RSC SRC

Excess All-Cause Mortality During the COVID-19 Epidemic in Canada

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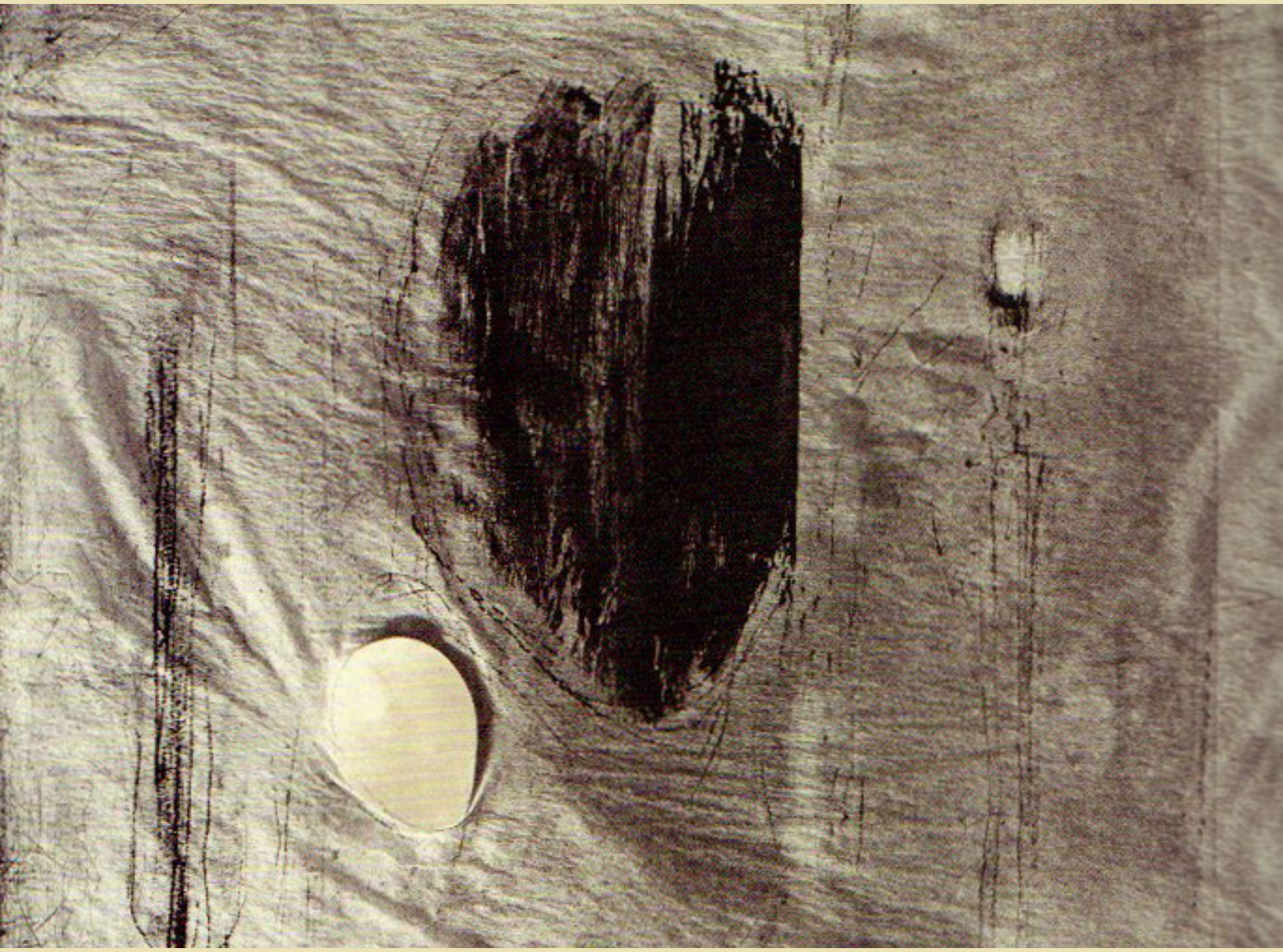

An RSC Policy Briefing

Excess All-Cause Mortality During the COVID-19 Epidemic in Canada

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Cover Art

Walter Jule, *By All Things Advancing, a clock for two kinds of time* (1993)

Etching, lithograph on gampi sukiawase, 40 x 36 cm

The title was inspired by the writings of Zen master Dogen who said, "Everything is a kind of time." In the prints I explore the combination of "additive" and "reductive" techniques. The drawn elements and photo images of wrinkled paper are "reductive" having been etched into a copper plate while the small luminescent "orb" has been "added" through offset lithography. I was attempting to create a visual metaphor for the universal law of cause and effect; being and non-being.

Land Acknowledgement

The headquarters of the Royal Society of Canada is located in Ottawa, the traditional and unceded territory of the Algonquin Nation.

The opinions expressed in this report are those of the authors and do not necessarily represent those of the Royal Society of Canada.

Background on the Policy Briefing Report Process

Established by the President of the Royal Society of Canada in April 2020, the RSC Task Force on COVID-19 was mandated to provide evidence-informed perspectives on major societal challenges in response to and recovery from COVID-19.

The Task Force established a series of Working Groups to rapidly develop Policy Briefings, with the objective of supporting policy makers with evidence to inform their decisions.

About the Authors

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Notes from the Working Group

Due to limited availability of death reporting as of the time of writing, this report does not directly address or make specific recommendations for preventing excess deaths during the COVID-19 epidemic among specific occupational groups, people experiencing homelessness and incarceration, Black, Indigenous and people of colour who do not live with clinical frailty or in high priority neighbourhoods.

Acknowledgements

The authors acknowledge the suffering and deaths of all people living and working in Canada who passed away during the COVID-19 epidemic and their loved ones.

The authors also thank Carolyn Abraham, David Naylor and Laura Rosella for critical editorial contributions to the development of this report.

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Abbreviations and Definitions

Abbreviations

CDC: United States Centers for Disease Control and Prevention

CFR: Case fatality rate

CI: Confidence interval

LTC: Long-term care

OECD: The Organisation for Economic Co-operation and Development

Definitions

Clinical frailty: People living with frailty have a greater vulnerability to developing increased dependency and/or mortality upon exposure to physiological and psychological stressors, due to an accumulation of deficits across multiple domains, including physical fitness and illness, ability to function independently and need for and access to psychosocial supports. These accumulated deficits can be graded on the Clinical Frailty Scale (Church et al., 2020).

95% Confidence interval (CI): Let us say you wish to know the average blood pressure of adults in Canada. You cannot measure everyone's blood pressure in the country, so you measure the blood pressure of a particular number of individuals ('sample statistic') and calculate their average blood pressure. Now you can use a 'Confidence Interval' (CI) to quantify your certainty that your 'sample statistic' has captured the average blood pressure of Canadian adults within a certain margin of error. A 95% CI would signify that you are 95% sure that true average blood pressure of Canadian adults lies between the (Lower CI value – 95% CI value – Upper CI value).

Case fatality rate (CFR) vs Infection fatality rate (IFR): The infection fatality rate is the percentage of infected people who die of the infection. There are different IFRs in distinct risk groups, such as younger and older people. The case fatality rate is the percentage of reported infections that resulted in death. It is strongly affected by the numbers of cases and deaths due to an illness that are detected.

Deficit mortality: The number of deaths during a specific period which is below the number expected under normal conditions.

Epidemiological link: A characteristic that links two cases of a disease, such as close contact between two people or a common exposure.

Excess deaths: The difference between the observed and expected number of deaths during a specific period. This is the same as excess mortality.

Excess mortality or Excess all-cause mortality: A term used in epidemiology and public health referring to the number of deaths from all causes in a specific period that is greater than the number of deaths expected under normal conditions. This is the same as excess deaths.

OECD countries: This refers to the 37 member countries of the Organisation for Economic Co-operation and Development, an international organisation that primarily includes high-income democratic nations.

Mortality rate or death rate: The proportion of a population that dies within a specific period (typically calculated as a number per 100,000 or a base of 10). Excess mortality differs from excess mortality rate since the former is not scaled to population size.

Seroprevalence: The proportion of people in a population who test positive for antibodies to a particular infectious agent in their blood serum indicating an earlier infection with that agent.

Toxic drug death epidemic: Canada is experiencing epidemic-like numbers of deaths due to toxic drugs such as opioids and stimulants.

Executive Summary

It is widely assumed that 80 per cent of Canada's deaths due to COVID-19 occurred among older adult residents of long-term care homes, a proportion double the 40-per-cent average of peer countries in the Organisation for Economic Co-operation and Development (OECD). But an in-depth analysis of all deaths that have so far been reported across Canada during the pandemic casts doubt on this estimate. It reveals evidence that at least two thirds of the deaths caused by COVID-19 in communities outside of the long-term care sector may have been missed.

Between February 1 and November 28, 2020, our study finds that the COVID-19 deaths of approximately 6,000 people aged 45 and older living in communities across Canada appear to have gone undetected, unreported or unattributed to COVID-19. This suggests that if Canada has continued to miss these fatalities at the same rate since last November, the pandemic mortality burden may be two times higher than reported.

Our conclusion is based on an examination of the best available reports of excess deaths across Canada, the pattern of COVID-19 fatalities during the pandemic, cremation data showing a significant spike in at-home versus hospital deaths in 2020 and antibody surveillance testing that collectively unmasked the likely broad scope of undetected COVID-19 infections.

The extent of likely missed COVID-19 fatalities in communities varies by province, and was, for example, less of an issue in Québec, where the virus accounted for all excess deaths. Yet when factored into the national equation, the number of possible missed deaths in the country's communities suggests that COVID-19 fatalities in long-term care actually account for 45 per cent of Canada's total COVID-19 death toll, a figure more in line with the OECD average. While this is roughly half the proportion assumed, it stands to reason: If Canada indeed had twice as many COVID-19 long-term care deaths as other OECD countries, the mortality and case fatality rates in Canada's long-term care sector should also have been as twice as high as the OECD average—but they were not.

In essence, our work presents a very different picture as to how the pandemic has unfolded in Canada. It strongly suggests that while the novel coronavirus was devastating the long-term care sector in two successive waves in 2020, it was also devastating communities outside long-term care. In fact, our analysis suggests that through the first year of the pandemic, COVID-19 was associated with many deaths that were not classified as such, most likely in low-income, high-density, racialized neighbourhoods of essential workers and recent immigrants where most COVID-19 cases were concentrated. Among these communities it is likely that many cases were never identified, and the resulting deaths were never counted.

In fact, we find that most of Canada's cases prior to November 28, 2020 were not reported until after excess deaths began rising rapidly, a trend that continued until the third wave. This disturbing pattern demonstrates that through much of 2020, the growing number of COVID-19 fatalities—not reported cases—was the earliest indicator of the epidemic's trajectory.

It may be that the public focus on the tragedy in nursing homes made it difficult to see the unusually high number of clinically frail older adults dying of COVID-19 in their own homes, where many had likely been residents of racialized communities. But 25 per cent of likely missed deaths also occurred in people between the ages of 45 and 64, likely frontline and essential workers,

recent immigrants and people living in multigenerational households. The failure to recognize the heightened COVID-19 risk faced by community-dwelling elders and economically precarious, racialized workers likely delayed the implementation of public health interventions that may well have saved lives.

As a result, our study—based as it is on the preliminary data currently available—demands urgent and further investigation to properly understand the true scope and nature of the COVID-19 death toll in Canada. It also warrants substantial and immediate improvement to the slow, patchwork system of reporting deaths, provincially and nationally, to enable relevant public policy planning and the rapid introduction of effective public health measures, and to ensure Canada has a workable, timely death-reporting system for the next epidemic. Finally, though not least, it merits deeper scrutiny to understand how the untimely loss of so many lives went unnoticed for so long.

*How did we miss this?

Calculating the number of lives lost to any epidemic of infectious disease is always challenging and gauging an accurate number of deaths due to COVID-19 presents unique difficulties: Many SARS-CoV-2 infections are asymptomatic, symptoms can be vague and tricky to recognize, especially among older adults, and symptoms can also be mild or easily mistaken for other ailments, such as cardiovascular or kidney conditions. But, as with any infectious disease epidemic, it's possible to more precisely estimate a death toll by examining reports of excess deaths, which capture information about higher-than expected numbers of fatalities during a specific time period.

Our analysis of excess deaths took into account those fatalities associated with the healthcare and social disruptions caused indirectly by the pandemic and its accompanying lockdowns. We also adjusted our estimates for the significant number of excess deaths linked to Canada's parallel epidemic of toxic drug deaths involving opioids, stimulants and other substances.

Crucially, we also accounted for an expected decline in excess deaths, using the COVID-19 adapted methods set out by the U.S. Centres for Disease Control, since the pandemic is believed to have reduced other causes of mortality, such as deaths due to non-COVID infections and traffic accidents. Without adjusting for the expected pandemic-related decline in deaths, any increase in the number of excess deaths is obscured.

In fact, our study finds that one of the prime reasons so many COVID-19 community deaths have yet to be recognized – more than a year into the pandemic—is due to the failure to consider the lives *not* lost as an indirect effect of public health restrictions. This, coupled with the country's slow system for reporting causes of death, left Canada without a crucial warning system to alert officials to the worrisome number of deaths happening outside of long-term care.

Without adequate situational awareness or surveillance testing, Canadian public health officials and policy makers may not have recognized the prevalence of COVID-19 cases and fatalities in the community, prior to and between the pandemic's major waves. Meanwhile, our study finds that approximately 80 per cent of excess deaths unattributed to COVID-19 occurred in Canada four to six weeks before and between each of the well-documented spikes in COVID-19 fatalities. These deaths were logged in the summer between waves, and even occurred in regions, such as Saskatchewan, Manitoba, and Atlantic Canada, thought to have been relatively untouched by Wave 1.

Other leading causes for the under-detection of COVID-19 deaths may include:

- Insufficient testing and/or testing accessibility and uptake to identify COVID-19 cases and deaths outside of long-term care, particularly among formal and informal caregivers in the hardest-hit neighbourhoods where case positivity rates have remained high through most of the epidemic. Nationally, Canada's testing levels rank 75 per cent lower than case number-adjusted testing in peer countries.
- Lack of systematic post-mortem testing for COVID-19 in all deaths during the pandemic – outside of Québec and Manitoba. This includes suspected COVID-19 cases that could not be linked to a test-confirmed COVID-19 case, even though contact tracing has been unable to determine the infection source in most cases of COVID-19.
- Lack of familiarity with the atypical symptoms of COVID-19 often present in older people, especially outside of a hospital or long-term care setting. This risk is almost certainly higher among informal or family caregivers, and those without strong English or French literacy skills and Internet access.
- Attributing the primary cause of a fatality on death certificates to a different cause when COVID-19 is listed as a co-morbidity.
- Failure to report probable COVID-19 fatalities that have been unconfirmed by testing. Several provinces, such as British Columbia, Alberta and the Atlantic provinces, either do not report probable causes of death, or unusually low probable causes.

It is possible that the gap we have uncovered between reported and missed COVID-19 fatalities in the community may be narrower than we currently estimate. But given the extreme delays in Canada's cause-of-death reporting, a system which remains largely paper-based and lags far behind other high-income countries, there is not enough data beyond June 27, 2020 to reach a concrete conclusion as to the full tally of missed deaths.

The knowledge gap is particularly acute in British Columbia, Saskatchewan, and Manitoba where cause-of-death data is only complete into February 2020, Alberta into June 2020, and the Atlantic provinces and Northern Territories into September 2020. Ontario's reports are more up to date until November 2020, while Québec leads the pack with timely reports that have been completed into February 2021.

Without access to timely case and fatality data related to COVID-19, Canada cannot have a clear understanding of what has happened, or continues to happen, until at least 2022. It was, for example, not possible to conduct this analysis until 2015-to-2019 death data became available late in 2020.

The pandemic has exposed many uncomfortable truths about Canadian society, among them, the limits of our healthcare system, tragic flaws in long-term care, our systemic racism, and our inability to protect the most at risk when an infectious threat arrives in our midst. As our multi-faceted study finds, it appears that we failed to notice two-thirds of all those who died of COVID-19 outside of the long-term care sector, most likely in financially precarious, racialized communities. It's critical that we now work urgently to protect those most at risk with intensive, frequent, and accessible testing, public health outreach and information, and ensuring these communities are among the highest priority recipients for both doses of COVID-19 vaccines. Too many lives are at stake to delay action, as our report raises the possibility that at this moment there may be twice as many people dying than we know.

Recommendations arising from this report:

1. **Mandate weekly preliminary reporting of numbers of deaths due to all causes, in all provinces and territories**, to Statistics Canada, similar to other countries.
2. **Perform COVID-19 testing on all people who die in any setting**, including hospitals, congregate living, shelters and private homes, and report by setting, neighbourhood of residence, race, and occupation.
3. **Immediately adopt U.S. CDC excess mortality methods for estimating Canadian excess mortality during the COVID-19 epidemic.**
4. **Establish a national COVID-19 Mortality task force** with provincial and territorial partners and independent advisors to investigate the reasons why so many Canadian COVID-19 cases and deaths have been missed/unreported to date, to examine the occupational and demographic characteristics of those who have died of COVID-19, and to set up immediate plans to prevent more epidemic waves and ensure COVID-19 cases and deaths are no longer undetected. The preliminary report of this task force should be released by November 30, 2021.

Recommendations from other advisory groups supported by evidence from this study:

Our evidence gives further support for the need to enact recommendations from other Canadian advisory bodies[1] concerning:

- Paid sick leave
- Isolation support
- Testing and vaccination accessibility and prioritization
- Allocation of resources and authority to create culturally safe COVID-19 prevention and support programs

Where prioritization is needed, the **highest priority people and populations** for interventions to prevent COVID-19 deaths are:

People living with **clinical frailty**, their household members and neighbours in congregate living settings, and formal and informal caregivers who enter the homes of frail individuals to give support.

People living in high priority neighbourhoods bearing the largest burden of COVID-19 exposure and death due to structural economic, social, and racial inequities. These include **low-income and racialized essential frontline workers, recent immigrants, people living in high density housing and multigenerational households.**

1 (Chief Public Health Officer of Canada, 2020; Santé Montréal, 2020; Comité sur l'immunisation du Québec, 2021; Mashford-Pringle *et al.*, 2021; Mishra *et al.*, 2021; Ontario COVID-19 Science Advisory Table, 2021; Stall, Brown, *et al.*, 2021; Stall, Nakamishi, *et al.*, 2021; Thompson *et al.*, 2021; Turnbull *et al.*, 2021; Waldner *et al.*, 2021)

Excess All-Cause Mortality During the COVID-19 Epidemic in Canada

Introduction

The COVID-19 epidemic in Canada

In December of 2019, an epidemic of infections caused by a novel coronavirus was detected in Wuhan, China. This virus was later named SARS-CoV-2 and the disease it caused was called COVID-19. Canada's first cases were reported in Ontario and British Columbia in late January 2020, followed by cases in Québec and Alberta one month later (Little, 2020; Public Health Agency of Canada, 2021f). Canada's first inkling of community spread unlinked to a known case came on March 5 in British Columbia. By March 9-16, COVID-19 cases had been reported in every other province and territory except Nunavut. To date (June 10, 2021) nearly 26,000 COVID-19 deaths have been reported to date (June 10, 2021) in Canada. This grim total exceeds the death tolls of all epidemics and mass mortality events in Canadian history, except for the 1918-1920 influenza epidemic and World Wars I and II.

As of June 10, 2021 Canada has reported 19% fewer per capita COVID-19 cases and 34% fewer per capita deaths than the average for high income, medium-large peer countries (Australia, France, Germany, Italy, Japan, South Korea, Spain, Taiwan, United Kingdom, United States) (Little, 2020; Roser *et al.*, 2021). Canada has performed 74% fewer tests/positive case than its peers, meaning that Canadian case and death numbers may be underestimated relative to others'. Compared to the per capita case average for peers, Prairie provinces (Alberta, Manitoba and Saskatchewan) have reported 5% more cases, and Québec, Ontario, British Columbia, and Atlantic and Northern Canada (New Brunswick, Newfoundland, Nova Scotia, the Northwest Territories, Nunavut, Prince Edward Island and the Yukon) have respectively reported 5%, 19%, 38% and 93% fewer cases. Québec has reported 25% more per capita deaths than the peer average, and Ontario, Prairie provinces, British Columbia, and Atlantic and Northern Canada have respectively reported 43%, 45%, 68% and 96% fewer deaths.

Canada has experienced two major waves of COVID-19 and is currently in a third wave (Little, 2020). The first wave declined to its lowest case number point in early July 2020, when cases again began slowly rising and building up to the second large wave that accelerated in late August 2020. The summer was associated with at least a 25% increase in SARS-CoV-2 seroprevalence compared to the first wave (Canadian Blood Services, 2021), confirming the epidemic was growing slowly. The second wave receded to its lowest level by about March 8, 2021, when the third wave quickly took off across much of Canada, propelled by more transmissible SARS-CoV-2 variants.

The first wave appeared to hit hardest in Ontario and Québec, where 95% of Canada's 8,720 COVID-19 deaths were reported, with two thirds of all deaths reported in Québec (Little, 2020). The regions with the highest to lowest reported per capita COVID-19 fatalities compared to the Canadian average were Québec (288%), Ontario (83%), British Columbia (15%), the Prairie provinces (11%), and Atlantic and Northern Canada (9%). These numbers were somewhat at odds with the results of seroprevalence studies in community-dwelling adults after the first wave, which collectively suggested that seroprevalence in Québec and Ontario was roughly similar at 25% more than the Canadian average, and that seroprevalence was 3% more than the Canadian average in the Prairie provinces, and 36% less than the Canadian average in British Columbia

and Atlantic and Northern Canada (Canadian Blood Services, 2021; Héma-Québec, 2021; Jha, 2021). However, about 80% of Canada's deaths in the first wave were reported in long-term and residential care homes (referred to hereafter as LTC) and seroprevalence studies did not sample LTC residents. Therefore, it seemed that discrepancies in seroprevalence and reported per capita COVID-19 deaths across Canadian regions were possibly due to disproportionate COVID-19 mortality in LTC.

From July 5, 2020 to March 8, 2021, which corresponded to the summer inter-wave period and the second wave, 68% of Canada's 13,546 new COVID-19 deaths were reported in Québec (36%) and Ontario (32%). During this period, the regions with the highest to lowest reported per capita COVID-19 fatalities compared to the Canadian average were Québec (164%), the Prairie provinces (125%), Ontario (84%), British Columbia (68%), and Atlantic and Northern Canada (3%). From March 9, 2021 to June 10, 2021, 71% of Canada's 3,545 new third wave COVID-19 fatalities were reported in Ontario (52%) and Québec (19%). Regions with the highest to lowest reported per capita COVID-19 fatalities compared to the Canadian average during the third wave are Ontario (135%), the Prairie provinces (105%) Québec (86%), British Columbia (72%), and Atlantic and Northern Canada (14%). Seroprevalence data are not yet available to the end of the second or third waves.

Canadian monitoring of the COVID-19 epidemic

One of the greatest challenges for understanding the true number of COVID-19 deaths has been knowing how many people living in Canada have been infected with SARS-CoV-2. Canada's COVID-19 epidemic has largely been monitored by laboratory testing for the SARS-CoV-2 virus. Seroprevalence studies of the percentage of people whose blood contains antibodies to SARS-CoV-2 provide evidence of past infection but tend to under-estimate total infection rates over time since antibody levels (titers) decline in some people after natural infection (Canadian Blood Services, 2021; Héma-Québec, 2021; Jha, 2021).

Across Canada and in peer countries there is considerable variability in the number of laboratory tests performed for each SARS-CoV-2-positive case detected. These variations can be due to differences in epidemic size, laboratory testing capacity, accessibility, uptake and the use of laboratory testing for active surveillance. Comparing the number of tests performed per positive case is especially important for comparing reported case numbers and deaths across regions with small and large epidemics. For example, the United States, which has experienced a very large epidemic, has performed 49% more tests per capita than Canada, but has performed 48% fewer tests per positive case (Roser *et al.*, 2021). By May 17, 2021, Canada's peer countries had performed a cumulative average of 98 tests per positive case over the course of the pandemic, while Canada had performed 25 tests per positive case (Little, 2020; Roser *et al.*, 2021). Compared to the average for Canada's peers, the cumulative number of tests performed per positive case by the same date was 54% higher in Atlantic and Northern Canada, but 58% lower in Québec, 71% lower in Ontario, and 80-84% lower in the Prairie provinces and British Columbia. Given the size of its epidemic, Canada's relatively low testing rate may have compromised the capacity to detect and recognize COVID-19 deaths, and to understand how, where and among whom the virus was spreading—all of which likely reduces the ability to control COVID-19 in the third wave and beyond.

Most laboratory testing for SARS-CoV-2 infections in Canada has been conducted passively, with testing restricted largely to symptomatic individuals or contacts of known cases who seek out testing. Laboratory testing is generally not used for active screening of any populations, including hospital, clinic, community and long-term care (LTC) healthcare workers or essential workers in any sector (Canadian Centre for Occupational Health and Safety, 2021; Public Health Agency of Canada, 2021a, 2021d, 2021b, 2021c). In Ontario, regular laboratory screening of staff and visitors to LTC homes began in the second wave (Stall *et al.*, 2021). There are no national data available describing who in Canada is most likely to be tested for active SARS-CoV-2. During the first wave in Ontario, people living outside LTC who were most likely to be tested were those with underlying health conditions or who lived in higher income neighbourhoods with greater proportions of single person households (Sundaram *et al.*, 2021). In contrast, men and people living in neighbourhoods with the highest proportions of visible minorities and recent immigrants were least likely to be tested. People of working age (20-64) and those older than 85 were more likely to be tested than people aged 65-84.

Who has been at greatest risk of exposure to SARS-CoV-2 in Canada?

Blood donor seroprevalence data for Canada outside Québec show that by January 2021 donors who self-identified as non-white were twice as likely to be seropositive for SARS-CoV-2 than whites, and that donors in the most materially deprived neighbourhoods were nearly four times more likely to be seropositive than donors in the most affluent neighbourhoods (Canadian Blood Services, 2021). Community-dwelling Ontario residents most at risk of exposure (testing positive) for SARS-CoV-2 during the first wave, after correcting for differences in testing rates, were those with frailty or dementia, as well as people with a history of healthcare use and those living in neighbourhoods with higher household and apartment building density and higher proportions of essential workers, visible minorities, recent immigrants and people with lower education levels (Sundaram *et al.*, 2021). In Ontario, the likelihood of LTC homes experiencing a COVID-19 outbreak depended on daily incidence of active cases in surrounding communities and staff infections (Fisman *et al.*, 2020; Stall *et al.*, 2020, 2021). More residents were infected in these outbreaks if they lived in crowded older homes managed by for-profit chains that had more occupants per room and bathroom (Stall *et al.*, 2020, 2021; Brown *et al.*, 2021).

Who has been at greatest risk of dying of COVID-19 in Canada?

Until vaccination began, nearly 80% of Canada's COVID-19 deaths were reported in LTC (Canadian Institute for Health Information, 2020b; Comas-Herrera *et al.*, 2020; Sepulveda, Stall and Sinha, 2020; Loreto, 2021). LTC deaths depended on the risk of outbreaks starting and spreading within homes. Living in LTC was one of the most important risk factors for dying of COVID-19, but as we will argue closer to 40-45% of Canada's COVID-19 deaths probably occurred in LTC when missed COVID-19 deaths of people living outside LTC are taken into account.

People living in the lowest income neighbourhoods in Canada respectively accounted for 2-, 2.5- and 2.9-times greater shares of COVID-19 emergency department visits, hospitalized COVID-19 cases and COVID-19 deaths in hospital by November 2020 (Canadian Institute for Health Information, 2021a). Age-standardized COVID-19 mortality rates were also two times higher in neighbourhoods with the highest proportion of visible minorities (Subedi, Greenberg

and Turcotte, 2020). This ratio was 2.2 for men, 1.9 for women, 11.2 in British Columbia, 3.5 in Québec and Ontario and 1.5 in Alberta.

In the United Kingdom and United States, where racialized people are more likely to die of COVID-19, the occupations at highest risk of COVID-19 death are in healthcare (personal care and homecare workers, nursing assistants and nurses), manufacturing and processing, agriculture, construction, security, property cleaning and maintenance, transportation (bus and taxi drivers), restaurants, administration, social and community services and retail sales (Office for National Statistics, 2020, 2021; Chen *et al.*, 2021; Hawkins, Davis and Kriebel, 2021). Most Canadian jurisdictions report very little occupation information for people who die of COVID-19. As part of the investigations for this report, we found that by November 28, 2020, 63% of people of working age (20-59) who were reported to have died of COVID-19 were men, that 45%, 36% and 19% of deaths were reported in Québec, Ontario/Nunavut, and the Prairie provinces/Northwest Territories, respectively, and that fewer than 2% of reported COVID-19 deaths were among people working in healthcare, school or daycare (Public Health Agency of Canada, 2021f). We collected information about 142 workplace outbreak-linked COVID-19 fatalities reported by media, and found that of workplace-linked deaths where occupation was reported 31% (n=36) were among healthcare aides, support workers, cleaners, social workers, and activity assistants; 26% worked in transportation, shipping, logistics and mail services (n=30); 23% worked in food processing, agriculture, and restaurants (n=27); 11% worked in energy, mines, lumber, manufacturing, and construction (n=13); and 9% were nurses and doctors (n=10) (Loreto, 2021). Of deaths where gender was identified, 69% were men (93% among non-healthcare workers), and 52%, 23%, 20%, 5% and <1% lived in Ontario, the Prairie provinces, Québec, British Columbia, and Atlantic provinces, respectively. Of deaths where race information was available, racialized people accounted for 72% of all mortalities and 76% of healthcare deaths.

In Canada, 90% of COVID-19 death certificates list at least one comorbidity (a condition that can pre-date or be a complication of COVID-19) (Statistics Canada, 2021a). Apart from pneumonia, by far the most common COVID-19 comorbidity in Canada is Alzheimer's disease or dementia. In Ontario, dementia and frailty were found to be the only conditions associated with increased risk of SARS-CoV-2 exposure in community-dwelling people, possibly because individuals with these conditions are more likely to live with others and/or receive formal and informal caregiver support (Sundaram *et al.*, 2021). Frailty is a clinical concept that refers to an accumulation of deficits across multiple domains, including physical fitness and illness, dementia, and the need for psychosocial support with activities of daily living (Church *et al.*, 2020). Frailty predicts risk of death from COVID-19 better than age or comorbidities (Hewitt *et al.*, 2020). Older people living in the community with support from family caregivers and homecare workers can be as frail as those living in LTC.

In most Canadian regions, public homecare services are largely restricted to people living with frailty. We estimated how many COVID-19 deaths might have occurred in Canada by November 28, 2020 if people receiving homecare were infected as frequently as others in the community. In 2018, 6.4% of Canadian households received formal homecare services, and households with lower socioeconomic status where parents live with adult children in rented housing were most likely to receive homecare (Gilmour, 2018). These demographic features overlap considerably with SARS-CoV-2 exposure risk determinants (Sundaram *et al.*, 2021). We found that if about 6% of SARS-CoV-2-infected Canadians were frail homecare recipients and if 10% of these people died (the

infection fatality rate for people 70 and older), this could have resulted in 6,000 COVID-19 deaths outside LTC by November 28, 2020. In addition, homecare workers, who visit multiple clients and locations daily, are often low-paid, recently immigrated, racialized women who themselves live in neighbourhoods most strongly associated with risk of SARS-CoV-2 exposure. No data are reported provincially or nationally about the proportion of formal homecare workers or informal care providers who have been infected with SARS-CoV-2, and these groups cannot access laboratory COVID-19 testing unless they are symptomatic or have been in close contact with a known case. Collectively, these observations suggest that the risk of COVID-19 death among frail people living outside LTC in high-risk neighbourhoods has likely been significant throughout the COVID-19 epidemic in Canada.

An additional concern is the risk of under-recognition, under-diagnosis, under-treatment and resulting death from COVID-19 in older people living outside LTC. Nearly 40% of people older than 65 can have so-called "atypical" COVID-19 symptoms (Gan *et al.*, 2021). Older people are more likely to present COVID-19 with very few noticeable symptoms (pauci-symptomatically), atypically (less frequent fever, cough, shortness of breath, more frequent gastrointestinal symptoms), or with unspecific signs/symptoms. Unspecific signs/symptoms can include low-grade/fluctuating fevers, fatigue, headache, aches and pains, balance problems and falls, high heart rate, fluctuating blood pressure, mental change or delirium, loss of interest in eating or the inability to perform daily tasks of living, and low blood oxygen levels that are not accompanied by telltale signs such as shortness of breath (Andrew *et al.*, 2020; Kennedy *et al.*, 2020; Nanda, Vura and Gravenstein, 2020; Ontario Ministry of Health, 2020; Poco *et al.*, 2021). Of concern, in preparing this paper we noted that official Canadian national and provincial COVID-19 information websites aimed toward the public often describe COVID-19 symptoms in older people as atypical, without explaining or supplying examples of what is atypical. Information about COVID-19 presentation in older people was also challenging to find in many general medical journals and on Canadian medical association websites outside the specialties of geriatrics and emergency medicine. It is therefore possible that older people with COVID-19, and their formal and informal care providers might not have recognized COVID-19 or known how quickly it can progress and when to seek emergency medical attention. The possible risk of COVID-19 death arising from this communication gap is almost certainly higher among non-English/French-speaking people, and those without strong English/French literacy skills and internet access.

The irregular landscape of Canadian COVID-19 death reporting

Canadian standards for COVID-19 death reporting and testing, including post-mortem testing, vary across provinces/territories, and in LTC. Across Canada, 87% of COVID-19 fatalities reported to the Public Health Agency of Canada by November 14, 2020, were laboratory test-confirmed: 100% in Atlantic provinces, 97% in Alberta and British Columbia, 87% in Ontario and Québec, and 71-73% in Manitoba and Saskatchewan (Statistics Canada, 2021d). Probable COVID-19 deaths unaccompanied by testing are reported only if they are clinically compatible with COVID-19 and occur in a person who is closely epidemiologically linked to a laboratory-confirmed case (Public Health Agency of Canada, 2021e). This means that during the frequent, lengthy periods of the Canadian COVID-19 epidemic when local public health contact tracing was overwhelmed and non-epidemiologically linked community cases were high, a person who died of symptoms clinically compatible with COVID-19 would not be reported as a COVID-19 death unless post-

mortem testing was conducted. In Manitoba, post-mortem COVID-19 testing is conducted for any recently untested individual who died with symptoms consistent with COVID-19 or whose cause of death is unclear (Manitoba Public Health, 2021). Québec post-mortem testing guidelines are similar, except that testing is confined to testing priority groups, unless the person lived and died alone at home (Institut National de Santé Publique du Québec, 2020). Some post-mortem COVID-19 testing is performed in other provinces but is not systematic.

The surveillance definition for a COVID-19 death specified by the Public Health Agency of Canada and the World Health Organization is a probable or laboratory-confirmed COVID-19 case whose death resulted from a clinically compatible illness, unless there is a clear alternative cause of illness (e.g., trauma, poisoning, drug overdose). However, 8% of certificates sent to the Canadian Vital Statistics Death Database for deaths up to July 31, 2020, listed COVID-19 as a comorbidity without naming COVID-19 as the primary cause of death (O'Brien *et al.*, 2020). COVID-19 death reporting in many countries besides has not always followed World Health Organization recommendations.

Canada's death reporting is very slow compared to peer countries compared in our report, where both before and during the COVID-19 pandemic reporting of any death and its cause is legally required to be completed within one week. Canada is the only country without this requirement. As of the date of writing (May 29, 2021), death reporting is only 95% or more complete up to February 1, 2020 in multiple Canadian jurisdictions. Similarly, detailed, cumulative LTC death reporting, which in many provinces was publicly inaccessible and relied on self-reporting by LTC homes, was never nationally coordinated during the COVID-19 epidemic. Instead, national numbers were pieced together by academic researchers, journalists and volunteers, including ourselves.

The importance and challenges of estimating excess all-cause mortality during the COVID-19 pandemic

The COVID-19 pandemic has often been described in terms of fog: drifting in like a thick mist that restricted us from properly seeing the illness, the many faces of its symptoms, its mechanism of spread and myriad public policy interventions that could have been or should not have been. The result of so many unknowns is that one of the most important statistics in a pandemic—how many people have died—has been extremely difficult to measure. This has been compounded by inadequate levels of testing in many countries and regions, leaving us to collectively fly through the fog with instruments that are only picking up a fraction of the information needed to navigate safely.

One testing-independent way to estimate how many people have actually died of COVID-19 is by examining data related to excess all-cause mortality—extra deaths due to any cause that occurred beyond the number of deaths expected in a normal year. During the COVID-19 pandemic, estimated excess all-cause mortality has been substantially greater than reported COVID-19 fatalities in many countries, including most high-income nations, and multiple studies have found that the majority of excess deaths unattributed to COVID-19 have likely been missed or unreported COVID-19 fatalities (Beaney *et al.*, 2020; Bilinski and Emanuel, 2020; Vestergaard *et al.*, 2020; Viglione, 2020; Amin and Cox, 2021; Financial Times Visual and Data Journalism Team, 2021; Giattino *et al.*, 2021; Institute for Health Metrics and Evaluation, 2021; Karlinsky and Kobak, 2021; Parildar, Perara and Oke, 2021; The Economist, 2021; Wu *et al.*, 2021).

Standard excess all-cause mortality estimation methods used in ordinary times count only unexpected mortality—that is, the deaths of people who die sooner than would have been expected based on death patterns in recent years. However, several crucial features of the COVID-19 epidemic have made the use of standard methods problematic, at least for estimating the likely number of COVID-19 fatalities.

First, older people face the highest risk of death from COVID-19 but in high-income countries they are also most susceptible to other major causes of death. This means that a certain portion of older people who die of COVID-19 would have died of other causes were it not for the pandemic. This can result in a phenomenon called mortality displacement, which occurs when people die during an epidemic wave who might ordinarily have died somewhat later, causing deaths due to all causes in this group to fall below expected death numbers after the wave has passed. When standard excess all-cause mortality estimation methods are used to add up excess deaths, the negative death numbers following a wave reduce the overall sum of excess deaths.

Second, in multiple countries the COVID-19 epidemic has been associated with reduced non-COVID-19 causes of death, such as accidents, suicides, violent crime, and otherwise more common fatal infections like influenza, which can also reduce total excess all-cause mortality estimates over time, creating deficit mortality (Beaney *et al.*, 2020; Karlinsky and Kobak, 2021). This issue is particularly important in the early weeks to months when a new epidemic wave is gathering force, and when deaths directly caused by the epidemic are accumulating but are not visible in excess death counts because of reductions in other causes of mortality. The same problem of underestimating excess deaths happens in regions where the epidemic is relatively small, but where people are still adhering to protective public health measures that reduce mortality due to other causes. Finally, for all these reasons, comparing excess deaths among regions using conventional excess death estimation methods is problematic, especially when the size and timing of epidemic waves and protective public health measures in these regions differ.

Without specialized epidemic-adapted excess mortality estimation methods, displacement and deficit mortality can make it challenging to estimate COVID-19 fatalities from excess all-cause mortality. To partially overcome these issues, the U.S. Centers for Disease Control (CDC) has adopted a method for estimating total all-cause excess mortality during the COVID-19 epidemic that is normally used during disasters and humanitarian crises. This method substitutes zeros for negative values in each week of an epidemic where excess mortality estimates for a specific age group and region fall below zero, and improves excess mortality comparisons across jurisdictions over the same period, even when the onsets and declines of local epidemic waves differ (Centers for Disease Control and Prevention and National Center for Health Statistics, 2021). This method is not adopted in Canada.

COVID-19 fatalities that occur among people who would normally have died of other causes during the epidemic wave itself may also not be "visible" in total excess all-cause mortality estimates, even with approaches such as the CDC method. For example, in Ontario approximately 2% of residents of long-term care homes normally die each month because people living in long-term care are on average more clinically frail than people of the same age living in the community (Tanuseputro *et al.*, 2015; Canadian Institute for Health Information, 2021b; Stall *et al.*, 2021). Over the approximately fourteen months of the Canadian COVID-19 epidemic before widespread vaccination of long-term care residents was completed, it is quite possible that 30% or more of reported COVID-19 fatalities in these settings might not have been "counted" in total excess all-

cause mortality estimates, even when deficit mortality-offsetting estimation methods are used. As we will describe in this report, these effects were prominent in Québec, which unlike the rest of Canada appeared to have accurately identified and reported most if not all of its COVID-19 deaths, especially in LTC, and where excess all-cause mortality has been significantly lower than reported COVID-19 fatalities.

Anomalies in Canada's COVID-19 death numbers

Several features of reported COVID-19 mortality in Canada have been unusual compared to peer countries. First, by June 30, 2020, a date when the major peak of the first wave had ended but cases were not yet increasing again in most peer countries, Canada's case fatality rate (CFR) was surprisingly high. It was nearly twice the CFR for Canada's nearest geographical neighbour, the United States, and peer countries with older populations and comparable proportions of the population in LTC like Germany and Japan. It was also nearly twice the CFR of the world average (Roser *et al.*, 2021). This suggested that Canadians diagnosed with COVID-19 were two times more likely to die than people diagnosed with COVID-19 in other countries—an unusual statistic for a wealthy country with universal public healthcare that did not appear to have been as hard hit by COVID-19 as many other countries.

In addition, a study from Postill and colleagues estimating excess mortality from January 1-June 30, 2020 using Ontario cremation data reported several findings that did not align well with public understanding of the timing and location of COVID-19 fatalities during the epidemic (Postill *et al.*, 2020). This study found that none of Ontario's excess deaths during this period occurred in hospitals, and surprisingly, only 30% happened in LTC, while 63% of excess deaths took place in people's residences. Furthermore, excess LTC deaths did not appear until March (there were none in January and February, then climbed to 7% in March, shot up to 89% in April, declined to 41% in May and by June had fallen to <1%). However, excess numbers of people began dying at home as early as January when there was a 5% increase, followed by an 8% increase in February, a jump of 24% in March followed by an increase of 69% in April, 68% in May and 56% in June. Notably, excess death increases in people's homes began before national stay-at-home measures were implemented in mid-March, and continued at elevated levels through June, after Ontario had begun relaxing public health restrictions. The percentage of excess deaths that occurred in LTC (30%) was also less than half the proportion of Ontario's total COVID-19 fatalities reported in LTC during the same period (71%) (Canadian Institute for Health Information, 2021b).

Finally, the percentage of total reported COVID-19 fatalities in Canada in LTC after both the first and second waves has remained twice the average reported by other OECD countries (Canadian Institute for Health Information, 2020b; Comas-Herrera *et al.*, 2020; Sepulveda, Stall and Sinha, 2020). Importantly, the high proportion of Canadian COVID-19 fatalities in LTC has not been because Canadians living in these settings were more likely to die than LTC residents in other countries if they were infected by SARS-CoV-2. Canadian LTC CFRs were similar to CFRs in other OECD countries in the first wave, the latest period for which international comparisons are available (Canadian Institute for Health Information, 2020b). This suggests that when the epidemic hit LTC, it was as likely to kill infected Canadian LTC residents as it was to kill infected LTC residents in the average OECD country.

The simplest but most troubling explanation for the anomalies in Canada's reported COVID-19 death numbers is that we have missed twice as many community cases and deaths as peer

countries. The results of the excess death cremation study from Postill and colleagues suggested that this might in fact have been true, at least in the first wave in Ontario, and that these deaths were undetected because they occurred not in hospitals but in people's homes.

Study outline and methods

In this study we used the CDC COVID-19-adapted excess mortality estimation method (Centers for Disease Control and Prevention and National Center for Health Statistics, 2021) to investigate excess all-cause mortality in Canada and peer countries from February to November 2020. Canada's excess mortality estimates obtained using this method were compared to estimates obtained with Canada's current official methods (**Figure 1, Table 1**). To investigate whether Canada had possibly missed COVID-19 deaths, we compared reported COVID-19 fatalities with excess mortality for Canada and peer countries (**Figure 1, Table 1**). To determine if excess all-cause mortality could explain why LTC deaths comprised an unusually high proportion of Canada's total reported COVID-19 death toll, we compared proportions of total excess deaths accounted for by LTC COVID-19 fatalities in Canada and peer countries (**Figure 1, Table 1**). To understand when and among whom Canadian excess all-cause mortality occurred, we first adjusted excess mortality estimates for the continued surge in toxic-drug deaths, including opioids and other substances, then compared toxic drug-adjusted excess mortality in people 45 and older with reported COVID-19 fatalities over time in multiple age groups (**Figure 1, Table 1**). To investigate whether estimated toxic drug-adjusted excess deaths in people 45 and older corresponded to the expected number of COVID-19 fatalities for Canada's population age structure and estimated total case numbers, we compared excess deaths to COVID-19 fatalities predicted from test positivity-adjusted case numbers and SARS-CoV-2 seroprevalence (**Figure 2, Appendix 1** and **Appendix 2**). To investigate whether any specific cause of death other than COVID-19 contributed to excess mortality, we determined whether the most common causes of death in Canada increased during the first wave (the latest date when these analyses were possible) (**Figure 3**). To understand which COVID-19 fatalities might have been missed, we estimated likely undercounted COVID-19 deaths in individual age groups and Canadian regions over time (**Figure 4, Table 2, Appendix 3**), and estimated how many COVID-19 deaths were likely missed in LTC and people living in community. Finally, we revisited inter-regional differences in reported COVID-19 fatalities and excess toxic drug-adjusted deaths to obtain a more accurate picture of the COVID-19 epidemic in Canada (**Figure 5**). Through much of the report we compare key data for Québec to the rest of Canada outside Québec. This is because Québec was the only region in Canada where reported COVID-19 deaths largely accounted for all-cause excess mortality, and which appeared to be the province that came closest to accurately and completely measuring the full magnitude of its COVID-19 fatalities.

Data sources

Specific data sources used for analyses shown in each figure and table are shown in corresponding legends and footnotes.

Figure 1 and **Table 1**: Unadjusted death counts used for excess death analysis of peer countries were obtained from tables collated by Our World in Data (source: Human Mortality Database) (Giattino *et al.*, 2021; Karlinsky and Kobak, 2021; Max Planck Institute for Demographic Research and University of California, Berkeley, 2021). Unadjusted death counts used for Canadian excess

death analyses reported here were obtained from Table 13-10-0768-01: Weekly death counts, by age group and sex (Statistics Canada, 2021b). Statistics Canada population age and reporting completeness-adjusted estimates of excess deaths were obtained from Table 13-10-0792-01: Adjusted number of deaths, expected number of deaths and estimates of excess mortality, by week, age group and sex (Statistics Canada, 2021c). COVID-19 death numbers for peer countries were obtained from tables collated by Our World in Data (source: COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University) (Dong, Du and Gardner, 2020; Roser *et al.*, 2021). Canadian COVID-19 death numbers were obtained from COVID-19 Tracker Canada, which collates official data reported by regional jurisdictions (Little, 2020). Numbers of COVID-19 fatalities reported in LTC and comparable congregate care settings in peer countries were obtained from the International Long-Term Care Policy Network (Comas-Herrera *et al.*, 2020). Corresponding Canadian LTC COVID-19 death numbers were obtained from the sourced public spreadsheet maintained by Nora Loreto (Loreto, 2021). Numbers of toxic drug deaths from 2016-2020 used to estimate excess 2020 deaths due to toxic drugs were obtained from the Public Health Infobase table Opioid- and Stimulant-related Harms in Canada (Special Advisory Committee on the Epidemic of Opioid Overdoses, 2021). Population numbers for peer countries and Canadian regions were obtained World Bank 2017 population estimates and the 2016 Canadian census, respectively (Statistics Canada, 2016; The World Bank, 2017).

Figure 2, Appendix 2 and Table 3: Age-specific toxic drug death-adjusted excess death numbers were obtained from sources described for **Figure 1** and **Table 1**. Age-specific COVID-19 death numbers were obtained from the Preliminary dataset on confirmed cases of COVID-19, 2020-2021 (Public Health Agency of Canada, 2021f), which has 95% of deaths reported publicly by provinces and territories. Where provincial/territorial reported death numbers were higher, all age-specific values for the same jurisdiction were multiplied by the ratio of provincial/territorial vs Public Health Agency of Canada (PHAC)-reported deaths for the region. Seroprevalence estimates were from a representative sample of Canadians who supplied samples from May to June 2020 (Jha, 2021). Age-stratified population numbers for jurisdictions were obtained from the 2016 Canadian census (Statistics Canada, 2016). Age-stratified estimates of SARS-CoV-2 infection fatality rates were obtained from a meta-analysis of infection fatality rates in OECD countries, including Canada (Levin *et al.*, 2020). Values used for calculations are shown in **Appendix 2**.

Figure 3: Weekly attributed cause of death data from 2015-2020 used to estimate excess mortality due to COVID-19 and specific attributed causes were obtained from Table 13-10-0810-01: Selected grouped causes of death, by week (Statistics Canada, 2021d). Dates of stay-at-home orders and the start of public health measure relaxation were from a timeline reported by Vogel (Vogel, 2020).

Figure 4 and **Figure 5:** Reported COVID-19 fatalities and estimates of excess toxic drug-adjusted deaths were obtained using data sources reported for **Figure 1** and **Table 1**.

Estimation of excess deaths. Excess deaths in several categories (all reported deaths stratified by age group and region, deaths attributable to specific causes) were estimated by calculating the mean and 95% confidence interval (CI) for deaths during the corresponding CDC weeks of 2015-2019. The value of the mean and the upper 95% CI interval were then subtracted from 2020 weekly values to find numbers of deaths significantly greater than during the same week in preceding years. As per the CDC method for estimating excess deaths during the COVID-19 epidemic, all negative values were adjusted to zero before visualization and addition of cumulative

excess death numbers (Centers for Disease Control and Prevention and National Center for Health Statistics, 2021).

Excess deaths due to toxic drugs were estimated differently since data for these deaths is available on a quarterly and annual basis. The mean and 95% CI of annual deaths due to all drugs (opioids and stimulants, including apparent suicides) from 2016-2019 in specific age groups and regions were subtracted from the adjusted drug death numbers for 2020 (1.25 times the number of deaths reported to the end of September 2020). The excess 2020 toxic drug death value in each region and age group was divided by 52 to obtain a weekly estimate of excess toxic drug deaths. This weekly toxic drug death estimate was subtracted from the total weekly excess death value for the corresponding age group and region, and any negative values were adjusted to zero.

Unadjusted death counts used for estimation of excess deaths were not smoothed prior to analysis to help comparison of excess deaths across multiple countries and regions. Using unadjusted data does not allow identification and elimination of statistical outliers. Therefore, it reduces the statistical power of excess death estimates, and under normal epidemiological conditions can sometimes incorrectly identify outliers as excess deaths. However, reported death numbers during the COVID-19 epidemic in Canada and most peer countries are so much larger than variation in death numbers over the previous five years that statistically significant excess deaths were readily identified. For similar reasons, unadjusted death counts were also not adjusted for trends expected from demographic change (e.g., population aging). All excess death estimates were performed using age-stratified data.

Results

Comparison of excess all-cause mortality in Canada, peer countries and Canadian regions

Using the CDC method for calculating excess all-cause mortality during the COVID-19 epidemic, we estimated mortality in Canada and high-income democratic peer countries with populations greater than 25 million people (Australia, France, Germany, Italy, Japan, South Korea, Spain, Taiwan, United Kingdom, United States) (Centers for Disease Control and Prevention and National Center for Health Statistics, 2021) (**Table 1, Figure 1**). Excess deaths in individual provinces with >1,000 cases/100,000 people by November 14, 2020 (Québec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia) were analyzed by the same method. Unadjusted fatality counts for smaller provinces and territories with fewer than 250 cases/100,000 by the same date (Atlantic and Northern Canada: Atlantic provinces, Northern territories) were grouped together before excess death analysis. Excess deaths in Atlantic and Northern Canada were also corrected for the tragic fatalities resulting from the April 2020 mass shooting in Portapique, Nova Scotia. In contrast to other peer countries, where cause-of-death reporting is far more timely, 2020 fatalities reported across most Canadian jurisdictions are only >70% complete to November 28 as of the date of this report, and less than 95% complete past February 2020 in several Canadian provinces (Statistics Canada, 2021c). Slow death reporting means that all Canadian excess death estimates provided in this report are provisional and will keep increasing as death reporting becomes more complete.

We performed similar analyses using expected 2020 deaths from Statistics Canada that are adjusted to reflect increased expected numbers of non-COVID-19 fatalities in 2020 because of

population aging (Shiels *et al.*, 2021; Statistics Canada, 2021c). However, as we illustrate below and in **Figure 1E**, using age-adjusted 2020 fatality numbers for analysis possibly magnified deficit mortality effects, and reduced sensitivity during some periods in regions such as Québec where many COVID-19 fatalities occurred in LTC homes. Analyzing excess all-cause mortality using age-adjusted expected fatality numbers and the non-CDC conventional excess death estimation method employed by Statistics Canada is useful for finding how many people died during the COVID-19 epidemic, who would not have died in the same period (e.g., for finding premature deaths). However, it is not as useful for estimating how many COVID-19 deaths have occurred in Canada, which was the focus of our investigation.

Only 2020 mortalities that were likely to be statistically significant (greater than the upper 95% confidence interval (CI) of the mean deaths reported in corresponding 2015-2019 CDC weeks) were counted as excess deaths (**Table 1**). However, using the upper 95% CI of the mean as the counting threshold had its limits. This method under-estimated excess deaths when compared to reported COVID-19 fatalities in some countries and regions with older populations or a larger percentage of older people living in LTC (France, Germany, Québec), possibly because some people in these countries would have died during the same period of other causes. More sensitive estimates that count as excess all deaths greater than the 2015-2019 mean in corresponding weeks (**Table 1**) captured all reported COVID-19 fatalities in all countries and regions but were more likely to artefactually inflate excess death numbers in regions with very low COVID-19 case numbers (e.g., Taiwan).

From February 1 to November 14, 2020, Canadian per capita excess and reported COVID-19 death numbers corresponded to the median among peer countries, with greater excess and reported COVID-19 fatalities in France, Italy, Spain, the United Kingdom and United States (**Figure 1A**). Within Canada, British Columbia experienced the median number of excess deaths per capita, with more excess deaths in Québec, Ontario, and Alberta. Alberta and Manitoba reported the median number of per capita reported COVID-19 fatalities, with Québec and Ontario reporting more.

Reported COVID-19 fatalities as a proportion of excess all-cause mortality in Canada, peer countries and Canadian regions

Comparing the proportion of excess all-cause mortality that is reported as COVID-19 deaths provides insight into whether COVID-19 fatalities have been fully detected and/or reported. Consistent with reports for the first COVID-19 wave in peer countries (Beaney *et al.*, 2020; Bilinski and Emanuel, 2020; Karlinsky and Kobak, 2021), excess deaths by November 14, 2020, were approximately 50% greater than reported COVID-19 fatalities in Italy, Spain, the United Kingdom and United States; and excess deaths were comparable to or lower than reported COVID-19 fatalities in Australia, France, and Germany (**Figure 1B**). However, by November 14, 2020, excess deaths exceeded reported COVID-19 fatalities in Canada, Japan and South Korea, and excess to reported COVID-19 death ratios in all Canadian regions except Québec were greater than these ratios for most peer countries.

It might be expected that the largest excess to reported COVID-19 fatality ratios would be seen in regions hardest hit during the first wave of COVID-19 (Québec, Ontario). However, this was not true for Québec, which had experienced 2.6 times more reported COVID-19 fatalities than the Canadian average (**Figure 1B**). By contrast, excess deaths in Ontario were twice as high as

reported COVID-19 fatalities by November 14, and the largest excess to reported COVID-19 death ratios were seen in provinces commonly understood to be less affected by the first epidemic wave, Saskatchewan, British Columbia and Alberta, where public health measures were relaxed and remediation of healthcare backlogs began earlier than in Ontario and Québec. Excess deaths were also nearly twice the reported COVID-19 fatalities in Atlantic and Northern Canada, where few COVID-19 cases had been reported, and in Manitoba, which was beginning a prolonged, death-intensive COVID-19 wave by November 14. Thus, it appeared that Québec was the only Canadian province to capture most COVID-19 fatalities by November 14, 2020.

Indeed, in Québec, where 87% of all official COVID-19 fatalities by November 14, 2020 were reported in LTC, excess deaths were approximately 20% lower than reported COVID-19 fatalities (**Figure 1B**). This is actually to be expected, since about 20% of LTC residents might ordinarily have died during this period from other causes (see **Introduction**). Québec did not report a higher percentage of probable COVID-19 fatalities unconfirmed by laboratory testing than other Canadian regions, since the ratio of probable to lab-confirmed reported COVID-19 fatalities in this province was the same as the Canadian average (Statistics Canada, 2021d). Thus, reported COVID-19 fatalities were not greater than excess deaths in this province because of higher rates of laboratory-unconfirmed diagnosis. These observations suggested that total all-cause excess mortality estimates should actually have been lower than reported COVID-19 fatalities in other Canadian provinces too, especially among the oldest age groups. However, they were not.

Reported COVID-19 fatalities in long-term care as a proportion of excess all-cause mortality in Canada, peer countries and Canadian regions

Across most Canadian regions, the percentage of COVID-19 fatalities reported in LTC has remained close to double the OECD average throughout the COVID-19 epidemic until the start of LTC vaccination (81%, 80% and 79% in Canada and 38%, 46% and 41% in OECD countries by May 24, October 14, and December 27, 2020, respectively) (**Figure 1C**) (Canadian Institute for Health Information, 2020b; Comas-Herrera *et al.*, 2020, 2021; Loreto, 2021). The only province to report a lower percentage of total COVID-19 fatalities in LTC was Saskatchewan (7% by November 14), which was very low by OECD and Canadian standards. As of the same date, Saskatchewan also had a lower-than-expected reported CFR (0.60%) than the population's expected age structure-adjusted infection fatality rate of 1.12% (Levin *et al.*, 2020), possibly because the province was only just beginning a large wave of reported cases by November 14. Reporting of all causes of death in Saskatchewan to the Canadian Vital Statistics Death Database is largely incomplete after April 4, 2020 (Statistics Canada, 2021d). Without these data, it is extremely difficult to estimate the true COVID-19 death toll both inside and outside LTC in Saskatchewan.

The observation that twice as many of Canada's COVID-19 fatalities occurred in LTC than the average for OECD countries is quite odd, because the percentage of infected LTC residents who have died of COVID-19 (CFR) is similar in Canada and OECD countries, and because per capita COVID-19 fatalities in Canadian LTC are not greater than the OECD average (Comas-Herrera *et al.*, 2020; Sepulveda, Stall and Sinha, 2020). One possible, and troubling, explanation for this anomaly is that the proportion of Canada's deaths in LTC only appears to be double the OECD average because detection and reporting of COVID-19 fatalities was better in Canadian LTC settings than among people living in the community outside LTC, and that half of COVID-19 community deaths outside LTC might have been missed or unreported.

To examine this possibility we asked whether the proportion of Canadian COVID-19 fatalities in LTC more closely resembled our peers if we expressed it as a percentage of excess deaths from February 1 to November 14, 2020 (**Figure 1C**). Indeed, reported Canadian LTC COVID-19 fatalities made up 45% of excess deaths during this period, a value that closely approximated the median for peer countries. This suggested that at least 50% of Canadian COVID-19 community deaths outside LTC were possibly missed or unreported. In addition, although Québec LTC COVID-19 fatalities still accounted for nearly 100% of excess deaths in this province, and Ontario and Manitoba were close to the peer median, the proportion of excess deaths accounted for by LTC COVID-19 fatalities in other regions was quite low, suggesting that LTC COVID-19 fatalities outside Québec, especially in the Atlantic provinces, Saskatchewan, Alberta and British Columbia were possibly under-detected or under-counted.

Impact of the toxic drug epidemic on Canadian excess all-cause mortality during COVID-19

Comparing the proportion of excess deaths from February 1 to November 14, 2020 that occurred in people 65 years and older in Canada with the same data from peer countries showed that, excluding Québec and Manitoba, the Canadian average and values for many regions were quite low (**Figure 1D**). Canada had comparatively few excess deaths among older people than other peer countries, except for the United Kingdom and the United States. This observation suggested that an unexpectedly high proportion of Canada's excess deaths were among younger people. However, Canada has experienced a pronounced worsening of toxic opioid and stimulant deaths during the COVID-19 epidemic, especially in Alberta, British Columbia, and Ontario (Special Advisory Committee on the Epidemic of Opioid Overdoses, 2021). Thus, estimates of excess mortality and the proportions of excess deaths attributable to COVID-19 must be adjusted to account for indirect effects of the COVID-19 epidemic on toxic drug deaths.

To adjust for the contribution of excess toxic drug deaths to Canada's excess mortality during the COVID-19 epidemic, we estimated weekly excess age-stratified toxic drug deaths in each Canadian region in 2020 using data obtained from Health Canada's Opioid and Stimulant-Related Harm database (Special Advisory Committee on the Epidemic of Opioid Overdoses, 2021), and adjusted total excess death estimates in corresponding age groups and regions with these values. No 2020 Manitoba toxic drug death data were available, so Manitoba excess deaths were adjusted with average national per capita toxic drug death values for each age group. Adjusting for excess toxic drug deaths caused the proportion of excess deaths among people 65 years and older in Canada (overall) and in three Canadian provinces (Ontario, Québec, and Manitoba) to more closely resemble values for peer countries, although toxic drug-adjusted excess deaths still skewed younger in other regions (**Figure 1D**). Subsequent analyses in our report were performed exclusively with toxic drug death-adjusted estimates of excess mortality, to ensure that we focused primarily on excess deaths due to other causes.

Timing of toxic drug-adjusted excess all-cause mortality in Canada compared to reported COVID-19 deaths and cases

Although estimates of total excess all-cause mortality accumulated over a specific period are critical for grasping the scale of possible missed and unreported COVID-19 fatalities, it is also important to understand when excess deaths occurred, especially in relation to reported COVID-19 fatalities

and cases. This comparison can provide insight into whether excess deaths are likely COVID-19 fatalities, and when and where COVID-19 deaths might have been missed.

A temporal comparison of the onset of excess deaths due to all causes and COVID-19 fatalities in Northern Italy and Ecuador during the first wave, for example, has shown that excess deaths began increasing exponentially in these regions weeks before similar increases in reported COVID-19 fatalities (Michelozzi *et al.*, 2020; Cuéllar *et al.*, 2021). Excess toxic drug-adjusted deaths in Canada showed a similar temporal pattern (**Figure 1E:** left). This early onset of excess deaths was not seen when official Canadian excess death estimates from Statistics Canada were plotted (Statistics Canada, 2021c), implying that the CDC excess-death estimation method we used was more sensitive for catching early excess deaths immediately preceding waves of reported COVID-19 fatalities (**Figure 1E**: left). We found that as of November 14, 2020, the Statistics Canada excess mortality estimation method detected 49% fewer excess deaths than the CDC method.

It is important to examine who was dying before reported COVID-19 fatalities began rising, since epidemics can take time to spread to all age groups. Excess all-cause mortality in people 44 years and younger was close to baseline and did not show any specific temporal pattern or mirror the timing of reported COVID-19 fatalities (**Figure 1E**: right). This would be expected if most excess deaths were COVID-19 fatalities, since COVID-19 mortality rates in people younger than 45 are low. Excess deaths among people 85 and older largely coincided with reported COVID-19 fatalities and comprised about 50-60% of excess deaths at the peak of the first wave. This also was expected if a high proportion of Canada's reported COVID-19 fatalities were in LTC, since most people living in LTC are 80 years and older. However, excess deaths among people older than 45, and people 65 and older preceded reported COVID-19 fatalities in the first wave by 4-6 weeks. This suggested that COVID-19 deaths began increasing rapidly before the COVID-19 epidemic reached LTC but were largely undetected.

Between the first and second waves, from July 4 to October 3, excess all-cause mortality in people 85 years and older and reported COVID-19 fatalities also tracked closely together in low death spikes (**Figure 1E**: right). These spikes were accompanied by larger peaks of excess deaths in those 45 and 65 years and older. From October 3 onward, reported COVID-19 fatalities and excess deaths in people 45 years and older began climbing faster. Reported COVID-19 fatalities and excess deaths became more closely linked in time from late October onward as excess deaths in people 85 and older began increasing, suggesting that detection and reporting of COVID-19 fatalities again improved once deaths began appearing in LTC.

Most COVID-19 deaths generally follow COVID-19 diagnosis and case reporting by about 3-4 weeks. We compared reported COVID-19 cases and deaths with toxic drug-adjusted excess all-cause mortality from February 1 to November 14, 2020 (**Appendix 1**). These comparisons were performed using both reported cases and test positivity-adjusted cases, which exhibited a greater dynamic range than reported case numbers alone. Test positivity-adjusted case numbers were ten times greater than reported COVID-19 cases by August 31, 2020, consistent with previous estimates of missed Canadian COVID-19 cases during the first wave (Phipps, Grafton and Kompas, 2020). From January 2020 to May 29, 2021 there were nearly 5.5. million test positivity-adjusted estimated cases and about 1.3 million reported COVID-19 cases in Canada, a possible under-detection ratio of 76%. Intriguingly, Canadian COVID-19 case fatality rates approximated the expected infection fatality rate for the age structure of the Canadian population (1.2%) quite closely when deaths were expressed as a percentage of test positivity-adjusted cases but not

reported cases alone, suggesting that test positivity-adjusted cases were likely a reasonable approximation of actual COVID-19 cases in Canada.

We found that case increases lagged growth of excess deaths until mid-October 2020, when cases began to coincide more closely with excess and reported COVID-19 fatalities (**Appendix 1**). However, case growth never preceded corresponding increases in excess or reported COVID-19 deaths during the period of this analysis. In fact, we found that cases did not begin to precede reported COVID-19 fatalities by three weeks until the week of March 8, 2021, the approximate onset of Canada's third COVID-19 wave. Thus, until the third wave excess all-cause mortality appeared to be an earlier indicator of growth of the COVID-19 epidemic than either reported COVID-19 cases or deaths.

Toxic drug-adjusted excess all-cause mortality compared to COVID-19 deaths predicted from SARS-CoV-2 seroprevalence

Although the timing of toxic drug-adjusted excess all-cause mortality up to November 14, 2020 strongly suggested that many or most excess deaths were likely COVID-19 deaths, we wanted to test whether this inference was reasonable using a method independent of COVID-19 death and active case reporting. To do this, we estimated the number of expected COVID-19 fatalities to July 4, 2020 in different age groups and regions using SARS-CoV-2 seroprevalence data for this period obtained from a representative sample of the Canadian population that conducted head-to-head comparisons of all Canadian provinces and age groups (Jha, 2021). Similar representative head-to-head seroprevalence data are not available for the second wave, and seroprevalence estimates obtained during the second wave using convenience and blood donor samples have been lower than head-to-head representatively sampled estimates from the first wave, possibly because SARS-CoV-2 antibodies decline in a significant proportion of infected people (COVID-19 Immunity Taskforce, 2021). The number of COVID-19 deaths expected for seroprevalence-based case numbers in the first wave were predicted using age-specific estimated OECD infection fatality rates (Levin *et al.*, 2020) and region-specific 2016 Canadian population age demographics (Statistics Canada, 2016) (**Figure 2** and **Appendix 2**). Unlike all-cause mortality, age-stratified seropositivity and COVID-19 case and death data from the Public Health Agency of Canada (PHAC) used for our comparisons are reported by region, not individual provinces. The age groups reported for all-cause mortality also differ slightly from seroprevalence and reported COVID-19 cases and death data. We performed our comparisons using the same regions and slightly non-overlapping age groups to avoid introducing potential errors into excess all-cause mortality estimates.

We found that in all Canadian regions except Québec, estimated excess deaths in people 45 years and older fell within the range of seroprevalence-estimated deaths, while reported COVID-19 fatalities were less than or within the lower range of seroprevalence-estimated deaths (**Figure 2A** and **Appendix 2**). For Canada outside Québec, seroprevalence-predicted deaths were approximately twice as high as reported COVID-19 fatalities, which was very similar to the ratio of excess all-cause mortality to reported COVID-19 fatalities. These observations suggested that at least during the first wave many if not most excess deaths were likely COVID-19 fatalities. Of concern, both excess and seroprevalence-predicted COVID-19 deaths were 70-80% greater than reported COVID-19 fatalities in Atlantic Canada, the Prairie provinces and Northwest Territories, and in British Columbia and the Yukon (**Appendix 2**), suggesting that under-detection or under-reporting of COVID-19 fatalities in these regions was particularly acute. The toxic drug-adjusted

excess death estimate for Ontario (30%), which corresponded well to seroprevalence-predicted COVID-19 deaths, was also close to Ontario excess death estimates for a similar period (32%) obtained from cremation data (Postill *et al.*, 2020).

Contributions of specific non-COVID-19 specific causes of death to toxic drug-adjusted excess all-cause mortality

Another way to examine whether excess all-cause mortality during the COVID-19 epidemic has been directly due to COVID-19 deaths is to determine if any of these excess deaths might be explained by specific non-COVID-19 causes. The top ten causes of death in Canada in 2019 were cancer, heart disease, accidents, cerebrovascular diseases (e.g., strokes), chronic lower respiratory diseases, diabetes, influenza and pneumonia, Alzheimer's disease, suicide and kidney disease (Statistics Canada, 2020). We examined whether deaths due to any of these specific causes increased by estimating how many deaths attributed to each cause during the COVID-19 epidemic were greater than the upper 95% CI of the average number of deaths due to the same cause from 2015-2019 (estimated excess deaths due specific non-COVID-19 causes) (**Figure 3**) (Statistics Canada, 2021d). Excess deaths attributed to these specific causes were compared to total toxic drug-adjusted excess deaths in people 45 and older that were not attributed to COVID-19 (**Figure 3: Non-COVID excess**). We used the CDC method of adjusting negative 2020 death values for each specific cause of death to zero to maximize sensitivity and facilitate comparison to toxic drug-adjusted all-cause mortality estimates.

As of the last date of our analysis (May 29, 2021) reporting of specific causes of death in most Canadian regions was only 70% or more complete up to July 4, 2020 and was still less than 95% complete for multiple provinces by the end of February 2020 (British Columbia, Manitoba and Saskatchewan) and June 2020 (Alberta) (Statistics Canada, 2021d). Specific cause of death reporting was >95% complete in the Atlantic provinces and Ontario to the end of September and November, 2020, respectively, and was >95% complete in Canada's leader in death reporting (Québec) to February 2021. Delays in completion of specific cause of death reporting made it challenging to confidently estimate (within 95% confidence intervals) whether other specific causes of death increased during the first wave in British Columbia, Manitoba and Saskatchewan, after the first wave in Alberta, or in Atlantic Canada after September 2020. Therefore, we could not determine if any specific cause of death other than COVID-19 increased across Canada after Wave 1, and even Wave 1 estimates for multiple western provinces remained quite provisional.

It was quite possible that deaths attributed to any of the specific causes of death we analyzed could have included COVID-19 fatalities attributed to other causes—that is, deaths of people who had COVID-19 but whose death certificate listed a different condition as the primary cause of death. This is because the specific causes of death we examined are among the most common co-morbidities linked to COVID-19 on death certificates registered in the Canadian Vital Statistics Death Database (O'Brien *et al.*, 2020), as well as the most common lethal complications of acute COVID-19 and post-acute COVID-19 syndrome (long COVID), including thrombotic, cardiovascular, cerebrovascular, kidney and respiratory complications (Nalbandian *et al.*, 2021).

We found no excess deaths attributed to suicide or accidents during this period, and that excess deaths attributed to other specific causes of death were quite small and variable across Canadian regions, especially compared to reported COVID-19 deaths (**Figure 3**). To ensure we had not missed any non-COVID-19 deaths stemming from healthcare disruptions, we combined specific

causes of death into groups reflecting different healthcare sectors. Specific causes of death most likely to be affected by disrupted hospital care for life-threatening conditions were grouped together and included the top five causes of death in Canadian hospitals (**Figure 3, Hospital Top 5**: heart, cerebrovascular and chronic lower respiratory diseases, and influenza and pneumonia) (Berthelot *et al.*, 2019; Canadian Institute for Health Information, 2020a). We found 78% of deaths in the Hospital Top 5 category were linked to cardiovascular and cerebrovascular causes, with 22% attributed to respiratory illness. Deaths due to specific causes most likely to be linked to disruptions in ongoing care supplied both in and outside hospitals were grouped together (**Figure 3: Cancer, Diabetes, Kidney disease**). In this group 53% of deaths were attributed to cancer, and 47% were attributed to diabetes and kidney disease. The third category included excess deaths attributed to dementia, which were potentially affected by disruptions in LTC (**Figure 3: Alzheimer's**), since most deaths attributed to dementia occur in LTC, and not in hospitals or people's private homes.

Once again, Québec, the province hardest hit by COVID-19, was strikingly different than the rest of Canada. Unlike other Canadian regions, in Québec all toxic drug-adjusted excess deaths in people 45 and older during this period were attributed primarily to COVID-19, and none were attributed to the specific non-COVID-19 causes we examined (**Figure 3**). This suggested quite strongly that excess deaths attributed to specific non-COVID-19 causes in other Canadian regions were likely COVID-19 fatalities that were instead attributed to other primary causes of death. Indeed, COVID-19 was reported on the certificates of about 80% of deaths attributed to specific causes in the Hospital Top 5 category, and 100% of deaths attributed to Alzheimer's disease (O'Brien *et al.*, 2020). The picture was less clear for deaths attributed primarily to cancer, diabetes and kidney disease, which are more likely to happen in a residential or residential care setting than in hospital. COVID-19 was listed on the death certificate for about 60% of excess fatalities attributed primarily to cancer (O'Brien *et al.*, 2020). However, the proportions of deaths primarily attributed to diabetes and kidney disease that also listed COVID-19 on death certificates have not been reported. Outside Québec, deaths attributed to cancer, diabetes and kidney disease increased very rapidly starting six weeks before the onset of the first wave of reported COVID-19 deaths, when COVID-19 testing was limited, but slowed after national stay-at-home orders were implemented and as reported COVID-19 deaths began rising (**Figure 3**). At the point where excess deaths attributed to cancer, diabetes and kidney disease began slowing, they accounted for 37% of excess all-cause mortality unattributed to COVID-19, a much larger proportion of these deaths than Alzheimer's disease and conditions in the Top 5 Hospital category combined. Cancer, diabetes and kidney disease also collectively accounted for one third of the co-morbidities listed on the death certificates of fatalities attributed primarily to COVID-19 during the period we investigated (O'Brien *et al.*, 2020). The timing of excess deaths attributed to these specific causes, especially during a period when COVID-19 testing was limited, the absence of excess deaths attributed primarily to these causes in Québec, and the substantial proportion of COVID-19-attributed deaths that list these conditions on death certificates collectively suggested that many if not most excess deaths attributed primarily to these diseases were quite likely COVID-19 deaths.

Toxic drug-adjusted excess mortality during the second wave

Next, we asked whether total toxic drug-adjusted excess all-cause mortality in people 45 and older continued to be greater than reported COVID-19 fatalities after July 4 up to November 28,

2020 in the second COVID-19 wave (**Figure 4, Table 2**). Reporting after November 28 was <70% complete as of the date of our analysis in multiple Canadian regions, meaning that excess death estimates after this date were considerably less certain. Charts for Canada, Québec, and Canada outside Québec (Canada minus Québec/Can-QC) are shown in **Figure 4**. Charts for individual provinces and regions are found in **Appendix 3**. Due to the small number of reported COVID-19 fatalities and excess deaths in Atlantic and Northern Canada, these regions are grouped together (**Appendix 3**). Total estimated excess deaths for each Atlantic province are provided in **Appendix 3**.

Toxic drug-adjusted excess all-cause mortality estimates for this period will keep increasing as death reporting for the first and second waves is slowly completed across Canada. We will continue to update our excess all-cause mortality estimates on a regular basis, and report them publicly in **English** and **French** at our **Canadian Excess Death Tracker**.

From February 1-November 28, 2020, there were an estimated 16,953 toxic drug-adjusted excess deaths in people 45 years and older across Canada, compared to 11,787 reported COVID-19 fatalities (**Table 2, Figure 4, Appendix 3**). Once again, total reported COVID-19 fatalities (7,097) continued to be greater than excess deaths (5,963) in Québec (reported to excess ratio: 119%), but not in Canada outside Québec. Excess deaths in the rest of Canada (10,990) continued to be greater than reported COVID-19 fatalities (4,978), and fewer excess deaths were reported as COVID-19 fatalities than during the first wave (reported to excess ratio from July 11 to November 28: 34%, compared to 56% by July 4). It is possible the further decline in COVID-19 to excess all-cause mortality ratios outside Québec during Wave 2 reflected slower COVID-19 death reporting in many jurisdictions, especially western provinces. However, the striking difference between Québec and the rest of Canada, and the (at least) two-fold difference between reported COVID-19 and excess all-cause deaths outside Québec remained remarkably stable through both the first and second waves. This suggested strongly that the problems contributing to under-recognition and/or under-reporting of COVID-19 deaths outside Québec during and after the first wave almost remained largely unchanged during the second wave. Among the other provinces and regions, reported COVID-19 to excess all-cause death ratios by November 28, 2020 were lowest in Atlantic and Northern Canada (15%), Saskatchewan (16%), British Columbia (22%), Alberta (34%) and Ontario (56%), and highest in Manitoba (79%).

In Québec, temporal changes, and slopes of curves for excess deaths in all age groups and reported COVID-19 fatalities were also largely similar from July 4 to November 28, as they had been during the first wave (**Figure 4**). This suggested that even though the number of excess deaths differed for each age group, these changes happened in tandem with changes in reported COVID-19 fatalities, as would be expected if most excess deaths were COVID-19 fatalities and if SARS-CoV-2 was spreading uniformly among people older than 45.

The picture outside Québec was quite different. As during the first wave, reported COVID-19 fatalities in the rest of Canada continued to track closely with excess deaths in people 85 and older during the second wave. However, the number of reported COVID-19 fatalities did not reflect steadily increasing excess deaths in working aged people (45-64) and older people more likely to be living in the community than in LTC (65-84). In fact, from July 4 to November 28, excess deaths in people between the ages of 65 and 84 became greater than the number of excess deaths in people aged 85 and older. Excess deaths among those aged 65 to 84 also increased at a faster rate than both reported COVID-19 fatalities and excess deaths in the 85+

group. This pattern was seen throughout the second wave in every province except Québec and Saskatchewan (**Appendix 3**).

It is possible that the acceleration of deaths in people aged 45 to 64 and 65 to 84 reflected more successful isolation of LTC from SARS-CoV-2 circulating in the general population in regions outside Québec starting after July 4. However, the proportion of total excess deaths that occurred in people 85 and older dropped by 18% from Wave 1 to Wave 2 in Québec, by 11% in Ontario, and by 3% in the rest of Canada. Therefore, better isolation or protection of LTC settings did not explain this discrepancy. Instead, it appears that outside Québec people from 45 to 84 years of age might have been at greater risk of exposure to SARS-CoV-2 and/or dying of COVID-19 than during the first wave. It is also possible that indirect effects of the COVID-19 epidemic were disproportionately driving deaths in people 45 to 84 years old, although it is difficult to imagine why these factors did not have similar impacts in Québec.

Estimated toxic drug-adjusted excess all-cause mortality in working age adults, and people living in and outside long-term care to November 28, 2020

We also roughly estimated what proportions of toxic drug-adjusted excess all-cause mortality in people 45 and older were reported as COVID-19 fatalities by November 28, 2020, for people living in LTC and in the community outside LTC (**Table 3**). To do this, we compared toxic drug-adjusted excess all-cause mortality in people 45-64 years of age ("Working" age group) with reported COVID-19 fatalities in people 59 and younger in Canada's COVID-19 dataset (Public Health Agency of Canada, 2021f). To estimate deaths among people most likely to be living in the community and not in LTC, we compared excess deaths in people 45-84 years of age ("Community" age group) with reported COVID-19 fatalities in people 79 and younger. We estimated deaths in LTC by comparing excess deaths in people 85 and older ("LTC" age group) with reported COVID-19 fatalities in people 80 and older (**Table 3**).

To estimate actual LTC COVID-19 fatalities we assumed that reported COVID-19 fatalities among people 80 and older should be at least 20% greater than excess deaths among those 85 and older (see **Introduction**). In Québec, reported COVID-19 fatalities in the LTC age group and COVID-19 fatalities reported in LTC were actually respectively 57% and 83% greater than excess all-cause mortality in the LTC age group (**Table 3**). Québec's supportive living, retirement and long-term care system provides residential care to people with a wide range of needs, including those younger than 85. Therefore, some Québec LTC COVID-19 fatalities likely included people in the 65-84 age group. We estimated how many LTC COVID-19 deaths would be expected for Canadian regions outside Québec, by multiplying excess all-cause mortality in people 85 and older by 120% and found that at least 900 LTC COVID-19 fatalities were likely missed by November 28, 2020.

Among working age people only 14% of excess all-cause mortality was reported as COVID-19 fatalities nationally (**Table 3**). Once again, Québec was distinct, with reported COVID-19 fatalities accounting for 91% of excess all-cause mortality in this age group. Outside Québec, only 9% of excess deaths were reported as COVID-19 fatalities. The proportions of excess mortality reported as COVID-19 deaths were 0% in British Columbia and the Yukon, 0% in Atlantic provinces, 10% in the Prairies provinces and Northwest Territories, and 16% in Ontario and Nunavut. In Québec a total of 10 estimated excess deaths were not reported as COVID-19 fatalities. In Canada outside

Québec, 1,387 estimated excess deaths among working age people were not reported as COVID-19 fatalities.

Across Canada 62% of estimated excess all-cause mortality in the community-dwelling age group (45-84) was not reported as COVID-19 deaths (~6,000 deaths), two to six times more than total estimated COVID-19 deaths missed in LTC (**Table 3**). Québec reported 70% of estimated excess mortality as COVID-19 deaths. This number might have been closer to the value for the working age group (91%) due to some reported LTC COVID-19 deaths almost certainly being among LTC residents younger than 85. In the rest of Canada, only 26% of estimated excess mortality in this group was reported as COVID-19 deaths, 2% in the Atlantic provinces, 11% in British Columbia and the Yukon, 30% in Ontario and Nunavut, and 33% in the Prairie provinces and Northwest Territories.

Guesses about COVID-19 deaths after November 28, 2020

Early cremation-based excess death estimates available for Ontario indicate that from January 2020 to March 2021 excess deaths in people 45 and older were 40% greater than reported COVID-19 fatalities (Postill *et al.*, 2021). Using cumulative test positivity-adjusted estimated Ontario case numbers as of March 31, 2021 (approximately 1.02 million) (**Appendix 1**) and the SARS-CoV-2 infection fatality rate estimated for Ontario's 2016 population age structure (1.2%) (Levin *et al.*, 2020), we found the approximate number of Ontario COVID-19 fatalities expected by this date (approximately 12,100) was 39% greater than reported COVID-19 fatalities (7,366), a value almost identical to the excess to reported COVID-19 death ratio obtained from cremation data (Postill *et al.*, 2021). This suggested that most excess deaths in Ontario up to March 31, 2021 might have been COVID-19 fatalities.

Test positivity-based COVID-19 case and death estimates for all of Canada by March 31, 2021 were also concerning. We estimated that by this date 3.5 million people living in Canada might have been infected with SARS-CoV-2, that 42,000 might have died, and that 45% of deaths were potentially missed. For Canadian regions outside Québec, total COVID-19 death numbers predicted from test positivity-adjusted case numbers remained 50% higher than total reported COVID-19 fatalities as of March 31, 2021. Similar estimates up to June 4, 2021 performed using test positivity-adjusted case numbers for specific age groups suggested that predicted COVID-19 deaths might have remained twice as high as reported COVID-19 fatalities in the third wave in all Canadian regions except Québec, possibly amounting to 57,000 deaths from the start of the epidemic. However, it is crucial to recognize that outside Ontario there is no evidence available that could either corroborate or cast doubt on these estimates to the end of the second wave, and no evidence for any part of Canada to corroborate third wave estimates. Third wave estimates are even murkier than first and second wave estimates because of likely vaccination-dependent reductions in mortality among some who contracted COVID-19. However, given the scale of possible unreported COVID-19 deaths to date and the possibility that up to half of Canadian COVID-19 deaths are still going unnoticed, it is imperative that all-cause mortality reporting to the end of the third wave is completed as soon as possible in every province and territory in Canada. It is also essential that specific cause of death reporting is completed immediately, since without these data we have no way of knowing if historically unusual numbers of people are now dying of causes other than COVID-19.

A recalibrated view of COVID-19 epidemic deaths across Canadian regions

Finally, comparing toxic drug-adjusted excess deaths across regions up to November 28, 2020 altered and refocused the picture of how the COVID-19 epidemic had unfolded in Canada (**Figure 5**). We compared total reported COVID-19 fatalities with excess drug-adjusted deaths of people 45 years and older (**Figure 5A**), per capita reported COVID-19 fatalities and excess deaths (**Figure 5B**), and per capita reported COVID-19 and excess deaths adjusted for differences in the population age structure of each region (**Figure 5C**). The last comparison was important for understanding how different provinces had "performed" in preventing epidemic deaths independent of factors that could not be changed, such as having younger or older populations.

These comparisons revealed a very different picture of the epidemic, where Ontario experienced more total deaths than Québec by November 28 (**Figure 5A**), and regions that had assumed themselves relatively unscathed by COVID-19 until the fall (everywhere except Québec and Ontario) were in fact much closer to the per capita death rates of Ontario (**Figure 5B**). Per capita excess deaths in Québec were twice the national average, instead of the three-fold difference that appeared in reported COVID-19 fatalities. British Columbia and Alberta also had more per capita deaths than Manitoba, and per capita deaths in Saskatchewan were much closer to Manitoba than previously thought, an unsurprising observation given their geographical proximity. It also appeared that Alberta and British Columbia were more closely epidemiologically linked than commonly understood (**Figure 5B**). Age adjustment showed that Alberta would have experienced more per capita deaths than every province except Québec if not for its younger population (**Figure 5C**). Finally, although per capita age-adjusted excess and reported COVID-19 deaths were lower in Atlantic and Northern Canada than all other Canadian regions by late November, and lower than most Canadian regions through most of the epidemic, it is clear that there were more probable COVID-19 fatalities than thought. This is despite the region's apparent success in keeping case numbers low after the first wave. This is also not surprising, given the proximity of New Brunswick to Québec and the United States border. It will be important to see if Atlantic and Northern Canada continued to keep a slow, steady but damped-down increase in excess deaths through the second and third waves of reported COVID-19 fatalities compared to other regions, once more death reporting is available.

Discussion

Factors contributing to under-detection and under-reporting of COVID-19 fatalities in Canada

1. Insufficient testing and post-mortem testing

Canada has conducted 75% fewer tests per positive case to date than peer countries and may have failed to detect about three quarters of COVID-19 cases since the beginning of the epidemic. Better situational awareness resulting from more testing in Québec may have helped the province identify a larger proportion of its COVID-19 deaths and the regions and settings where they were occurring compared to most other Canadian regions. Lack of systematic post-mortem testing of everyone who died during the COVID-19 epidemic outside Québec and Manitoba has almost certainly been a major factor in lower rates of identification of COVID-19 fatalities in other provinces. Systematic post-mortem testing for every death in Canada would require only 1,000

more COVID-19 tests/day nationally and should be implemented in every region until COVID-19 deaths have become rare.

2. Absence of routine or accessible COVID-19 testing for formal and informal care providers for frail people living in community

Barriers to testing access for formal and informal care providers in the community also likely contributed to transmission leading to COVID-19 deaths among frail community dwellers, as well as a failure to identify possibly COVID-19 deaths in community if asymptomatic cases in formal and informal care providers were never identified. Both formal and informal care providers in community are often stretched impossibly thin under normal conditions and would have found it extremely challenging to get to testing sites when these were open, especially if they were also working or held multiple jobs. We advocate that all people who live with or enter the homes of frail individuals to supply informal or formal homecare should be tested for active SARS-CoV-2 or earlier SARS-CoV-2 exposure at least once weekly until at least one month after their final COVID-19 vaccination and the final vaccination of those they support, and that this be provided as a door-to-door service if needed. Investigating and reporting numbers of deaths among homecare recipients during the COVID-19 epidemic and in the five years pre-COVID-19 will also be imperative for understanding whether homecare services contributed to the spread of COVID-19 among those most at risk in the community. Tracking and reporting of deaths among homecare recipients should always be a fundamental part of health outcome monitoring, not only during COVID-19, just as this reporting is mandatory in hospitals and LTC.

3. Inadequate communication about COVID-19 presentation in older people, especially in the highest risk communities

The frequency and features of pauci-symptomatic and atypical presentation of COVID-19 in older people has almost certainly been insufficiently communicated to at-risk people in the community and their caregivers, which in turn may have prevented life-saving access to diagnosis and treatment. This was likely especially acute in the highest risk communities. We recommend developing and widely distributing simple multilingual guidelines for recognizing "atypical" COVID-19 symptoms common in older and frail people, via official websites, radio, television, social media, and local community media outlets. These guidelines should be shared directly with frail individuals and their formal and informal caregivers by homecare, clinic and hospital workers, volunteers and the staff of organizations who support frail individuals, such as Meals on Wheels, community and religious leaders, and by homecare worker social and advocacy groups who reach private in-home caregivers.

4. Under-recognition/under-reporting of COVID-19 (laboratory-confirmed and probable) deaths

Some under-attribution of deaths to COVID-19 outside Québec likely happened when COVID-19 was listed as a co-morbidity on the death certificate but was not identified as a primary cause of death. We estimate that death certificates listing COVID-19 without naming it as the primary cause of death might have accounted for about 30% of excess deaths unattributed to COVID-19 by the end of the first wave. The Atlantic provinces, Alberta, and British Columbia reported at least four times fewer probable COVID-19 deaths unaccompanied by laboratory tests than the Canadian average. Reporting only COVID-19 fatalities confirmed by laboratory testing might account for approximately 15% of under-reporting of COVID-19 fatalities in these provinces to November 2020.

5. Slow, uncoordinated, non-transparent death and LTC death reporting systems inadequate for mass mortality monitoring during crisis

Left without accurate, timely information about the COVID-19 epidemic in community settings, it appears many Canadian regions did not act with urgency to detect or control spread of the epidemic until it reached LTC, long after it had likely begun killing people living in community. We speculate that the relative speed and completeness of all-cause mortality, specific cause of death, and COVID-19 death reporting in and outside LTC, together with the relatively high degree of coordination of LTC and community health clinic systems in Québec might have improved situational awareness and information sharing during the epidemic compared to other Canadian regions.

6. Use of conventional excess mortality estimation methods lacking insufficient sensitivity to monitor deaths during periods of mass mortality

The lack of prompt information about excess deaths was exacerbated using excess mortality estimation methods appropriate for normal times, but not during mass-mortality events such as epidemics. This meant that when excess death data finally became available, the extent of all-cause mortality during COVID-19 was significantly underestimated, and important warnings of the accumulation of likely COVID-19 deaths outside LTC were missed.

7. Failure to investigate concerning, persistent anomalies in Canada's all-cause mortality and COVID-19 death data

Québec has supplied a perfect illustration throughout the epidemic of how COVID-19 fatalities among the oldest and the frailest can cause excess all-cause mortality estimates to be considerably lower than reported COVID-19 death numbers, and why reported COVID-19 deaths in LTC should likely have been consistently higher than excess all-cause mortality in the oldest age groups in all of Canada. Québec appears to have been the only province to identify and report many or most of its COVID-19 deaths, as soon as they began happening, not 4-6 weeks after their initial onset once deaths started being reported in LTC. These problems do not seem to have been recognized and/or acted upon in other Canadian regions or nationally. However, in the absence of timely evidence that excess mortality was in fact two times greater than reported COVID-19 deaths through much of the epidemic, or of official, coordinated national LTC case and death reporting, it is unsurprising that this problem was not investigated. Again, because Québec has reported all-cause mortality significantly faster than most other regions it may have had a better sense of the true impact of COVID-19 earlier than in other regions. Importantly, the people and institutions working on the ground to control the epidemic, diagnose and treat COVID-19 cases and report COVID-19 deaths have been stretched beyond capacity since the first days of the epidemic. The failure to recognize how much higher excess all-cause mortality was than reported COVID-19 deaths was the critical failure of an overwhelmed system no longer able to work safely or as intended, not of the people struggling to work with what they had at hand.

Other explanations for Canada's excess deaths during the COVID-19 epidemic

Statistics Canada has reported that excess deaths from January 2020 to January 2021 were largely due to death from COVID-19 itself (Statistics Canada, 2020). As of the date of the writing of this report (June 5, 2021), it does not yet appear that there are any obvious alternative explanations for Canada's toxic drug death-independent excess deaths other than COVID-19. As in multiple peer

countries, officially reported suicides appeared to decline or remain stable in several Canadian provinces and nationally during the first wave (Pirkis *et al.*, 2021). Police-reported violent crime, which ironically is reported substantially faster and more completely than deaths due to any cause in Canada, was lower compared to previous years up to the most recent date of reporting (March 2021) (Statistics Canada, 2021e). We found no increase in accidental deaths or clear COVID-19-independent increases in other major causes of death. However, given the extreme slowness of Canada's reporting of all specific causes of death, we have no real idea as to whether COVID-19 deaths continued to account for nearly all excess mortality after the first wave.

Conclusion

It appears the focus on the tragedy in Canadian LTC and the belief that this is where most Canadian COVID-19 deaths happened led to underestimation of how many COVID-19 cases and fatalities were happening among people living in the community, and prevented recognition of the full scale of risk in low-income, racialized communities, among those who are older, frail, or living with dementia, among essential workers and recent immigrants and people living in high-density neighbourhoods, often in multi-generational households.

Our failure to understand the true scope and nature of the COVID-19 death toll is because of challenges in data infrastructure, death reporting and tracking both nationally and provincially. The lack of timely data may have delayed the implementation and widespread adoption of public health interventions that could have saved many lives both outside and inside LTC. A death reporting system that is decades out of date, the inability to easily integrate reporting systems with each other or nationally, and the failure of Canadian leaders to fund the modernization of health data reporting have directly contributed to our lack of situational awareness during the COVID-19 epidemic. We have also known since the beginning of the pandemic that in most OECD countries, high density, low-income neighbourhoods where essential, often racialized and recently immigrated workers live were disproportionately harmed, a manifestation of systemic racism. It is unimaginable how this many deaths would or could have been missed if they had occurred in predominantly white, privileged neighbourhoods of working adults with powerful economic, political and social voices. We should have actively investigated earlier how and why we were not seeing the expected deaths in the most systemically disadvantaged communities in our society, and how it was possible that COVID-19 deaths could bypass these communities to kill disproportionately in LTC. We have effective tools to prevent more deaths in the coming months and we must act with the urgency to prioritize the most clinically frail, systemically marginalized, ignored, and at-risk members of our society.

Figures, Tables, and Legends

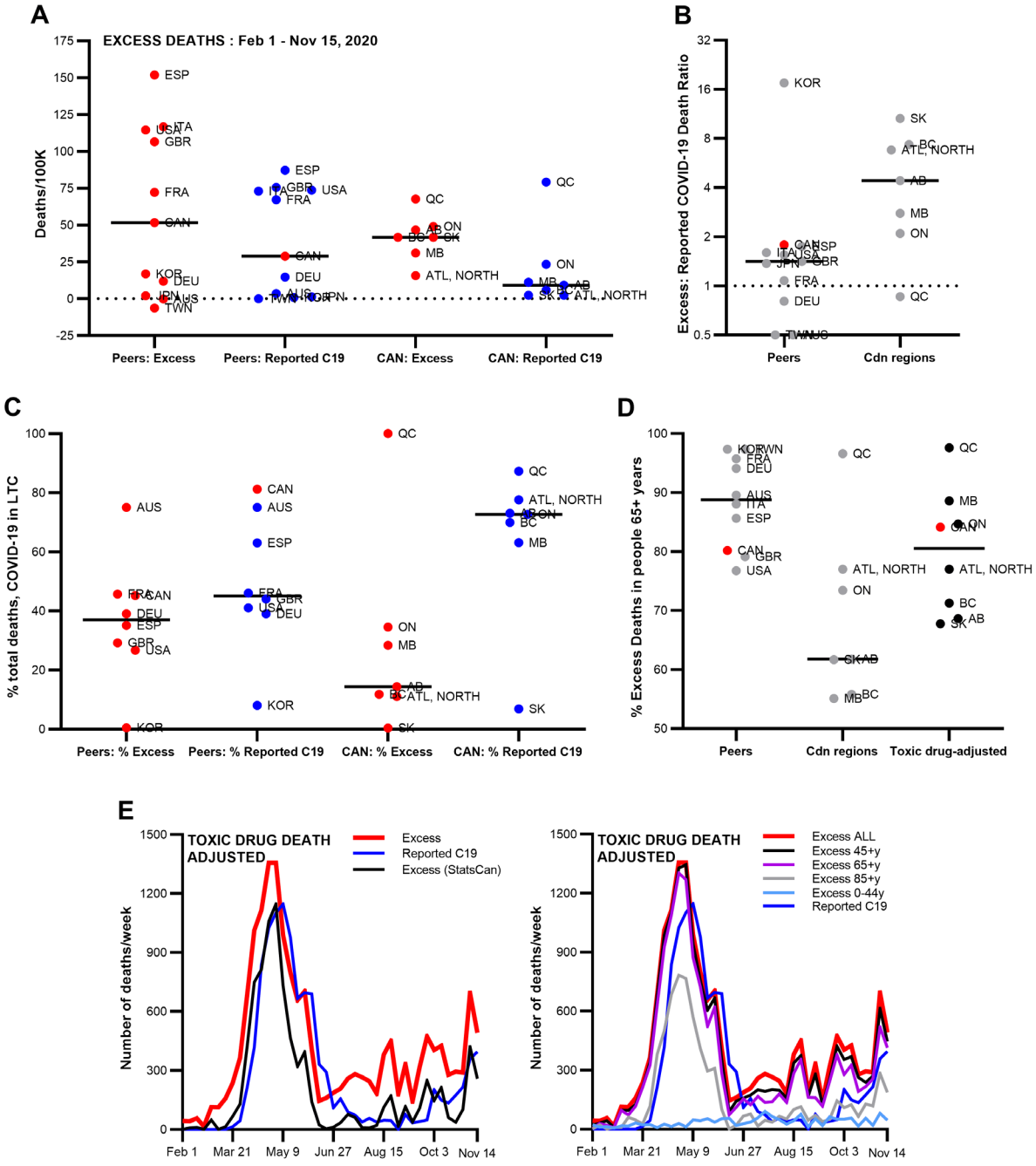


Fig. 1. Estimated excess deaths and reported COVID-19 deaths in LTC and the general population, Canadian regions and peer countries, February 1-November 14, 2020. Excess deaths estimated using U.S. Centres for Disease Control COVID-19 excess mortality estimation method (Centers for Disease Control and Prevention and National Center for Health Statistics, 2021). Excess deaths are numbers of deaths greater than the upper 95% CI of mean weekly deaths for corresponding CDC weeks from 2015-2019 (i.e., statistically significant excess deaths only). **A)** Cumulative excess deaths from Feb 1-Nov 15, 2020, in high=income peer countries with populations greater than 25 million and Canadian regions. **B)** Ratio of excess deaths to reported COVID-19 fatalities in the same period. Detailed data presented in **Table 1**. **C)** Percentage of total excess and COVID-19 deaths reported in long-term/congregate care settings (Feb 1-Oct 10, 2020). **D)** Percentage of excess deaths that occurred in people 65 years and older, without (Peers, Cdn regions) and with adjustment for excess deaths due to toxic drugs (Toxic drug-adjusted). **E)** Weekly total (left) and age-specific (right) excess deaths. Excess deaths in the corresponding period estimated by Statistics Canada using age-adjusted projections are shown in the left panel. **Data sources**: Excess deaths (Giattino *et al.*, 2021; Karlinsky and Kobak, 2021; Max Planck Institute for Demographic Research and University of California, Berkeley, 2021; Statistics Canada, 2021b, 2021c), COVID-19 fatalities (Dong, Du and Gardner, 2020; Little, 2020; Roser *et al.*, 2021), LTC COVID-19 fatalities (Comas-Herrera *et al.*, 2020; Loreto, 2021), toxic drug deaths (Special Advisory Committee on the Epidemic of Opioid Overdoses, 2021), country and region population estimates (Statistics Canada, 2016; The World Bank, 2017).

Table 1: February 1-November 14, 2020, estimated excess deaths and reported COVID-19 fatalities in high income countries with populations greater than 25 million and Canadian regions

Region	Estimated excess deaths/100K *(Total deaths)*[1]		Reported COVID-19 deaths/100K *(Total deaths)*[2]	% Excess mortality accounted for by reported COVID-19 deaths	
	Lower estimate *(values greater than 2015-2019 95% CI of mean)*	**Upper estimate** *(values greater than 2015-2019 mean)*		Excess deaths above 2015-2019 95% CI of mean	Excess deaths above 2015-2019 mean
Australia	**-0.11** *(0)*	**9.15** *(2333)*	**3.56** *(908)*	100	39
France	**72.32** *(33,805)*	**82.84** *(54,069)*	**67.24** *(43,908)*	105	93
Germany	**11.90** *(9970)*	**35.62** *(29,843)*	**14.77** *(12,377)*	124	42
Italy	**116.71** *(70,565)*	**133.48** *(80,704)*	**73.00** *(44,165)*	63	55
Japan	**2.05** *(2593)*	**27.10** *(34,279)*	**1.49** *(1885)*	73	6
South Korea	**16.84** *(8634)*	**27.01** *(13,848)*	**0.96** *(492)*	6	4
Spain	**151.85** *(70,997)*	**161.52** *(75,518)*	**87.20** *(40,810)*	57	54
Taiwan	**-6.25** *(0)*	**7.12** *(1695)*	**0.03** *(7)*	100	1
United Kingdom	**106.53** *(72,334)*	**111.65** *(75,795)*	**75.57** *(51,312)*	71	68
United States	**114.62** *(379,392)*	**127.95** *(423,513)*	**73.82** *(244,344)*	64	58
Canada	**51.79** *(19,680)*	**70.28** *(24,441)*	**28.97** *(11,009)*	56	41
Atlantic, Northern Canada	**15.82** *(511)*	**27.49** *(888)*	**2.35** *(76)*	15	9
Québec	**67.73** *(5712)*	**80.27** *(6769)*	**79.29** *(6660)*	117	99
Ontario	**49.09** *(7069)*	**69.98** *(10,110)*	**23.34** *(3372)*	48	33
Manitoba	**31.03** *(422)*	**37.86** *(515)*	**11.17** *(152)*	36	30
Saskatchewan	**41.67** *(487)*	**49.55** *(579)*	**2.48** *(29)*	6	5
Alberta	**46.78** *(2033)*	**62.48** *(2715)*	**9.23** *(401)*	20	15
British Columbia	**41.79** *(2098)*	**57.07** *(2865)*	**5.84** *(293)*	14	10

[1]*Calculated from reported weekly deaths for Feb 1-Nov 15, 2020, compared to deaths during corresponding weeks of 2015-2019. Sources:* (Giattino *et al.*, 2021; Max Planck Institute for Demographic Research and University of California, Berkeley, 2021; Statistics Canada, 2021b).

[2]*Sources:* (Dong, Du and Gardner, 2020; Little, 2020; Roser *et al.*, 2021).

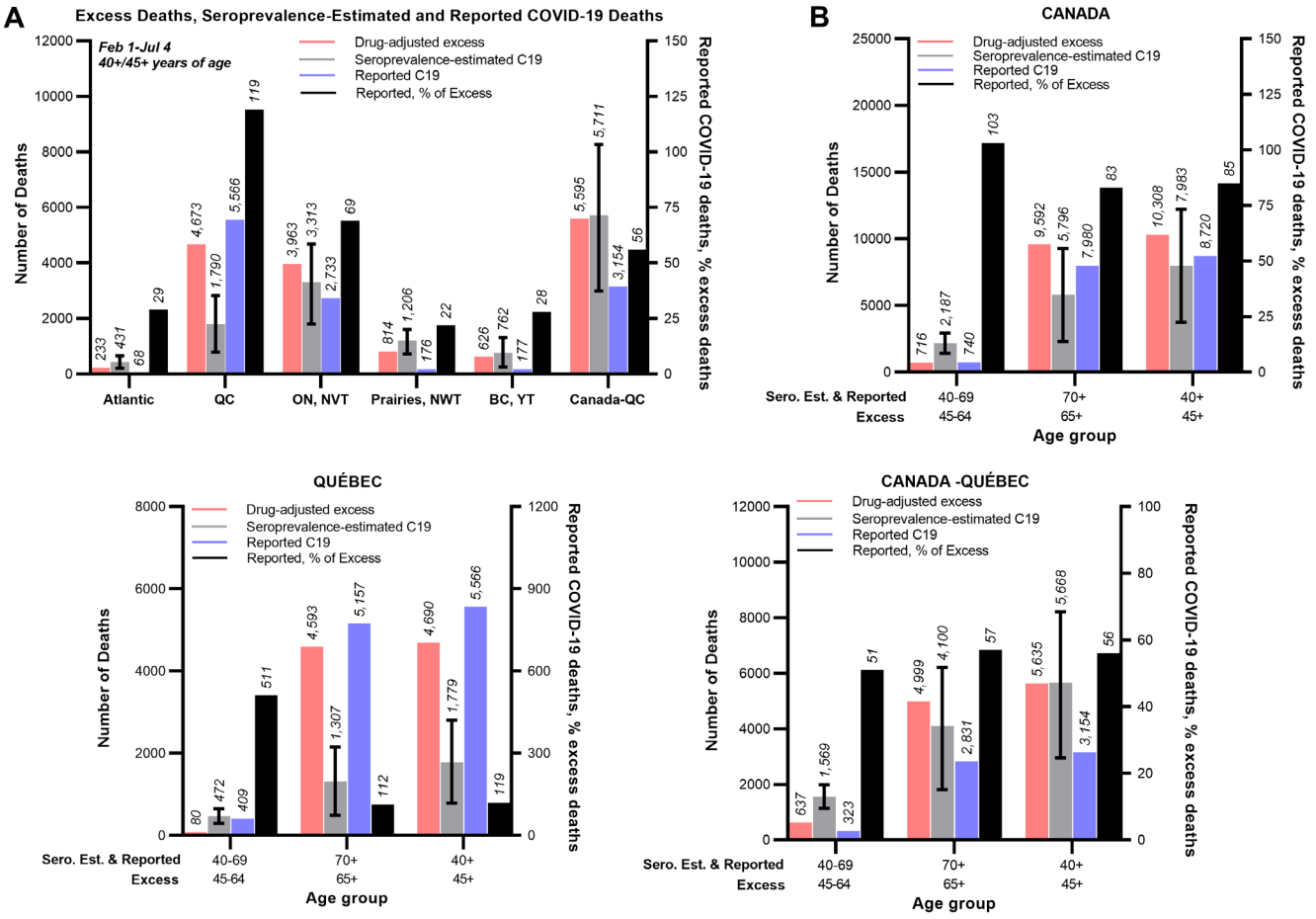


Fig. 2. Comparison of total estimated toxic drug-adjusted excess deaths with seroprevalence-estimated and reported COVID-19 fatalities in Canadian regions, February 1-July 4, 2020. **A)** Excess toxic drug-adjusted deaths in people 40/45 years and older (Drug-adjusted excess) compared to reported COVID-19 fatalities (Reported C19) as of July 4, 2020, and COVID-19 fatalities estimated from seroprevalence estimates from June-August 2020 and global estimates of age-specific infection fatality rates in OECD member countries (Levin *et al.*, 2020). Canada-QC shows the values for Canada outside Québec. Whiskered lines on bars showing seroprevalence-estimated deaths correspond to high specificity (lower) and high sensitivity (upper) range of COVID-19 seroprevalence estimates for a representative sample of the Canadian population from June-August 2020 (Jha, 2021). Numbers above bars are total deaths in each group. Black bars, plotted on the right axis, show the percentage of total drug-adjusted excess deaths in those older than 40/45 years reported as COVID-19 fatalities. Data source for age-specific COVID-19 deaths: (Public Health Agency of Canada, 2021f). Age ranges differ slightly for Statistics Canada-reported all-cause deaths used to estimate excess deaths and reported COVID-19 fatalities and seroprevalence. The Canada-QC group shows values for all Canadian regions except Québec. **B)** Seroprevalence values, excess deaths, reported and seroprevalence-estimated COVID-19 fatalities, and percentage of excess deaths reported as COVID-19 deaths for age groups shown. Detailed data for all age groups and regions are shown in **Appendix 2**.

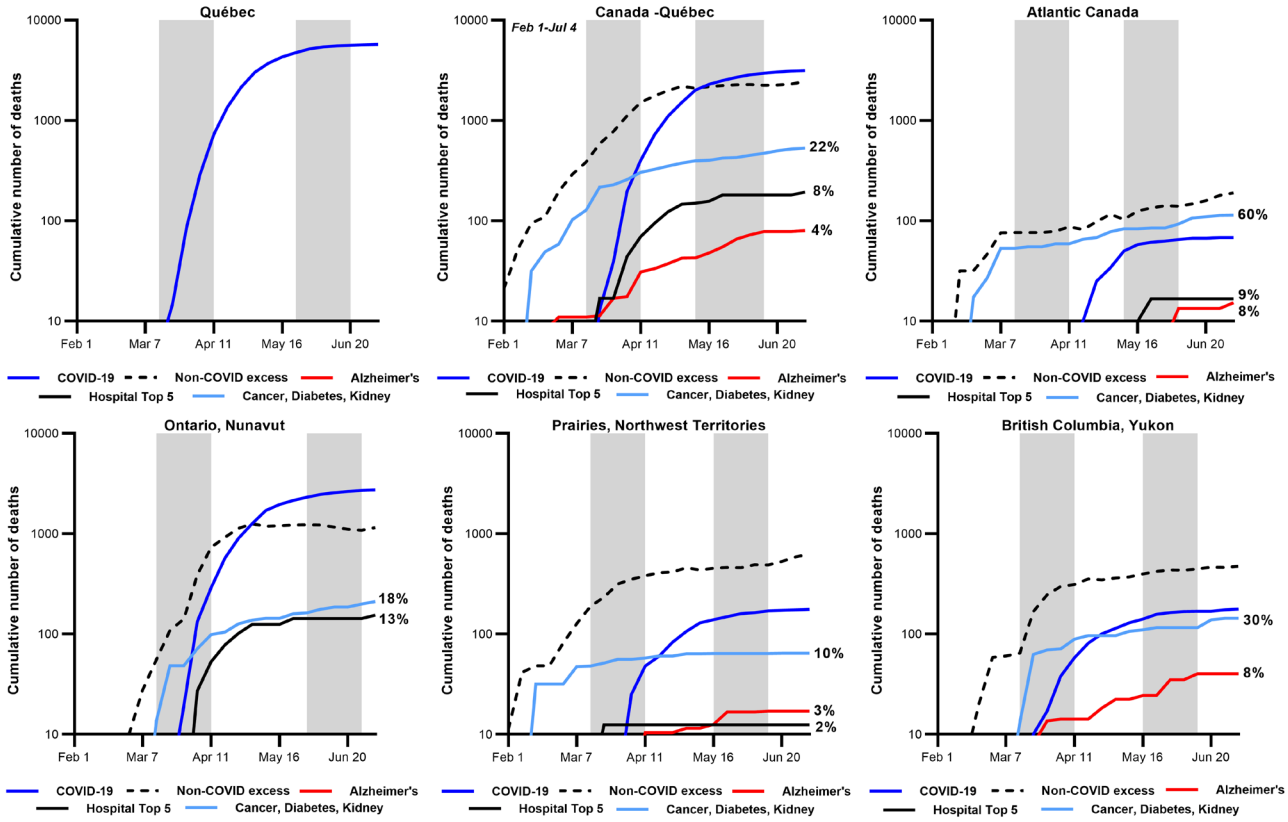


Fig. 3. Attributed cause of estimated excess deaths compared to reported COVID-19 fatalities over time in Canadian regions, February 1-July 4, 2020. Cumulative numbers of excess deaths in all age groups attributed to named causes and reported COVID-19 fatalities. Black dotted lines show excess toxic drug-adjusted deaths in people 45 and older not attributed to COVID-19 (Non-COVID excess). Values to the right of specific cause of death groups show the percentage of non-COVID-19 excess deaths accounted for by this category of deaths. Areas of gray fill show four-week periods following first stay-at-home orders (left) and the approximate first full week after relaxation of public health measures began (right) (Vogel, 2020). These are the periods within which the effects of changes in public health restrictions should be reflected in death numbers. Data source for cause of deaths, including COVID-19 fatalities:(Statistics Canada, 2021d). Cause of death groups: Alzheimer's disease (marker of LTC deaths, possibly due to public health restrictions in LTC and/or COVID-19 fatalities unreported as COVID-19). Hospital Top 5: Top five causes of death in Canadian hospitals pre-COVID-19, including heart diseases, cerebrovascular diseases, influenza and pneumonia, chronic lower respiratory diseases (marker of deaths possibly due to disruptions in emergency care and/or acute/post-acute COVID-19 complications unreported as COVID-19). Cancer, Diabetes, Kidney: Major causes of death in and outside hospitals pre-COVID-19, including malignant neoplasms, nephritis, nephrotic syndrome, nephrosis, diabetes mellitus (marker of deaths possibly due to disruptions in ongoing healthcare and/or acute-post-acute COVID-19 complications unreported as COVID-19).

Table 2: February 1-November 28, 2020, total estimated toxic drug-adjusted excess deaths in Canada

Region	Total reported COVID-19 deaths	% of total excess deaths accounted for by reported COVID-19 deaths	Estimated toxic drug-adjusted excess deaths				
			45-64	65-84	85+	45+	65+
CAN	11,787	70	1,625	7,672	7,655	16,953	15,328
CAN-QC	4,978	45	1,517	5,179	4,293	10,990	9,472
Atlantic, Northern Canada	77	15	106	279	142	528	421
Québec	7,097	119	108	2,493	3,362	5,963	5,855
Ontario	3,650	56	536	3,070	2,896	6,503	5,966
Manitoba	290	79	69	185	116	369	301
Saskatchewan	45	16	74	85	117	276	201
Alberta	524	34	292	718	539	1,548	1,256
British Columbia	392	22	441	842	484	1,767	1,326

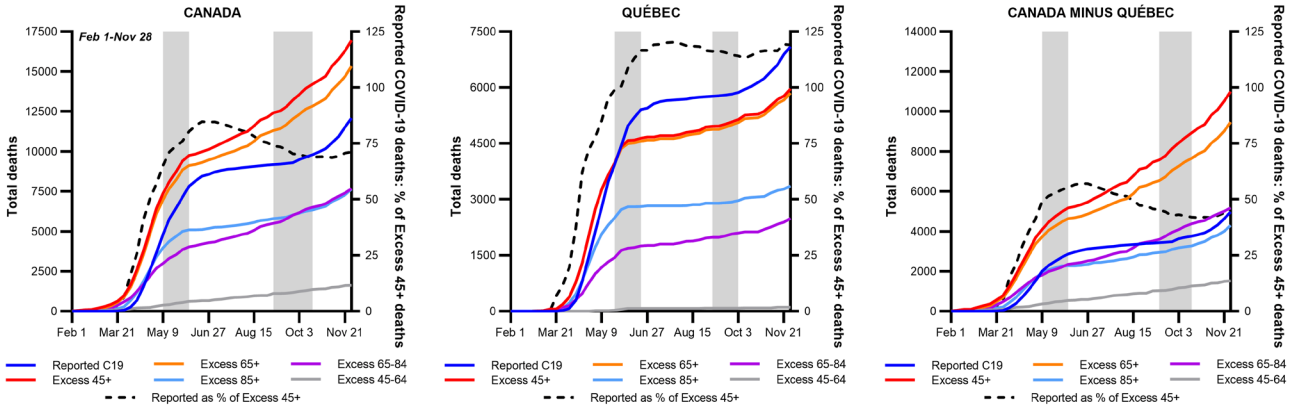


Fig. 4. Comparison of cumulative estimated toxic-drug adjusted excess deaths to reported COVID-19 fatalities over time in Canadian regions, February 1-November 28, 2020. Black dotted lines plotted on the right axis show the cumulative percentage of total excess deaths in people 45 years and older reported as COVID-19 fatalities. Gray shaded regions in each graph correspond to the first four weeks after relaxation of spring public health interventions began (left), and after return to in-person primary and secondary school (right).

Table 3: February 1-November 28, 2020, comparison of total estimated toxic drug-adjusted excess deaths and reported COVID-19 fatalities by age group

Region	Age Groups												Reported LTC COVID-19 deaths[3]
	45-64 years *(working age group)*			**65-84 years**			**45-84 years** *(community age group)*			**85+ years** *(LTC age group)*			
	Excess	***C19***[1]	***%***[2]	***Excess***	***C19***	***%***	***Excess***	***C19***	***%***	***Excess***	***C19***	***%***	
CAN	1,625	228	14	7,672	3,303	43	9,297	3,531	38	7,655	9,628	126	9,691
CAN-QC	1,517	130	9	5,179	1,587	31	6,696	1,717	26	4,293	4,338	101	3,530
Atlantic Canada	106	0	0	279	6	2	385	6	2	142	29	20	59
Québec	108	98	91	2,493	1,716	69	2,601	1,814	70	3,362	5,290	157	6,161
Ontario, Nunavut	536	88	16	3,070	1,011	33	3,606	1,099	30	2,896	2,898	100	2,620
Prairies, Northwest Territories	435	42	10	988	431	44	1,423	473	33	771	970	126	553
British Columbia, Yukon	441	0	0	842	139	17	1,283	139	11	484	441	91	298

[1]*Reported COVID-19 fatalities (age groups are slightly different than excess death age groups. For reported COVID-19 deaths, deaths in people 40-59 years are listed in the 45-64 age group, deaths in people 60-79 are listed in the 65-84 age group, and deaths in people 80 and older are listed in the 85+ years age group.*

[2]*Percentage of total excess deaths reported as COVID-19 fatalities.*

[3]*Total deaths reported in LTC* (Loreto, 2021).

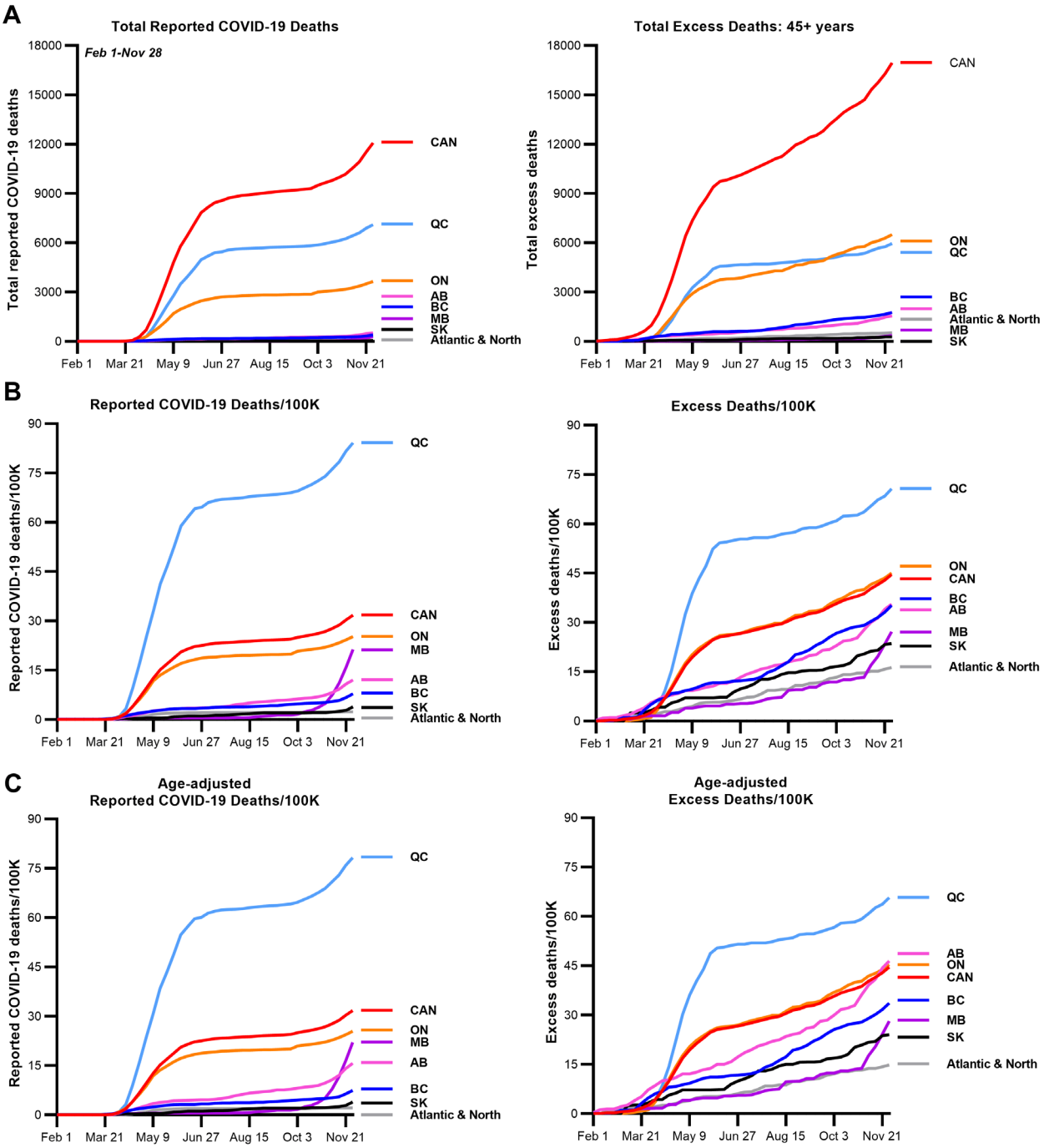


Fig. 5. Canadian regional comparisons, February 1-November 28, 2020: Cumulative toxic drug-death adjusted excess deaths in people 45 years and older and reported COVID-19 fatalities. Reported COVID-19 deaths and excess deaths are shown in left and right panels, respectively. **A)** Total deaths. **B)** Deaths/100,000 population. **C)** Deaths/100,000 population adjusted for differences in age composition among regions.

Appendix 1: Comparison of reported and test positivity-adjusted COVID-19 cases with excess all-cause mortality

We compared weekly COVID-19 case numbers/100,000 in all age groups (**Figure A**: left) and people 40 years and older (**Figure B**: left) to total weekly reported COVID-19 deaths and toxic drug-adjusted excess all-cause mortality. For people 40 and older, case numbers were reported as a proportion of the population 40 years and older. In all figure panels dotted lines are shown corresponding to the week ending July 11, 2020, when the lowest national case numbers of the COVID-19 epidemic were reported. Shaded areas after November 14 indicate the period in which all-cause mortality reporting is incomplete in multiple jurisdictions and where excess deaths will increase as reporting continues.

Estimates of under-detection of COVID-19 cases among high income peer countries suggest that by August 31, 2020, 2.3-5.7% of the Canadian population (average 3.2%) was infected by SARS-Cov-2, and that 85-94% of all infections were undetected (average 89%) (Phipps, Grafton and Kompas, 2020). Estimated reported by Phipps and colleagues are based on detailed retrospective reporting of age-specific case numbers, testing and test-positivity rates. However, this level of detailed reporting is not always available for all Canadian jurisdictions in real-time. Therefore, we investigated whether adjusting reported case numbers for test-positivity rate could provide a crude estimate of true case numbers in different jurisdictions, because this information is reported daily and is widely publicly available.

Since reported case numbers/100,000 were generally similar for the whole population and people 40 years and older (**Figure A** and **B**: compare left panels), we assumed that test positivity rates were roughly similar in all age groups. Actual case numbers were estimated by multiplying reported case numbers by test positivity rate in each week where test positivity rate was greater than 1%. For example, in a week where the test positivity rate was 4%, case numbers for that week were multiplied by four. Using this method, by August 31, 2020, estimated actual case numbers were ten times greater than reported COVID-19 cases, implying that 90% of cases were missed. This result closely resembled the estimate of 89% obtained up to the same date using detailed input data and more sophisticated estimation methods (Phipps, Grafton and Kompas, 2020). We concluded that adjusting reported case numbers for test positivity rates provided a reasonable rough approximation of true case numbers. Right panels in **Figure A** and **B** show test positivity-adjusted case numbers. **Figure C** compares cumulative all-cause excess and reported COVID-19 deaths/100,000 to cumulative test-positivity-adjusted and unadjusted case numbers/100K to November 14, 2020.

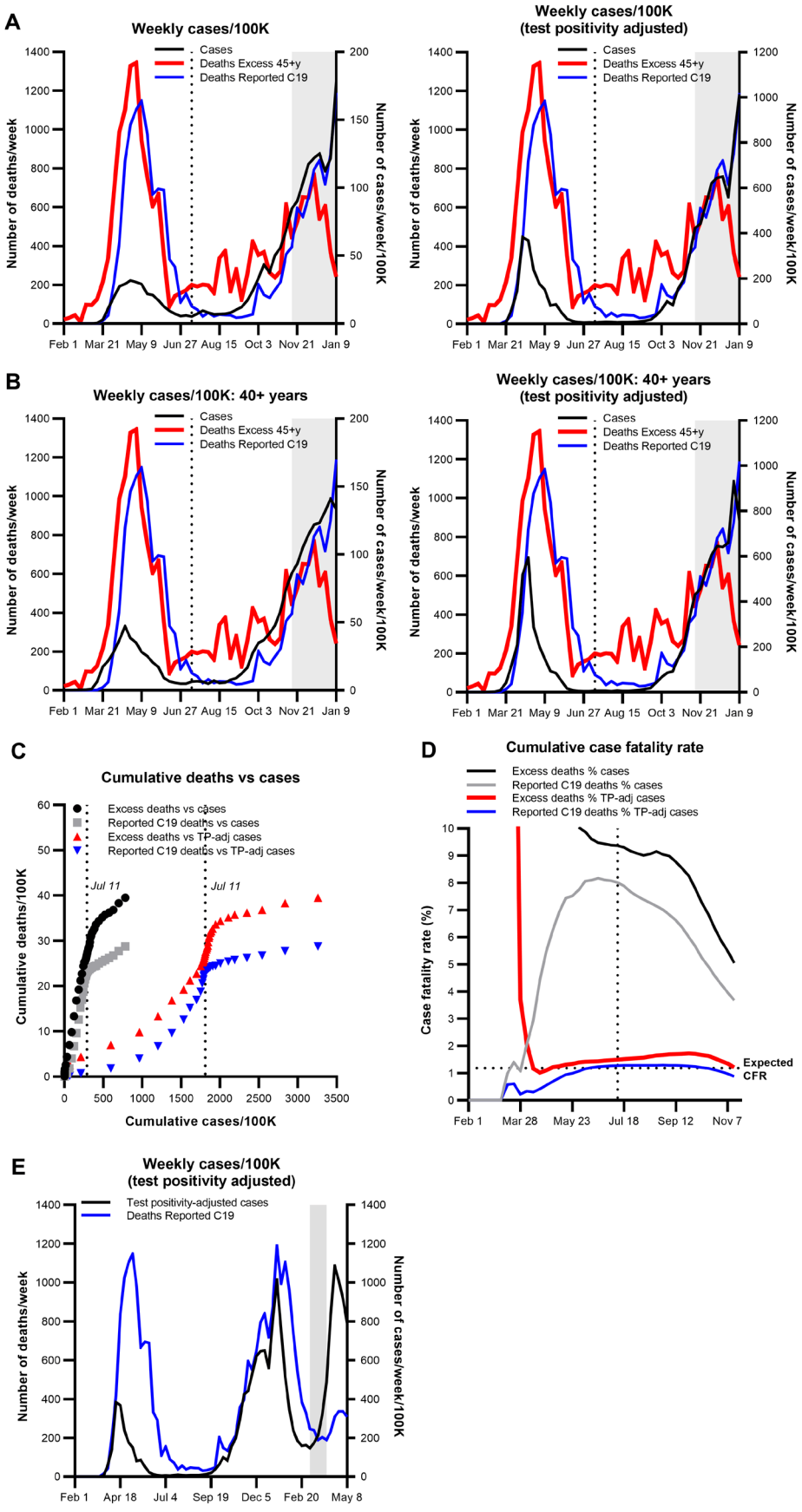
We asked whether under-detection of COVID-19 cases to November 14, 2020 contributed to Canada's unusually high observed CFR to this date, by comparing cumulative CFRs calculated for excess deaths and reported COVID-19 deaths as percentages of reported and test positivity-adjusted COVID-19 cases (**Figure D**). These values were compared to the expected COVID-19 CFR for the Canadian population estimated from age-specific infection fatality rates in OECD countries (Levin *et al.*, 2020) and the 2016 census population age structure (1.2%) (**Figure D**). By April 11 excess deaths and June 6 reported COVID-19 deaths closely approximated the expected Canadian CFR when deaths were expressed as a proportion of test positivity-adjusted cases, but not when deaths were expressed as a proportion of reported cases (**Figure D**).

We also examined the temporal relationship between test positivity-adjusted case numbers and reported COVID-19 deaths to May 8, 2021 to determine whether test positivity-adjusted case numbers could be a useful current predictor of COVID-19 deaths (**Figure E**). Unfortunately, because of the delays in Canadian death reporting, it is unlikely that we will be able to estimate excess deaths from November 2020 to May 2021 until the end of 2021. Troublingly, changes in test positivity-adjusted case numbers generally followed or coincided with excess deaths and reported COVID-19 deaths to November 14, 2020 and January 9, 2021, respectively, suggesting that relying on test positivity-adjusted case numbers before these dates as a predictor of future deaths would have been ineffective as a tool for preventing deaths. However, after March 6, 2021 test positivity-adjusted case numbers finally began to precede reported COVID-19 deaths by ~4 weeks, the period after diagnosis when most COVID-19 deaths would typically occur (**Figure E**: shaded region).

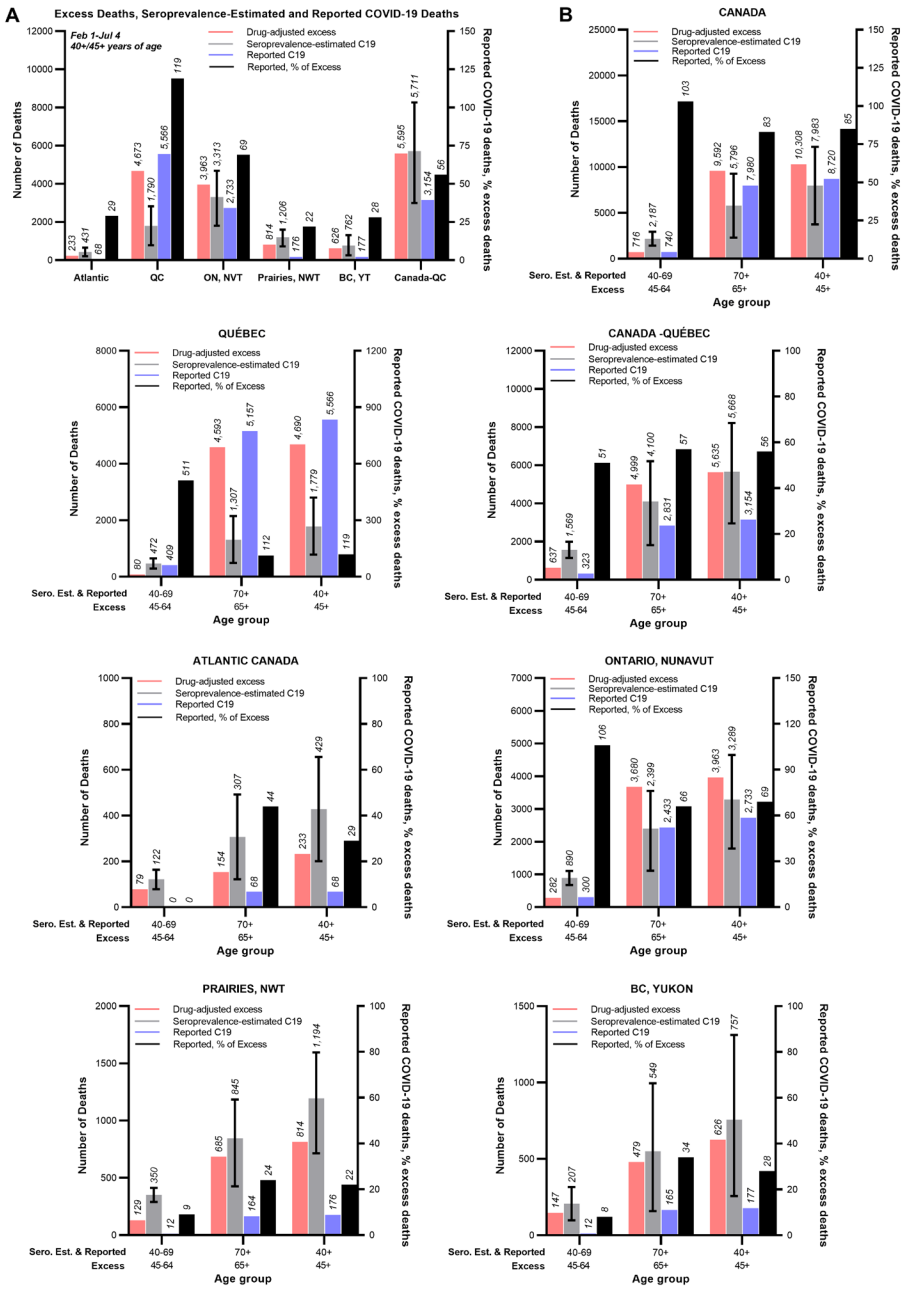
References

Levin, A. T. *et al.* (2020) 'Assessing the age specificity of infection fatality rates for COVID-19: systematic review, meta-analysis, and public policy implications', *European Journal of Epidemiology,* 35(12), pp. 1123–1138. doi: https://doi.org/10.1007/s10654-020-00698-1.

Phipps, S. J., Grafton, R. Q. and Kompas, T. (2020) 'Robust estimates of the true (population) infection rate for COVID-19: a backcasting approach', *Royal Society Open Science,* 7(11), p. 200909. doi: https://doi.org/10.1098/rsos.200909.


A
Weekly cases/100K
Cases
Deaths Excess 45+y
Deaths Reported C19
Number of deaths/week
Number of cases/week/100K
Feb 1 Mar 21 May 9 Jun 27 Aug 15 Oct 3 Nov 21 Jan 9
Weekly cases/100K
(test positivity adjusted)
B
Weekly cases/100K: 40+ years
Weekly cases/100K: 40+ years
(test positivity adjusted)
C
Cumulative deaths vs cases
Excess deaths vs cases
Reported C19 deaths vs cases
Excess deaths vs TP-adj cases
Reported C19 deaths vs TP-adj cases
Jul 11
Jul 11
Cumulative deaths/100K
Cumulative cases/100K
D
Cumulative case fatality rate
Excess deaths % cases
Reported C19 deaths % cases
Excess deaths % TP-adj cases
Reported C19 deaths % TP-adj cases
Case fatality rate (%)
Expected CFR
Feb 1 Mar 28 May 23 Jul 18 Sep 12 Nov 7
E
Weekly cases/100K
(test positivity adjusted)
Test positivity-adjusted cases
Deaths Reported C19
Feb 1 Apr 18 Jul 4 Sep 19 Dec 5 Feb 20 May 8

Appendix 2: Comparison of excess deaths with reported COVID-19 deaths and COVID-19 deaths predicted from SARS-Cov-2 seroprevalence



Appendix 2 Figure: Comparison of total estimated toxic drug-adjusted excess deaths with seroprevalence-estimated and reported COVID-19 deaths in Canadian regions, February 1-July 4, 2020.

A) Excess toxic drug-adjusted deaths in people 40/45 years and older (Drug-adjusted excess) compared to reported COVID-19 deaths (Reported C19) as of July 4, 2020, and COVID-19 deaths estimated from seroprevalence estimates from June-August, 2020 and global estimates of age-specific infection fatality rates in OECD countries (Levin *et al.*, 2020). Canada-QC shows the values for Canada outside Québec. Whiskered lines on bars showing seroprevalence-estimated deaths correspond to high specificity (lower) and high sensitivity (upper) range of COVID-19 seroprevalence estimates for a representative sample of the Canadian population from June-August, 2020 (Jha, 2021). Numbers above bars are total deaths in each group. Black bars, plotted on the right axis, show the percentage of total drug-adjusted excess deaths in those older than 40/45 years reported as COVID-19 deaths. Data source for age-specific COVID-19 deaths: (Public Health Agency of Canada, 2021b). Age ranges differ slightly for Statistics Canada-reported all-cause deaths used to estimate excess deaths, and reported COVID-19 deaths and seroprevalence. Age ranges used for each type of data are indicated in each panel in Fig. 2. **B)** Excess deaths, reported and seroprevalence-estimated COVID-19 deaths, and percentage of excess deaths reported as COVID-19 deaths for indicated age groups and regions. Detailed data for all age groups and regions are shown in **Appendix 2 Table below**.

Region/ Age group	Population (million)[1]	Est. IFR (%)[2]	Seroprevalence estimate (%)[3]			Seroprevalence-estimated infections (thousands)[4]			Seroprevalence-estimated deaths[5]			Reported[6]			Ratio: Reported CFR to expected IFR	% Estimated infections reported			% Estimated deaths reported		
			Low	*Mid*	*High*	*Low*	*Mid*	*High*	*Low*	*Mid*	*High*	Cases (thousands)	Deaths	CFR (%)		*Low*	*Mid*	*High*	*Low*	*Mid*	*High*
Canada																					
18-39	9.98	0.02	2.48	3.42	4.36	247.58	341.41	435.25	42	57	73	27.16	0	0	0.00	11	8	6	0	0	0
40-59	9.91	0.23	1.35	2.12	2.88	133.83	209.67	285,506	302	473	644	29.92	145	0.48	2.15	22	14	10	48	31	23
60-69	4.26	1.38	1.92	2.91	3.90	81.85	124.05	166.26	1,131	1,714	2,297	9.68	538	5.56	4.02	12	8	6	48	31	23
70+	3.96	8.45	0.69	1.73	2.77	27.35	68.56	109.78	2,312	5,796	9,280	24.45	7,369	30.14	3.57	89	36	22	319	127	79
18+	**28.12**	**1.49**	**1.87**	**2.89**	**3.91**	**490.60**	**743.70**	**996.80**	**3,786**	**8,040**	**12,295**	**91.21**	**8,052**	**8.83**	**5.93**	**19**	**12**	**9**	**213**	**100**	**65**
Atlantic																					
18-39	0.58	0.02	1.76	2.43	3.10	10.16	14.08	17.99	2	2	3	0.33	0	0	0	3	2	2	0	0	0
40-59	0.69	0.23	0.96	1.51	2.04	6.61	10.40	14.20	15	23	32	0.37	0	0	0	6	4	3	0	0	0
60-69	0.34	1.38	1.36	2.07	2.77	4.66	7.10	9.54	64	98	132	0.18	0	0	0	4	3	2	0	0	0
70+	0.30	8.45	0.49	1.23	1.97	1.44	3.63	5.82	122	307	492	0.28	35	12.54	1.48	19	8	5	29	11	7
18+	**1.91**	**1.64**	**1.32**	**2.05**	**2.78**	**22.87**	**35.21**	**47.55**	**203**	**431**	**659**	**1.16**	**35**	**3.03**	**1.59**	**5**	**3**	**2**	**17**	**8**	**5**
Québec																					
18-39	2.24	0.02	2.06	3.04	3.97	46.37	68.03	89.22	8	11	15	12.47	0	0	0	27	18	14	0	0	0
40-59	2.28	0.23	1.12	1.89	2.62	25.70	42.83	60.00	58	97	135	14.87	77	0.52	2.29	58	35	25	133	80	57
60-69	1.05	1.38	1.59	2.59	3.55	16.83	21.14	37.42	233	375	517	4.53	298	6.58	4.77	27	17	12	128	79	58
70+	1.01	8.45	0.57	1.54	2.52	5.80	15.46	25.47	490	1,307	2,153	14.64	4,731	32.32	3.82	253	95	57	965	362	220
18+	**6.58**	**1.60**	**1.56**	**2.57**	**3.57**	**94.69**	**153.46**	**212.11**	**788**	**1,790**	**2,820**	**46.50**	**5,106**	**10.98**	**6.86**	**49**	**30**	**22**	**648**	**285**	**181**
Ontario, Nunavut																					
18-39	3.83	0.02	3.12	3.69	4.36	119.26	141.74	166.84	20	24	28	10.43	0	0	0	9	7	6	0	0	0
40-59	3.86	0.23	1.70	2.29	2.88	65.53	88.47	111.24	148	200	251	10.80	68	0.63	2.79	16	12	10	46	34	27
60-69	1.59	1.38	2.42	3.14	3.90	38.26	49.97	61.84	528	690	854	4.03	223	5.54	4.01	11	8	7	42	32	26
70+	1.51	8.45	0.87	1.87	2.77	13.13	28.38	41.96	1,110	2,399	3,547	8.43	2,364	28.06	3.32	64	30	20	213	99	67
18+	**10.79**	**1.48**	**2.35**	**3.13**	**3.91**	**236.17**	**308.56**	**381.87**	**1,807**	**3,313**	**4,680**	**33.68**	**2,655**	**7.88**	**5.32**	**14**	**11**	**9**	**147**	**80**	**57**
Prairies, Northwest Territories																					
18-39	2.02	0.02	3.12	3.42	3.79	62.89	68.78	76.73	11	12	13	3.18	0	0	0	5	5	4	0	0	0
40-59	1.74	0.23	1.70	2.12	2.51	29.49	36.63	43.66	67	83	99	3.02	0	0	0	10	8	7	0	0	0
60-69	0.67	1.38	2.42	2.91	3.39	16.08	19.33	22.67	222	267	313	0.66	8	1.21	0.88	4	3	3	4	3	3
70+	0.58	8.45	0.87	1.73	2.41	5.03	9.99	14.00	425	845	1,184	0.57	110	19.16	2.27	11	6	4	26	13	9
18+	**5.00**	**1.25**	**2.35**	**2.88**	**3.41**	**113.49**	**134.73**	**157.06**	**724**	**1,206**	**1,608**	**7.43**	**118**	**1.59**	**1.27**	**7**	**6**	**5**	**16**	**10**	**7**
British Columbia, Yukon																					
18-39	1.32	0.02	1.19	2.29	3.27	15.71	29.99	43.31	3	5	7	0.77	0	0	0	5	3	2	0	0	0
40-59	1.34	0.23	0.65	1.42	2.16	8.69	18.84	29.06	20	43	66	0.85	0	0	0	10	5	3	0	0	0
60-69	0.62	1.38	0.92	1.95	2.93	5.69	11.94	18.13	79	165	250	0.29	9	3.08	2.23	5	2	2	11	5	4
70+	0.56	8.45	0.33	1.16	2.08	1.87	6.50	11.78	158	549	996	0.53	129	24.39	2.88	28	8	4	81	23	13
18+	**3.83**	**1.55**	**0.90**	**1.93**	**2.95**	**31.97**	**67.27**	**102.28**	**259**	**762**	**1,319**	**2.44**	**138**	**5.66**	**3.65**	**8**	**4**	**2**	**53**	**18**	**10**
Canada – Québec																					
18-39	7.74	0.02	2.69	3.29	3.94	208.02	254.58	304.87	35	43	51	14.70	0	0	0	7	6	5	0	0	0
40-59	7.63	0.23	1.45	2.02	2.60	110.31	154.35	198.16	249	348	447	15.05	68	0.45	2.00	14	10	8	27	20	15
60-69	3.21	1.38	2.01	2.75	3.49	64.70	88.34	112.17	894	1,220	1,550	5.16	240	4.65	3.37	8	6	5	27	20	15
70+	2.95	8.45	0.73	1.64	2.49	21.47	48.50	73.56	1,815	4,100	6,219	9.81	2,638	26.90	3.18	46	20	13	145	64	42
18+	**21.54**	**1.45**	**1.88**	**2.53**	**3.20**	**404.50**	**545.77**	**688.76**	**2,993**	**5,711**	**8,267**	**44.71**	**2,946**	**6.59**	**4.54**	**11**	**8**	**6**	**98**	**52**	**36**

[1]Source: (Statistics Canada, 2016) [2]Age-specific SARS-Cov2 infection fatality rates (IFRs) from meta-analysis of IFRs in OECD countries (Levin *et al.*, 2020). [3]Seroprevalence estimates as of June-August, 2020 from (Jha, 2021). "Low" and "high" correspond to high specificity and high sensitivity estimates, respectively. "Mid" is the average of low and high estimates. [4]Infection estimates obtained by multiplying seroprevalence estimates from age-specific population sizes. [5]Death estimates obtained by multiplying estimated case numbers by estimated age-specific IFR. [6]Source: (Public Health Agency of Canada, 2021)

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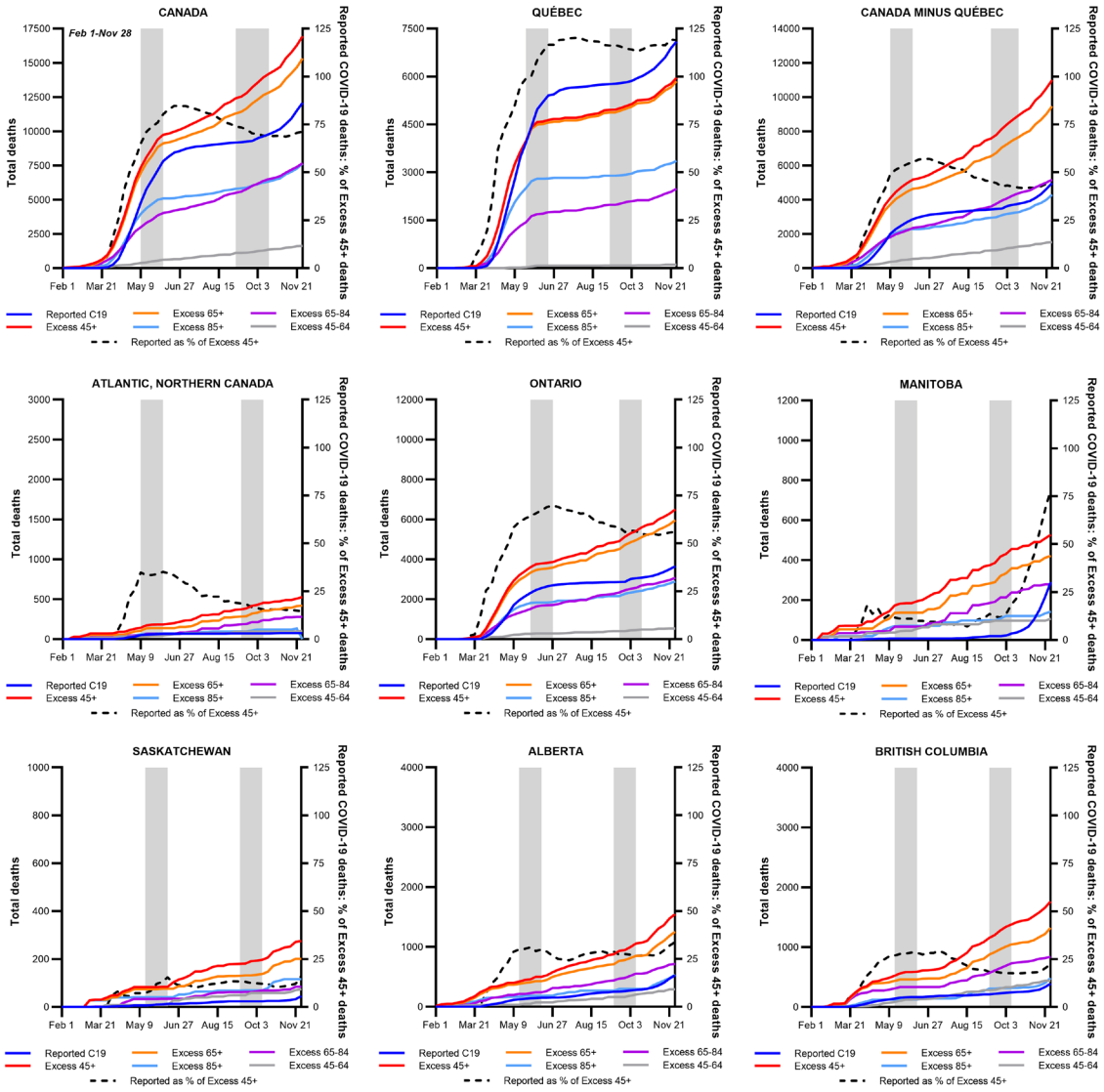
Appendix 3: Comparison of cumulative estimated toxic-drug adjusted excess deaths to reported COVID-19 deaths over time in Canadian regions, February 1-November 28, 2020



Region	Deaths/100K: Feb 1-Nov 28, 2020						Reported COVID-19 Deaths as % of excess 45+ deaths
	Reported COVID-19	*Excess deaths*					
		45-64	65-84	85+	45+	65+	
Newfoundland & Labrador	0.82	11.11	21.37	6.68	38.93	27.86	2%
Prince Edward Island	0	17.42	21.94	8.39	47.74	30.32	0%
Nova Scotia	6.74	2.59	19.90	11.71	34.09	31.50	20%
New Brunswick	0.91	7.38	13.47	5.18	25.91	18.52	4%

Appendix 3 Figure. Comparison of cumulative estimated toxic-drug adjusted excess deaths to reported COVID-19 deaths over time in Canadian regions, February 1-November 28, 2020. Black dotted lines plotted on the right axis show the cumulative percentage of total excess deaths in people 45 years and older reported as COVID-19 deaths. Gray shaded regions in each graph correspond to the first four weeks after relaxation of spring public health interventions began (left), and after return to in-person primary and secondary school (right).

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