in relative excess death for the first wave.

Keywords Excess mortality · COVID-19 · Nursing homes · Cause of death

Résumé

La première vague de la pandémie de la COVID-19 a entraîné une surmortalité dans plusieurs pays à travers le monde, incluant le Canada. Par contre, l'ampleur fut bien différente à travers les provinces canadiennes et l'objectif de cette analyse est d'étudier ces différences en se concentrant sur deux provinces spécifiques. Pour ce faire, nous comparons la mortalité de la Colombie-Britannique avec celle du Québec pour tenter de comprendre les grandes différences observées entre ces deux provinces durant la première vague de la pandémie. On constate qu'une grande partie de la sur-

✉ Pierre-Carl Michaud
pierre-carl.michaud@hec.ca

1 HEC Montreal, 3000 chemin Cote-Ste-Catherine, Montreal H3T 2A7, Canada

2 CIRANO, Montreal, Canada

mortalité différentielle est observée chez les personnes vivant en institutions de santé (maisons de soins). De plus, on remarque aussi que les restrictions concernant les déplacements internationaux, les processus d'enregistrement des décès, l'évolution de la grippe saisonnière ou les différences dans la façon dont la pandémie s'est propagée à travers les groupes sociaux-économiques de la population sont peu susceptibles d'expliquer ces grandes différences. Notre analyse montre que le nombre de décès attribués à la COVID-19 est d'environ 30% plus élevé que la surmortalité observée au Québec durant la première vague. Cet écart est, en partie, attribuable à une mortalité plus faible de d'autres causes de décès, en particulier les tumeurs malignes, les maladies cardiaques et les problèmes respiratoires durant la même période. Finalement, nous n'avons pas été en mesure de calculer un gradient de revenu (mesuré par le revenu au niveau du code postal) pour les décès excédentaires survenus lors de la première vague.
Mots clés: excès de mortalité, COVID-19, institutions de santé, cause de décès

1 Introduction

As of August 2021, the COVID-19 pandemic has led to more than four million deaths worldwide (World Health Organization[1]). One of the most comprehensive measure of the mortality burden of a pandemic is excess mortality. It measures the extent to which total mortality (from all causes) deviates from mortality expected in the absence of the pandemic, based on historical data (Zylke & Bauchner, 2020; Viglione; Simonsen et al., 1998). This avoids comparing apples and oranges because countries may assign causes of death in different ways, rendering comparisons difficult. Furthermore, excess mortality allows to look at the indirect effects of the pandemic on mortality from other causes (Lange et al., 2020). There is considerable variation across countries in mortality due to the pandemic (Kontis et al., 2020; Beaney et al., 2020; Khafaie & Rahim, 2020; Goldstein & Lee, 2020).

This paper focuses on the mortality experience of Canadian provinces in the first wave of the pandemic using individual level deaths records from Statistics Canada as of August 2020. Despite their best efforts, Canadian provinces have lagged in their mortality reporting. Moreover, there are also methodological differences—for example, some provinces adjust their data for inevitable reporting delays (Brookmeyer & Damiano, 1989), while others do not. British Columbia and Quebec are two examples where data is typically reported to Statistics Canada within 30 days.[2]

Yet, the mortality experience in Quebec and British Columbia during the first wave of the pandemic could not be more different. According to provincial authorities, 6214 COVID-19 deaths had been reported by Quebec as of October 30, against 263 in British Columbia (for a respective population of 8.4 M and 5.7 M, i.e., about

[1] https://www.who.int/emergencies/diseases/novel-coronavirus-2019

[2] Statistics Canada reports that Ontario and New Brunswick produce data with at least a 60-day delay while other provinces report within 30 days. This is problematic for looking at outcomes from the first wave as of August 2020 since the first wave was still ongoing in June 2020.

50% larger in Quebec). How can these numbers be so different, within the same country (Bignami & Van Assche, 2020), and in two provinces which otherwise have more in common than what separates them? This paper aims to answer this question.

We use individual-level death records from the August 28 release of Statistics Canada's Vital Statistics Database[3] (CVSD). An advantage of individual-level data is to allow for analysis of excess mortality by subgroups, including by age, institutional status, and income (at the postal code level). We first look at the total number of deaths by week and province and discuss data quality in Section 2. Overall, despite some differences, we find that STC data for British Columbia and Quebec seem to be of equal quality, in particular in terms of first wave experience. Even though there is a difference between STC and provincial (ISQ) data for Quebec, the difference is minor (less than 5%). But the gap in total mortality between the two provinces is abysmal when using an excess mortality modeling consisting, for both provinces, of Poisson models of weekly death counts. We then document differences between both provinces in socio-economic characteristics, in travel restrictions and in the strength of the flu season. We find that although some of these differences may yield slightly higher mortality in Quebec, none of these factors is likely to explain the gap.

Next, we investigate differences in excess mortality by subgroups of age, place of death, and income. We estimate that most of the gap is found in institutions (nursing homes). Given the—already high—mortality rate of this subgroup, cumulative excess mortality is quite large, with excess mortality rates increasing by 150% in Quebec but only 60% in British Columbia. Interestingly, we do not find evidence that excess mortality (as a fraction of expected mortality) differed by income at the postal code level. We then discuss how reports of COVID-19 deaths compare with the excess death measures we compute. We find that for Quebec COVID-19 deaths are more numerous than excess deaths. We show using cause of death data that this is because of a decrease in deaths due to other causes, in particular cancer, heart disease, and respiratory problems.

2 Data and Methods

The main data source used in this analysis is the August 28, 2020 release of the Canadian Vital Statistics Database (CVSD) – Death database, which we accessed from the Quebec inter-University Centre for Social Statistics (QICSS), part of the Canadian Research Data Centre Network (CRDCN). This is an administrative database that includes demographic and medical (cause of death) information from all provincial and territorial vital statistics registries on all deaths in Canada. We used data from 2015 to July 2020, the last month available at the time. According to Statistics Canada, the 2016 to 2019 data are considered preliminary due to improvements in methodology and timeliness which shortened the duration of data collection. The data for 2020 are considered provisional due to the shortened duration of data collection. The cause of death variable in the CVSD – Death database is

[3] https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3233

available until June 2020 and uses the World Health Organization's "International Statistical Classification of Diseases and Related Health Problems" version 10 (ICD-10). In addition to the cause and date of death, information such as the following is available: age, sex, marital status, income group (at postal code level), place of residence, and place of birth of the deceased.

We use these data to compute excess mortality in the aggregate and for particular subgroups. To do so, we group mortality at the weekly level (epidemiological week, from 1 to 52). Like several other research projects (including at the CDC[4] and EUROMOMO[5]), we model the count of the number of weekly deaths using a Poisson process (Farrington et al., 1996; Thompson et al., 2003; Vestergaard et al., 2020) with, in this specific analysis, multiplicative expectation in week and year fixed effects,

$$\lambda_{w,t} = e^{\gamma_t} e^{\gamma_w}$$

where $\lambda_{w,t}$ represents the expected number of deaths for epidemiological week w and year t, γ_t is the estimated parameter for year t, and γ_w is the estimated parameter for week w. We estimate fixed effects over data from January 2015 to the 1st of March 2020. We choose a fixed effects specification in order to avoid specifying a functional form for the year and month trends.[6] For some analysis, we will estimate such a process by subgroup (e.g., age, income at zip code level).

The literature offers a number of ways for computing weekly excess mortality (Noufaily et al., 2012; Maëlle et al., 2014; Xie et al., 2014; Aron et al., 2020; Adair et al., 2020; Choinière, 2020; Statistics Canada 2020a; Michaud, 2020). One is to compute the deviation between the actual number of deaths, denote by $d_{w,t}$ (the number of deaths in week w of year t) and the expected number of deaths, or

$$E^1_{w,t} = max\left(d_{w,t} - \lambda_{w,t}, 0\right).$$

Another we also explore is to use the upper bound of the 95% confidence interval of $\lambda_{w,t}$ and only count deaths above that threshold,

$$E^2_{w,t} = max\left(d_{w,t} - \lambda^U_{w,t}, 0\right)$$

where $\lambda^U_{w,t}$ is the upper bound of the confidence interval.

To compare Quebec and British Columbia, we also use the following data sources in various ways to explore differences in excess mortality:

[4] https://www.cdc.gov/nchs/nvss/vsrr/covid19/excess_deaths.htm#techNotes

[5] https://www.euromomo.eu/how-it-works/methods

[6] Our results are not sensitive to the assumption of function form on month and year effects. A negative binomial specification gives similar estimates for excess deaths, while a log-linear specification also gives similar results. This is expected since given a correct conditional specification of deaths, quasi maximum likelihood is consistent with fixed effects if the true process has a distribution from the linear exponential family. Confidence intervals vary slightly across specifications. In what follows, we use the Poisson specification. Estimates using other specifications are available upon request.

- Preliminary dataset on confirmed cases of COVID-19, Public Health Agency of Canada
- Weekly number of deaths in Quebec 2010–2020, Institut de la statistique du Québec
- Detailed daily epidemiological reports issued by the Government of Canada
- FluWatch weekly report data
- Google Search Index from Google Trends

Confirmed cases are available on the Statistics Canada website.[7] In collaboration with the Public Health Agency of Canada (PHAC), this data file provides Canadians and researchers with preliminary data to monitor only confirmed cases of COVID-19 in Canada. According to Statistics Canada and given the rapidly evolving nature of the situation, these data are considered preliminary.

Weekly number of deaths in Quebec, 2010–2020 (retrieved October 2020) is a dataset provided by the *Institut de la statistique du Québec* (ISQ)[8] containing the number of deaths per week from all causes by sex, age group, and regional grouping. These data will be used to show the comparability of the data between provincial and national statistical agencies and investigate the methodological implications of data incompleteness.

The data on the number of tests or positivity rates are taken from the Epidemiological update publicly available on the Government of Canada website.[9] This information is based on data from provincial and territorial partners (complete list available on the webpage).

Data on the 2020 flu season are available through the Public Health Agency of Canada.[10] They are provided by provincial and territorial authorities (complete list available on the webpage). Data have been collected from the weekly reports using tabula-py.[11]

We also use data coming from Google Trends. Google Trends is a trend search feature that shows the popularity of a search term in Google, allowing one to view whether a trend is on the rise or declining. For this analysis, we collect the Google Search Index which reflects the proportion of searches for a given keyword for a specific region (Canada) and time period (2020), compared to the region with the highest usage rate for that keyword (value of 100). Under the assumption that research interest reflects the travel intention, data on Internet search intensity for the main international airport of each province can provide some understanding of the potential differential "spring break effect."

7 https://www150.statcan.gc.ca/n1/en/catalogue/13260003

8 https://statistique.quebec.ca/en/document/weekly-number-of-deaths-in-quebec

9 https://health-infobase.canada.ca/covid-19/epidemiological-summary-covid-19-cases.html

10 https://www.canada.ca/en/public-health/services/diseases/flu-influenza/influenza-surveillance/weekly-influenza-reports.html

11 https://pypi.org/project/tabula-py/

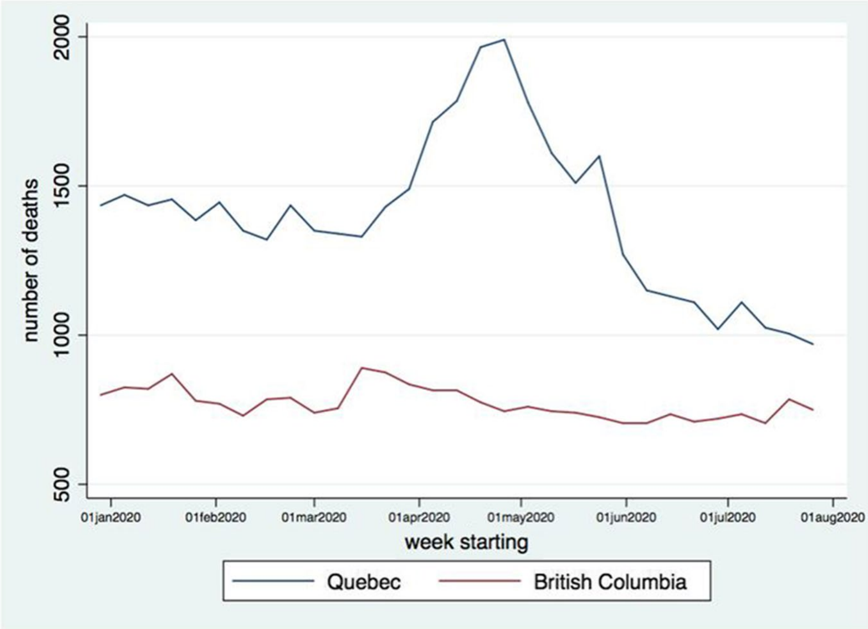


Fig. 1 Weekly number of deaths in Quebec and British Columbia. Source: CVSD data (August 28, 2020 release)

3 Overall Mortality in 2020

From the CVSD, we have the exact date of death for each death reported to Statistics Canada, as well as a number of characteristics for each death record including age, sex, marital status, income group, place of residence, place of death, and place of birth of the deceased. We compute weekly deaths using the definition of epidemiological weeks from the US Centers for Disease Control and Prevention (CDC).[12] In Fig. 1, we show unadjusted raw death counts for both provinces, computed directly from the data.

At the time of writing this paper, the observed discrepancies—in timing, methods and regional agencies involved—in the deaths reporting by provinces led us to decide against adjusting for reporting delays using the reporting delay factors by week computed by Statistics Canada.[13] One way to check the effect of omitting these reporting delay adjustments is to compare our mortality series to that produced

[12] We use the epiweek package available in Stata (Chu, 2010).

[13] Statistics Canada publishes estimates of excess deaths which include adjustments for delays. We have requested access to the reporting adjustments, and these will be included in the future. We expect this to have a minor effect for our focus on the first wave.

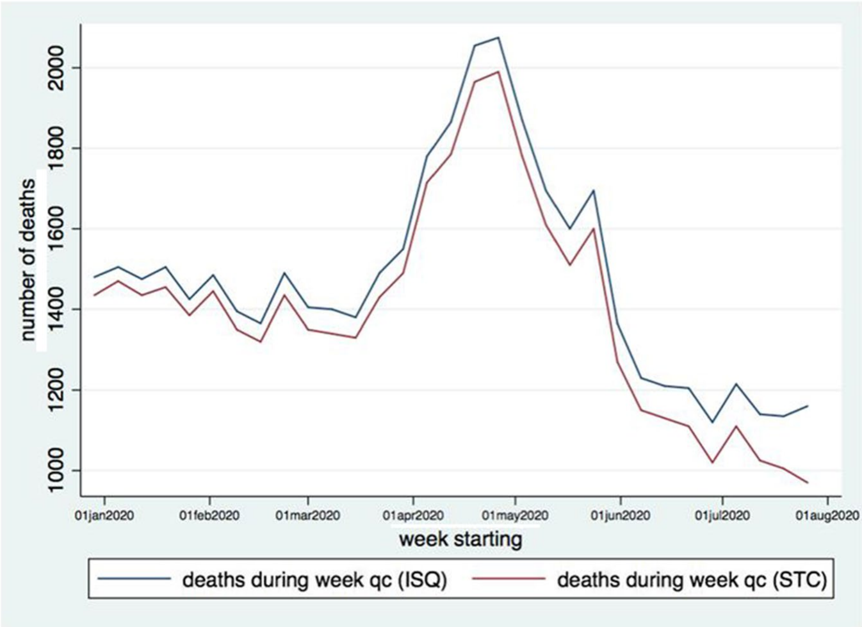


Fig. 2 Comparison of weekly death counts in Quebec: CVSD and ISQ. Source: CVSD data (August 28, 2020 release) and weekly number of deaths in Quebec (data of ISQ)

by a statistical agency that adjusts counts for reporting delays. For this, we use the data compiled by the Quebec statistical agency (ISQ), which also produces its own reporting delay model for data on deaths per week. We use this data as benchmark as the ISQ was updating the data more frequently (every 2 weeks) and was closely involved in the regional specificities of data collection.[14] In Fig. 2, we compare the (unadjusted) CVSD and (adjusted) ISQ weekly counts for Quebec. Overall, there is little difference between the counts until June, other than a slightly lower level leading to a small underestimate of mortality with CSVD data with a limited effect on the overall results as the database completeness rate reaches 90% after 8 weeks and 95% after 26 weeks. The differences can be explained by data transmission delays, and the adjustment method to take into account the database completeness.[,1516]

By comparison, unadjusted data from Ontario shows a rapidly declining pattern of deaths beginning in June, which is likely due to the fact that reporting usually takes place 2 months after the death occurred. Hence, we focus on British Columbia and Quebec for our analysis, two provinces where we observe a similar 4-week delay between death and the first available report.

[14] https://statistique.quebec.ca/en/document/weekly-number-of-deaths-in-quebec

[15] https://statistique.quebec.ca/en/document/weekly-number-of-deaths-in-quebec/publication/weekly-number-of-deaths-in-quebec-data-sources-and-methodology

[16] https://www.statcan.gc.ca/eng/statistical-programs/document/3233_D5_V1

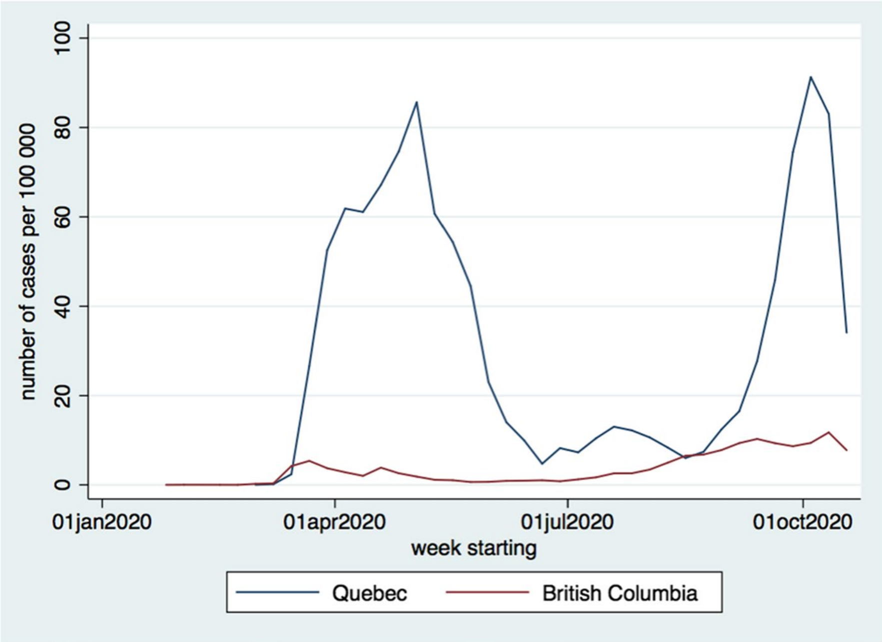


Fig. 3 Number of COVID-19 cases detected per 100,000 residents. Source: COVID-19 Statistics Canada data accessed October 2020. The number of cases is expressed per 100,000 individuals

4 COVID-19, the Seasonal Flu, and Spring Break

The extent to which the virus affected both provinces is of course likely to be in part responsible for the differing death toll. Figure 3 shows the number of cases reported in both provinces over time. Clearly, the number of cases per 100,000 residents is much higher in Quebec than in British Columbia.

Looking at test data clearly shows that Quebec has tested much more than British Columbia. But the ratio of cases detected to tests per week shows that the fraction positive was much higher in Quebec (see Fig. 10 in the Appendix). Because of differences in testing strategies, we do not make much more of these data, other than conclude that the total mortality data is consistent with the pandemic hitting harder in Quebec than in British Columbia.

4.1 Seasonal Flu

The seasonal flu is a key determinant of seasonal movements in mortality, in particular in the winter months (Troeger et al., 2019; Acosta et al., 2019; Fleury-Payeur, 2017). Although it is highly improbable that differences in flu dynamics explain differences in mortality across these two provinces in the spring, we use data from the

Flu Watcher program[17] to look the incidence of influenza of types A and B. For type A, the season seemed to start earlier in Quebec but had reached similar levels in both provinces by late April. For type B, the incidence in Quebec was higher than in British Columbia over the entire season (see Fig. 11 in the Appendix). Even if some research shows that complications related to influenza B affect children more (Tran et al., 2016) and that influenza A(H3N2) has typically been associated with higher infection rates, more severe clinical symptoms and higher mortality rates than other subtypes (Thompson et al., 2003; Wu et al., 2012), differences between Quebec and British Columbia in terms of influenza B incidence may require further analysis but are unlikely to explain the scale of excess mortality that was observed.

4.2 Spring Break

It was often mentioned in the media (and the government) that spring break in Quebec had taken place earlier than in other provinces. Indeed, Quebec's spring break varies across school districts but a large fraction of public schools, especially in the Montreal region, had their 2020 spring break in the week of March 2–6. By comparison, spring break was set to be in late March in British Columbia, after the start of the pandemic. Hence, this could be one of the reasons why the virus spread more quickly in Quebec, particularly if people travelled more around that time. Yet, the situation had very little effect on how air travel evolved during the weeks preceding and following the imposition of travel restrictions in Canada. Data on the number of passengers at major airports is not available on a weekly basis. Thus, we use the Google Search Index for YVR (Vancouver airport) and YUL (Montreal airport). We remark that the index did not drop at a different pace across airports (the index is normalized to its level in January 2020; see Fig. 12 in the Appendix). There is some indication of a blimp in searches for YUL in mid-February, before spring break, which could be correlated with elevated travel volume (Godin et al., 2021).

5 Excess Mortality

In this section, we present the comparison between Quebec and British Columbia of observed mortality during the first pandemic wave. In Fig. 4, we first show the historical number of deaths by week and year for Quebec and British Columbia. Generally, mortality is higher at the beginning and end of the year and reaches a minimum somewhere in the summer months. The year 2020 clearly stands out for British Columbia, but all the more so for Quebec. We estimate Poisson models separately for Quebec and British Columbia over the pre-COVID period (January 2015 to March 1, 2020).

In Fig. 5, we plot the E^1 measure of excess mortality using the average predicted count. We do this using both CVSD data for Quebec and British Columbia as well

[17] https://www.canada.ca/en/public-health/services/diseases/flu-influenza/influenza-surveillance.html

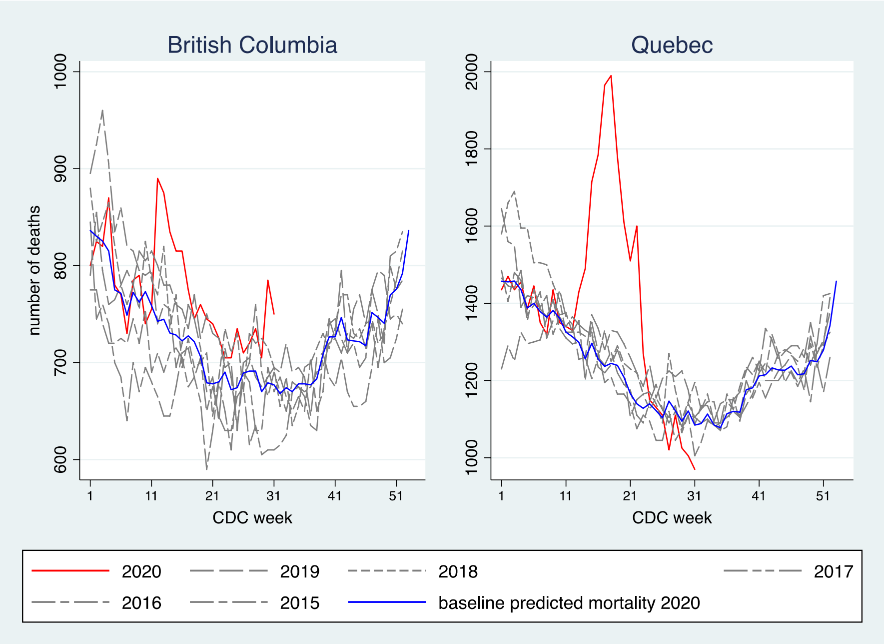


Fig. 4 Historical data on weekly mortality for Quebec and British Columbia. Source: CVSD data. The left panel shows data for British Columbia while the right panel shows data for Quebec

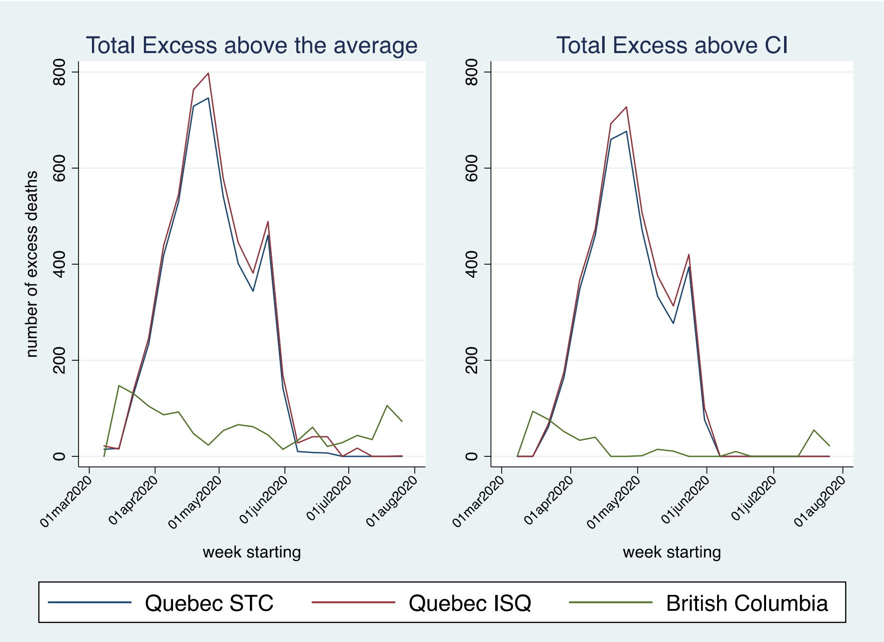


Fig. 5 Excess mortality in Quebec and British Columbia. Source: CVSD and ISQ data

Table 1 Total excess deaths, March to July 2020

Province and data	Total excess deaths above the expected average	Total excess deaths above upper bound of 95% CI	Total deaths
Quebec: CVSD	4732.4 (16.1%)	3921.6 (13.4%)	29,335
Quebec: ISQ	5295.8 (16.9%)	4227.9 (13.5%)	31,235
British Columbia: CVSD	1273.8 (7.9%)	409.47 (2.6%)	16,025

Source: Excess counts are computed using Poisson regressions and two measures of excess mortality. In the first data column, we show the cumulative total number of excess deaths using excess above the expected number of deaths (counting negative excess deaths as zero). In the second data column, excess deaths are computed relative to the upper bound of the 95th percentile confidence interval for the expected number of counts. Each cell also reports the number of excess deaths as a percentage of excess deaths (in parenthesis).

as using aggregate data from ISQ for Quebec. The picture is quite clear: excess mortality was much higher in Quebec than it was in British Columbia. Interestingly, however, excess mortality started being observed earlier in British Columbia than in Quebec but then was abruptly reduced by the end of the month of March.

In Table 1, we compare the cumulative total number of excess deaths in Quebec and British Columbia using the two measures of excess mortality (at the mean and above the upper bound of the confidence interval). We also report them as a percentage of total deaths. Hence, mortality was 16.1% higher during the first wave than what would be expected in Quebec while the comparable number is 7.9% in British Columbia.

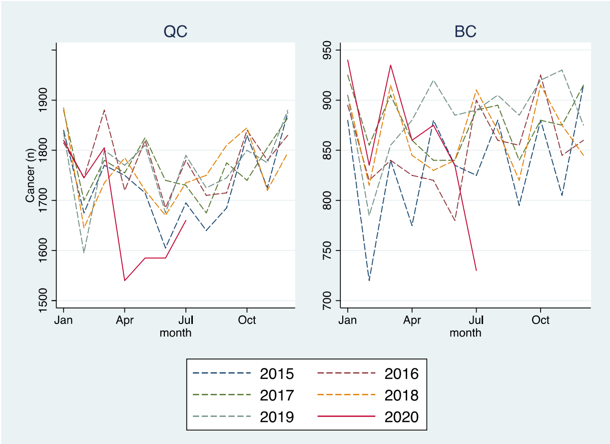
These figures of excess deaths are lower than the declared number of COVID-19 deaths during the period of March to July for both indicators in Quebec and for the second one in British Columbia (which were around 200 for British Columbia and just over 6000 for Quebec according to CSVD database). This is interesting and may suggest three underlying mechanisms:

1. Other causes of death went down, for instance because of reduced economic activity (Peeples, 2019; Strumpf et al., 2017)
2. Some deaths that would have been assigned another cause were attributed to COVID (Woolf et al., 2020)
3. Those who died from COVID would have died anyway from other causes during the same period (Luy et al, 2020; Toulemon & Barbieri, 2008)

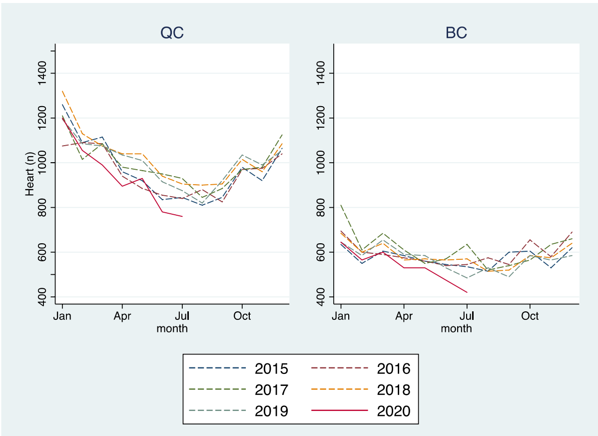
5.1 Excess Mortality by Cause of Death

To investigate this possibility, we use cause of death data reported by Statistics Canada at the monthly level (Statistics Canada, 2020b). Because data for July 2020 was incomplete at the time of writing this paper, we stop in June, meaning the results we obtain are not directly comparable to the ones shown in Table 1. However, we observe that excess mortality was around zero while the average

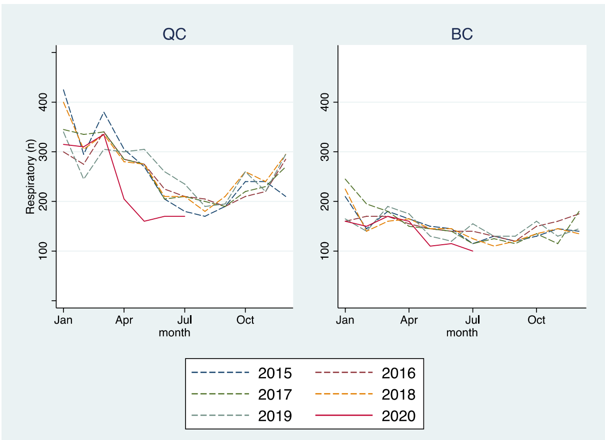
Malignant Tumors



Heart Disease



Respiratory Problems



◀ **Fig. 6** Number of deaths from selected causes in Quebec and British Columbia. Source: CVSD data for Quebec (left panel) and British Columbia (right panel)

number of daily new COVID-19 cases was steady at around 100 at the beginning of the summer 2020; this leads us to consider the end of the first wave of COVID-19. Indeed, after that point we should consider analyses over a longer period to capture the possible indirect effects (positive or negative) of the health measures implemented.

One example of a potentially negative effect on death numbers is accidents in both Quebec and British Columbia during the first wave (see Fig. 13 in the Appendix). However, those numbers should be analyzed with caution as the number is quite small, and those deaths have a higher probability to be under coroner investigation. However, there was also a decrease in the number of deaths, most notably in Quebec, from causes more strongly associated with the elderly—a particularly heavily hit group as we will see later: Fig. 6 shows the evolution of deaths from malignant tumors, heart disease and respiratory problems for Quebec and British Columbia. We see, particularly in Quebec, an abrupt drop in deaths from malignant tumors and respiratory problems. To quantify the importance of these effects, we perform an accounting exercise.

We first compute excess deaths from each of 12 causes using Poisson models at the monthly frequency. We also re-estimate the Poisson regressions for the monthly total number of deaths, this time projecting excess deaths up until June

Table 2 Monthly excess mortality by cause of death and COVID deaths, March to June 2020

Causes	British Columbia	Quebec
Excess mortality from…		
Accidents	−77.8	−120.3
Alzheimer	29.3	−38.5
Cancer	−45.0	−570.5
Cerebrovascular	−53.6	−127.1
Diabetes	29.1	−48.1
Flu and pneumonia	−0.8	−100.4
Heart disease	−67.1	−279.0
Non-specified	206.7	−6.1
Nephropathy	9.3	−46.6
Other	245.8	−134.1
Respiratory	20.5	−213.5
Suicide	−54.6	−151.3
Total of excess non-COVID deaths	**241.7**	**-1,835.5**
COVID deaths	170.0	6,060.0
Total of excess non-COVID and COVID deaths	**411.7**	**4,224.5**
Excess mortality computed from total deaths by cause	**760.2**	**4,322.1**

Source: Statistics Canada monthly cause of death data from January 2015 to June 2020. Excess mortality is computed from a Poisson model with month and year fixed effects. This is done for each cause of death in each province. Both positive and negative excess mortality is counted

2020. As we show in Table 2 (last row), total excess mortality is 760 for British Columbia and 4322 for Quebec, thus lower at the monthly level than at the weekly level shown previously. The reported number of deaths from COVID-19 in these data until June inclusively were 170 for British Columbia and 6060 for Quebec. If we sum the excess mortality from other, non-COVID causes of death, we get a positive number for British Columbia (242 deaths) while we get − 1836 deaths for Quebec; the number of reported deaths from cancer is 570 lower than expected in Quebec from March to June, and we see a similar decrease for almost all causes of death in Quebec. This suggests that cause of death was assigned generously to COVID-19 (particularly for causes with symptoms similar to those of the virus), or that individuals who got COVID-19 were very likely to die from one of these conditions within the period even in the absence of COVID (most vulnerable older individuals). It is difficult to separate these effects. For British Columbia, there is the potential for the total death toll from COVID-19 to be under-estimated, since cause of death is left unspecified for a significant number of deaths (207). We also observe that the sum of excess non-COVID deaths and COVID deaths is similar for Quebec to excess mortality from all causes of death (the last row of Table 2, which differs from the previous one by less than 100 deaths).

5.2 Excess Mortality by Age

In Fig. 7, we show the weekly number of deaths for various age groups. Excess mortality is apparent mostly for those age 70 +, in both Quebec and British Columbia. For BC, we see that the early peak during the pandemic is mostly the result of elevated mortality among the 80 to 89 years old group. In Quebec, the entire 70 + group experienced excess mortality.

We perform excess mortality calculations for each age group, which accounts for seasonal shifts in mortality by age group. We report excess mortality in number and in percentage terms to grasp the relative increase in mortality by age group. In the top panel of Fig. 8, we show that while excess mortality is observable in British Columbia and Quebec, the scale and the timing of the increase in the number of deaths was quite different among the elderly. While we observe excess deaths only in the early days of the pandemic in British Columbia, the increase in Quebec was more important for those aged 80 years old and over and more modest for those aged 70 to 79.

However, when looking at the percentage of excess deaths by age group (bottom panel), British Columbia and Quebec seem to have had a very different experience during the first wave of the pandemic. In British Columbia, the percentage of excess deaths was higher among the population aged under 59 years old, while in Quebec, the higher percentage was observed for those aged 70 and older. This difference can be explained by the increase of illicit drug toxicity deaths in British Columbia. More British Columbians died from illicit drug overdoses than from COVID-19 in the first 8 months of 2020 (Norton & Kerr, 2020). For example, in June 2020, the province recorded its

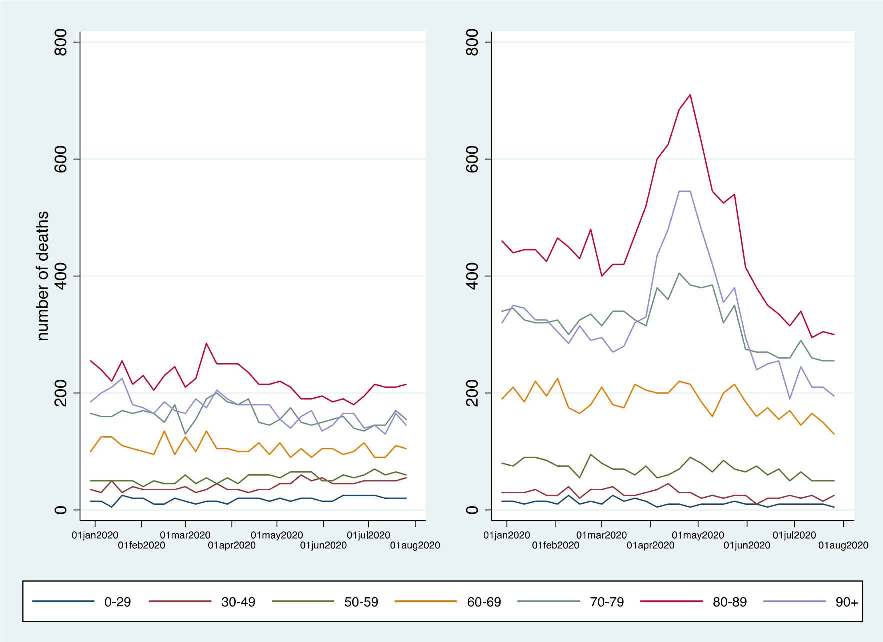


Fig. 7 Weekly mortality by age group. Source: CVSD data for British Columbia (left panel) and Quebec (right panel)

worst number of opioid-related deaths ever at 183, up from 76 in June of 2019 (British Columbia Coroners Service (2021)), compared to 10 deaths officially attributed to COVID-19.

5.3 Deaths in Institutions

Since most of the deaths occurred in older age groups, we might assess whether these occurred in institutions and estimate the extent of excess mortality there. Mortality rates are high in nursing homes (Fisman et al., 2020; Sepulveda et al., 2020), and therefore, we want to know by how much they have increased. The CVSD contains information about place of death. In Fig. 9, we show excess mortality (in percent) for those dying in nursing homes and outside nursing homes. Interestingly, excess mortality occurred in both settings in British Columbia at the beginning of the pandemic. While excess mortality was higher (in relative terms) in institutions, there was a 20% increase in mortality in the community as well. In Quebec, there was no such increase at the beginning of the pandemic. Instead, excess mortality in institutions started appearing later in March. At the peak of the pandemic, excess mortality represented an increase of more than 150% in mortality rates in institutional settings (hence 2.5 times what

Fig. 8 Excess mortality and proportion of excess deaths by age group. Source:CVSD data. Excess mortality obtained using Poisson regression models with week and year fixed effects. "Percent excess deaths" (bottom panel) is the ratio of weekly excess deaths and weekly expected deaths from the model

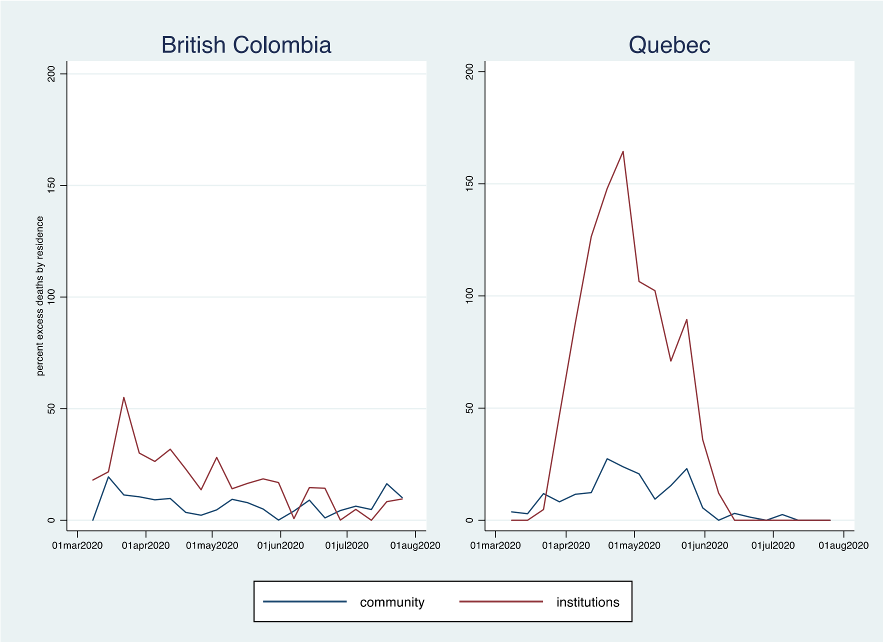


Fig. 9 Excess mortality by place of death. Source: CVSD data. Excess mortality relative to expected count using Poisson regressions with month and year fixed effects by place of death (institutions vs. community)

is observed normally). Total excess deaths were larger for females than males, but this is largely the result of the much larger female populations in nursing homes. Estimates of excess mortality by age between men and women reveal very similar patterns.

It is important to understand why these differences in institutions came about. Some evidence from comparing the Ontario and the British Columbia responses

Table 3 Total expected and excess deaths by income quintile

Income quintile	Quebec			British Columbia		
	Expected (A)	Excess (B)	% (B/A*100)	Expected (A)	Excess (B)	% (B/A*100)
Q1	3572	1116	31	2244	223	10
Q2	3884	890	23	2017	160	8
Q3	3593	888	25	1528	193	13
Q4	3935	654	33	1334	114	9
Q5	1920	573	30	795	105	13
Total	15,854	4122	26	7927	795	10

Source: CVSD data. Excess mortality relative to expected count using Poisson regressions with month and year fixed effects by income quintile.

to the pandemic has identified as key the decision of BC health officials to prohibit personnel movement across nursing homes (Liu et al., 2020). We think that understanding how the pandemic creeped into nursing homes in Quebec should be a research priority.

5.4 Excess Mortality by Income

In terms of cases, it has been documented that the pandemic was hitting harder poorer neighborhoods (Choi et al., 2020; McKie, 2020; Krieger et al., 2020). An interesting question is whether this translated into a higher mortality burden in these areas. The CVSD has postal code information for each death. Until 2011, information on household income quintile of the neighborhood was included in the dataset. Since the rank of neighborhoods in terms of income is unlikely to have changed much over the last 10 years, we use that measure of income for the period 2015–2020 of our mortality data to look at excess mortality.[18] We perform excess mortality Poisson regressions by income quintile for both Quebec and British Columbia. Table 3 shows the total number of expected and excess deaths by income quintile for Quebec and British Columbia during the first wave of the pandemic.

Looking only at the absolute number of excess deaths (columns B), the mortality burden of the first wave of the pandemic seems to have fallen disproportionately on lower income neighborhoods in both provinces. This discrepancy could, in part, be explained by working conditions that leave people more exposed to the virus and by smaller dwellings, which would reflect a more general health disparity observed not only during the pandemic (Woolf & Braveman, 2011; Frohlich et al., 2006). However, it is important to note that in relative terms, as a fraction of *expected* mortality (which reflects the non-COVID mortality gradient), excess mortality is in fact quite similar for all quintiles of the distribution in both provinces. Therefore, there is no evidence in these data that COVID-19 affected the population differently by income quintile than general mortality. This result may be specific to the first wave where conditions in institutions were probably much more important than community conditions in the surrounding neighborhood.

6 Conclusion

In this paper, we show how the first wave of COVID-19 hit hard in Quebec compared to British Columbia. The timing of spring break and the profile of the flu season cannot explain these large differences. Instead, the results

[18] Not all postal codes in 2015–2020 have a match to the 2011 postal code series for income quintile. Among those without a match (roughly 33%), there does not appear to be excess deaths in Poisson regressions. Results available upon request.

show that, in terms of mortality in Quebec, persons aged 80 years old and over and those living in a nursing home were much more affected than in British Columbia. For those aged over 80, the excess reaches double the number of deaths typically observed. For those living in a nursing home, excess mortality represents an increase of more than 150% of the expected values at the peak of the pandemic and it represents 6 times the excess deaths of those living in private households, compared to 3 times in British Columbia. However, age and living in a nursing home are not the only factors related to a higher risk of severe disease or death from COVID-19 (Jordan et al. 2020); some medical conditions also related to this most vulnerable population should be taken into account (Government of Canada, 2020; Centers for Disease Control & Prevention, 2020; Wang et al., 2020). We reconcile the difference between reported COVID-19 deaths in Quebec and estimates of excess deaths by noting that mortality from other causes of death went down, rather than up, during the pandemic. This could signal that some of those who died from COVID-19 would have died of another cause during the observation period, or that COVID-19 was assigned as a cause of death for records where perhaps the cause of death was unclear or a mixture of multiple causes. These lower-than-expected non-COVID deaths are important and represent up to one third of the COVID-reported deaths in Quebec. In British Columbia, we find an increase in deaths from unspecified causes during the pandemic, which could signal that COVID-19 deaths were under-reported there.

Even if we need to be cautious with this kind of comparison due to the sensitivity of the data, we think that we can learn from the different practices in place to reduce the burden of upcoming waves for people living in institutions. One could think of British Columbia as a good counterfactual of what would have happened if Quebec took measures quickly to avoid deaths and contagion in nursing homes. For example, it remains to be seen whether movement of personnel contributed to the spread of the virus in nursing homes, but casual observation from the media suggests that it did. If the counterfactual holds, then excess deaths measured for Quebec relative to British Columbia serve as an estimate of the lives lost due to suboptimal practices in Quebec nursing homes. Once data becomes more complete, there is the potential to put a dollar figure on the costs of mismanagement in nursing homes using those estimates. Aside from the issue of assigning a proper value to a life year for these estimates, one has to be careful to assign the correct number of years of life lost—which could be an even more difficult task. Using mortality tables for the general population appears inadequate. If those that died in nursing homes were likely to die in the following weeks, then the number of life years lost might be much smaller than if one uses mortality life tables to impute them as for a given age, the life expectancy of those living in a nursing home is smaller the those living in private household.

Appendix

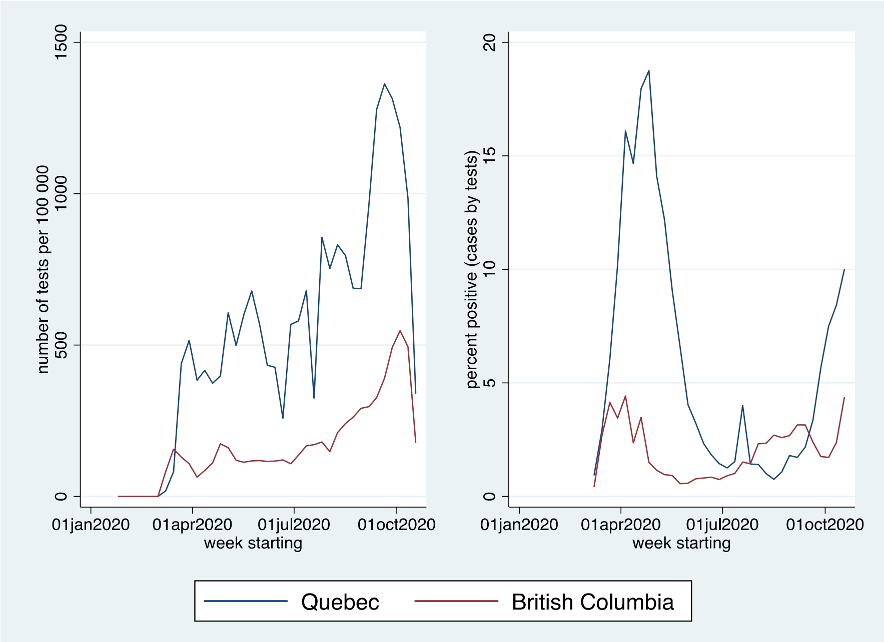


Fig. 10 COVID-19 tests per 100,000 residents and fraction positive. Source: Statistics Canada COVID-19 Data accessed October 2020. The left panel shows the number of tests per 100,000 residents while the right panel shows the ratio of the weekly number of cases to the weekly number of tests carried out

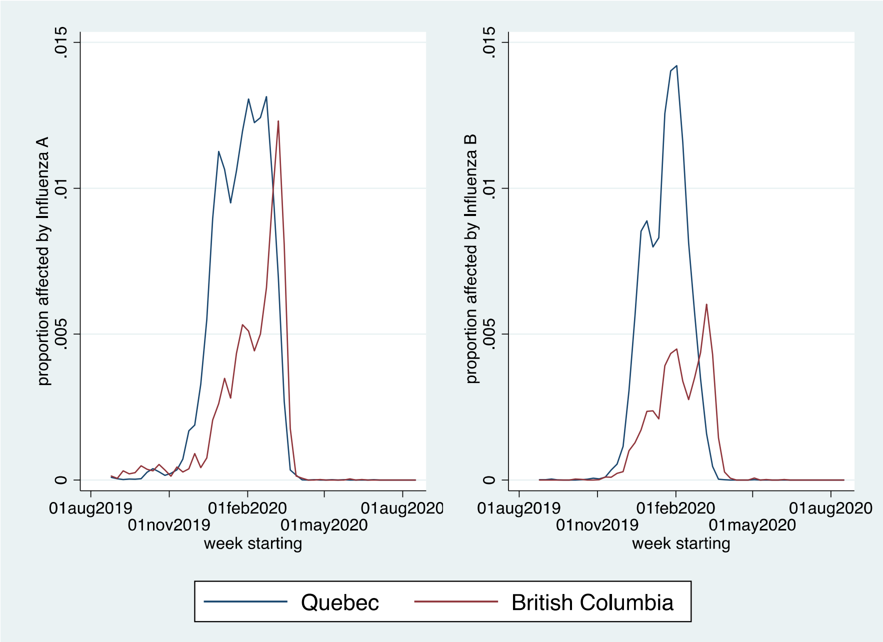


Fig. 11 Weekly incidence rate of influenza in 2019–2020 flu season. Source: Flu Watch Data accessed October 2020. The left panel shows positivity rates for influenza A while the right panel shows positivity rates for influenza B

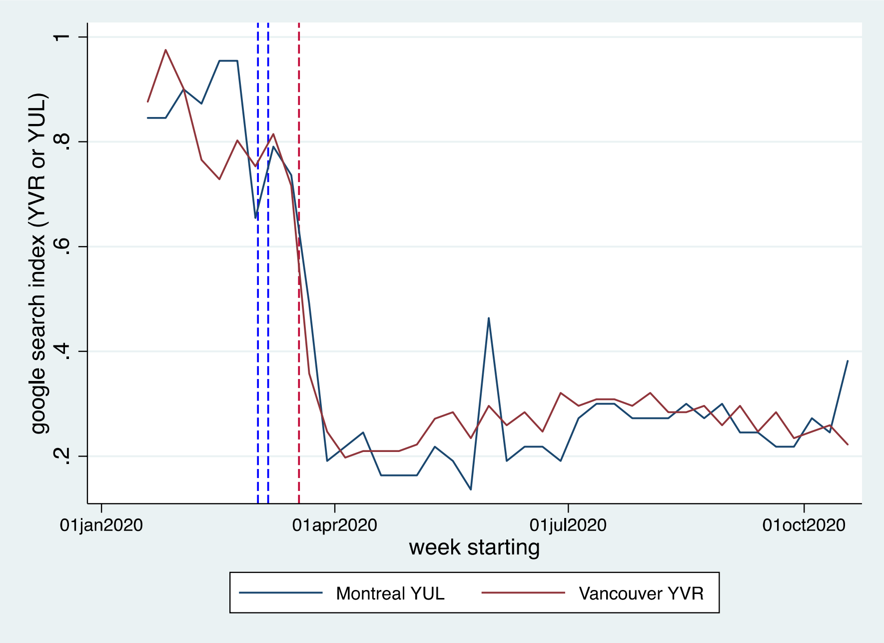


Fig. 12 Google Search Index for Montreal and Vancouver airports. Source: Google Search Index API, accessed October 12, 2020. The blue dashed lines represent the beginning and end of Quebec's spring break (Montreal, Outaouais and Laurentides), while the red dashed line marks March 18, the date when the federal government banned international flight arrivals (except from the USA)

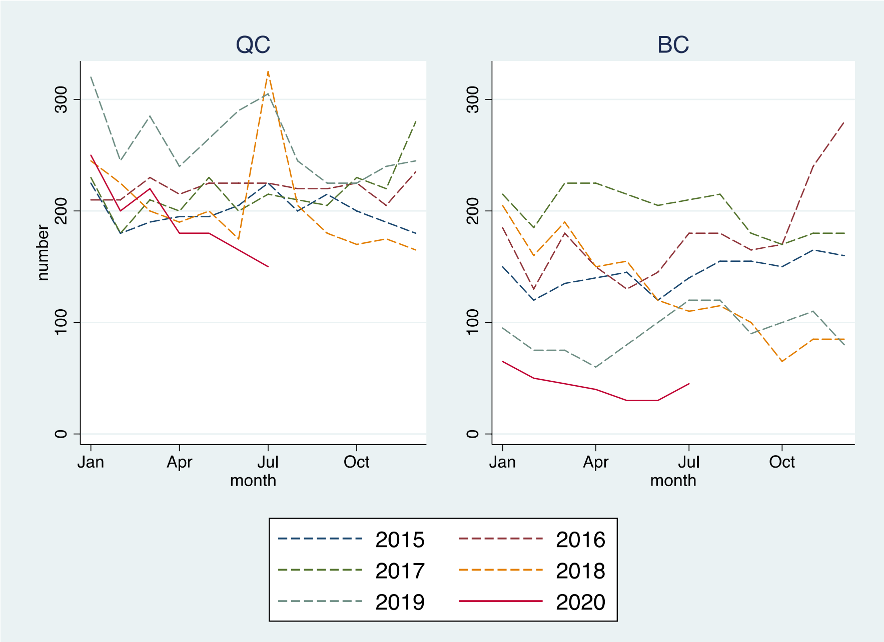


Fig. 13 Number of deaths from accidents in Quebec and British Columbia. Source: CVSD data for Quebec (left panel) and British Columbia (right panel)

Acknowledgements Some analyses reported in this paper were conducted at the Quebec Interuniversity Centre for Social Statistics (QICSS), which is part of the CRDCN. The services and activities provided by the QICSS are made possible by the financial or in-kind support of the SSHRC, CIHR, the CFI, Statistics Canada, FRQSC and the Quebec universities. The views expressed in this paper are those of the authors, and not necessarily those of the CRDCN or its partners.The services and activities provided by the QICSS are made possible by the financial or in-kind support of the SSHRC, CIHR, the CFI, Statistics Canada, FRQSC and the Quebec universities. The views expressed in this paper are those of the authors, and not necessarily those of the CRDCN or its partners. The authors would like to thank the reviewers for their insightful comments and their help in improving this article. They would also like to thank David Boisclair who greatly contributed to the improvement of the article with comments and proofreading.

Author Contribution The authors contributed equally to the design, analysis, and writing of this paper.

Data Availability The data tables from Vital Statistics and other aggregate data can be obtained from the authors. The underlying Vital Statistics micro-data can be accessed from the Research Data Centers of Statistics Canada.

Code Availability The STATA programs used to compute estimates of excess mortality are available from the authors.

Declarations

Conflict of Interest The authors declare no competing interests.

Human Subjects This project uses anonymized administrative data on deaths from the Vital Statistics Database and other aggregate data from various sources.

Ethics Approval This project uses anonymized data and is exempted from IRB review at HEC.

Consent to Participate N/A.

Consent for Publication We consent to publication.

References

Acosta, E., Hallman, S. A., Dillon, L. Y., Ouellette, N., Bourbeau, R., Herring, D. A., & Gagnon, A. (2019). Determinants of influenza mortality trends: Age-period-cohort analysis of influenza mortality in the United States, 1959–2016. *Demography, 56*(5), 1723–1746.

Adair, T., Lopez, A. D., & Hudson, S. (2020). *Approaches and methods for estimating excess deaths due to COVID-19. CRVS best practice and advocacy. Bloomberg Philanthropies Data for Health Initiative, Civil Registration and Vital Statistics Improvement*. University of Melbourne.

Aron, J., Giattino, C., Muellbauer, J. And H. Ritchie (2020). A pandemic primer on excess mortality statistics and their comparability across countries, *Our World in Data*, accessed November 3rd. https://ourworldindata.org/covid-excess-mortality

Beaney, T., Clarke, J. M., Jain, V., Golestaneh, A. K., Lyons, G., Salman, D., & Majeed, A. (2020). Excess mortality: the gold standard in measuring the impact of COVID-19 worldwide? *Journal of the Royal Society of Medicine, 113*(9), 329–334.

British Colombia Coroners Service (2021). Illicit drug toxicity deaths in BC: January 1, 2011–February 28, 2021. Accessed March 26, 2020. https://www2.gov.bc.ca/assets/gov/birth-adoption-death-marriage-and-divorce/deaths/coroners-service/statistical/illicit-drug.pdf

Bignami-Van Assche, S., & Van Assche, A. (2020). Assessing the burden of COVID-19 in Canada. medRxiv.

Brookmeyer, R., & Damiano, A. (1989). Statistical methods for short-term projections of AIDS incidence. *Statistics in Medicine, 8*(1), 23–34.

Centers for Disease Control and Prevention. 2020. Evidence used to update the list of underlying medical conditions that increase a person's risk of severe illness from COVID-19. https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/evidence-table.html

Choinière, R. (2021). Surmortalité hebdomadaire en 2020 et 2021 en lien avec la COVID-19 au Québec et ailleurs dans le monde. Dernière mise à jour, 15 août 2021. https://comparaisons-sante-quebec.ca/exceshebdomadaires-de-deces-en-2020-en-lien-avec-la-covid-19-au-quebec-et-ailleurs-dans-le-monde/

Chu, T. (2010). "EPIWEEK: Stata module to create epidemiological week and equivalent epidemiological year," Boston College Department of Economics, revised 11 May 2014. *Statistical Software Components*, S457151. https://ideas.repec.org/c/boc/bocode/s4571521.html.

Fisman, D. N., Bogoch, I., Lapointe-Shaw, L., McCready, J., & Tuite, A. R. (2020). Risk factors associated with mortality among residents with coronavirus disease 2019 (COVID-19) in long-term care facilities in Ontario. *Canada. JAMA Network Open, 3*(7), e2015957–e2015957.

Farrington, C. P., Andrews, N. J., Beale, A. J., & Catchpole, M. A. (1996). A statistical algorithm for the early detection of outbreaks of infectious disease. *Journal of the Royal Statistical Society Series A, 159*, 547–563.

Fleury-Payeur, F. (2017), La mortalité et l'espérance de vie au Québec en 2016. *Institut de la statistique du Québec*. https://statistique.quebec.ca/en/fichier/la-mortalite-et-lesperance-de-vie-au-quebec-en-2016.pdf

Frohlich, K. L., Ross, N., & Richmond, C. (2006). Health disparities in Canada today: Some evidence and a theoretical framework. *Health policy, 79*(2–3), 132–143.

Godin, A., Xia, Y., Buckeridge, D. L., Mishra, S., Douwes-Schultz, D., Shen, Y., & Maheu-Giroux, M. (2021). The role of case importation in explaining differences in early SARS-CoV-2 transmission dynamics in Canada—A mathematical modeling study of surveillance data. *International Journal of Infectious Diseases, 102,* 254–259.

Goldstein, J. R., & Lee, R. D. (2020). Demographic perspectives on the mortality of COVID-19 and other epidemics. *Proceedings of the National Academy of Sciences, 117*(36), 22035–22041.

Government of Canada, (2020). https://www.canada.ca/en/public-health/services/publications/diseases-conditions/people-high-risk-for-severe-illness-covid-19.html

Jordan, R. E., Adab, P., Cheng, K. K. Covid-19: risk factors for severe disease and death BMJ 2020; 368:m1198. https://doi.org/10.1136/bmj.m1198

Khafaie, M. A., & Rahim, F. (2020). Cross-country comparison of case fatality rates of COVID-19/SARS-COV-2. *Osong Public Health and Research Perspectives, 11*(2), 74.

Kontis, V., Bennett, J. E., Rashid, T., Parks, R. M., Pearson-Stuttard, J., Guillot, M., & Ezzati, M. (2020). Magnitude, demographics and dynamics of the effect of the first wave of the COVID-19 pandemic on all-cause mortality in 21 industrialized countries. *Nature medicine, 26*(12), 1919–1928.

Krieger, N., Waterman, P. D., & Chen, J. T. (2020). COVID-19 and overall mortality inequities in the surge in death rates by zip code characteristics: Massachusetts, January 1 to May 19, 2020. *American journal of public health, 110*(12), 1850–1852.

Lange, S. J., Ritchey, M. D., Goodman, A. B., Dias, T., Twentyman, E., Fuld, J., ... And Z. Stein (2020). Potential indirect effects of the COVID-19 pandemic on use of emergency departments for acute life-threatening conditions—United States, January–May 2020, Mortality and Morbidity Report, CDC, 69:25, pp. 795–800

Liu, M., Maxwell, C. J., Armstrong, P., Schwandt, M., Moser, A., McGregor, M. J., & Dhalla, I. A. (2020). COVID-19 in long-term care homes in Ontario and British Columbia. *CMAJ, 192*(47), E1540–E1546.

Luy, M., Di Giulio, P., Di Lego, V., Lazarevič, P., & Sauerberg, M. (2020). Life expectancy: Frequently used, but hardly understood. *Gerontology, 66*(1), 95–104.

Maëlle, S., Dirk, S., & Michael, H. (2014). Monitoring count time series in R: Aberration detection in public health surveillance. arXiv preprint arXiv:1411.1292.

McKie, D. (2020). Poverty and COVID-19: More data would help explain the connection. *Canada's National Observer*, May 12th 2020. https://www.nationalobserver.com/2020/05/12/analysis/poverty-and-covid-19-more-data-would-help-explainconnection

Michaud, P.-C. (2020). *Compter les morts? Une analyse de la mortalité excédentaire récente en temps de pandémie. CIRANO Perspectives 2020PE-19*. CIRANO.

Norton, A., & Kerr, T. (2020). Applying the lessons of COVID-19 response to Canada's worsening opioid epidemic. *EClinicalMedicine, 29*.

Noufaily, A., Enki, D. G., Farrington, P., Garthwaite, P., Andrews, N., & Charlett, A. (2012). An Improved Algorithm for Outbreak Detection in Multiple Surveillance Systems. *Statistics in Medicine, 32*(7), 1206–1222.

Peeples, L. (2019). How the next recession could save lives. *Nature, 565*(7740), 412–415.

Sanyaolu, A., Okorie, C., Marinkovic, A., Patidar, R., Younis, K., Desai, P., ... & Altaf, M. (2020). Comorbidity and its impact on patients with COVID-19. SN comprehensive clinical medicine, 1-8

Sepulveda, E. R., Stall, N. M., & Sinha, S. K. (2020). A Comparison of COVID-19 Mortality Rates Among Long-Term Care Residents in 12 OECD Countries. *Journal of the American Medical Directors Association, 21*(11), 1572–1574.

Simonsen, L., Clarke, M. J., Schonberger, L. B., Arden, N. H., Cox, N. J., & Fukuda, K. (1998). Pandemic versus epidemic influenza mortality: A pattern of changing age distribution. *Journal of Infectious Diseases, 178*(1), 53–60.

Statistics Canada (2020a), Excess mortality in Canada during the COVID-19 pandemic, Catalogue no 45280001. https://www150.statcan.gc.ca/n1/pub/45-28-0001/2020001/article/00076-eng.htm

Statistics Canada (2020b). Table 13–10–0785–01 Selected grouped causes of death, by month https://doi.org/10.25318/1310078501-eng

Strumpf, E. C., Charters, T. J., Harper, S., & Nandi, A. (2017). Did the Great Recession affect mortality rates in the metropolitan United States? *Effects on Mortality by Age, Gender and Cause of Death, Social Science and Medicine, 189*, 11–16.

Thompson William, W., et al. (2003). Mortality associated with influenza and respiratory syncytial virus in the United States. *Jama, 289.2*(2003), 179–186.
Toulemon, L., & Barbieri, M. (2008). The mortality impact of the August 2003 heat wave in France: Investigating the 'harvesting'effect and other long-term consequences. *Population Studies, 62*(1), 39–53.
Tran, D., Vaudry, W., Moore, D., Bettinger, J. A., Halperin, S. A., Scheifele, D. W., ... & Mersereau, T. (2016). Hospitalization for influenza A versus B. *Pediatrics, 138*(3).
Troeger, C. E., Blacker, B. F., Khalil, I. A., Zimsen, S. R., Albertson, S. B., Abate, D., & Ahmadi, A. (2019). Mortality, morbidity, and hospitalizations due to influenza lower respiratory tract infections, 2017: An analysis for the Global Burden of Disease Study 2017. *The Lancet Respiratory Medicine, 7*(1), 69–89.
Vestergaard, L. S., Nielsen, J., Richter, L., Schmid, D., Bustos, N., Braeye, T., ... & Mølbak, K. (2020). Excess all-cause mortality during the COVID-19 pandemic in Europe–preliminary pooled estimates from the EuroMOMO network, March to April 2020. *Eurosurveillance*, *25*(26), 2001214
Viglione, G. . (2020). How many people has the coronavirus killed? *Nature, 585*(7823), 22–24.
Wang, B., Li, R., Lu, Z., & Huang, Y. (2020). Does comorbidity increase the risk of patients with COVID-19: Evidence from meta-analysis. *Aging (albany NY), 12*(7), 6049.
Woolf, S. H., & Braveman, P. (2011). Where health disparities begin: The role of social and economic determinants—and why current policies may make matters worse. *Health Affairs, 30*(10), 1852–1859.
Woolf, S. H., Chapman, D. A., Sabo, R. T., Weinberger, D. M., Hill, L., & Taylor, D. D. (2020). Excess deaths from COVID-19 and other causes, March-July 2020. *Jama, 324*(15), 1562–1564.
Peng, Wu., et al. (2012). Excess mortality associated with influenza A and B virus in Hong Kong, 1998–2009. *The Journal of Infectious Diseases, 206.12*(2012), 1862–1871.
Xie, G., Guo, Y., Tong, S., & Ma, L. (2014). Calculate excess mortality during heatwaves using Hilbert-Huang transform algorithm. *BMC Medical Research Methodology, 14*(1), 1–10.
Zylke, J. W., & Bauchner, H. (2020). Mortality and morbidity: The measure of a pandemic. *Journal of the American Medical Association, 324*(5), 458–459.