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Retrospective study of non-natural manners of death in Ontario: Effects of the COVID-19 pandemic and related public health measures

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The Lancet Regional Health - Americas
2022;7: 100130
Published online 10 December 2021
https://doi.org/10.1016/j.lana.2021.100130

Summary

Background The effects of the COVID-19 pandemic on non-natural manners of death in Ontario is not known. Understanding the indirect consequences of the pandemic and related public health measures (i.e. lockdown) fills a vital need to inform best practice in public health and guide policy decisions.

Methods The Office of the Chief Coroner and the Ontario Forensic Pathology Service (OCC-OFPS) investigate sudden and unexpected deaths in the province of Ontario. The number of homicides, suicides, and accidental deaths (non-natural deaths=77,655) were extracted from the centralized Coroner's Information System database (total deaths=197,966), across four provincially defined stages of lockdown related to the COVID-19 pandemic (March 17 to December 31, 2020), and crude rates (per 100,000 people) were compared to the previous eleven years.

Findings There was no major change to the rate of homicides during 2020 compared to 2009-2019 (RR 1·1, 95% CI 0·95-1·2; p=0·19; estimated annual effect=21 more deaths in 2020). The rate of suicides also did not show an overall major change in 2020 (RR 1·02, 95% CI 0·96-1·1; p=0·50; estimated annual effect=27 more deaths in 2020). However, during the first stage of lockdown (Stage 0), there was a decrease in the rate of suicides compared to all combinations of recent years from 2013 onwards (RRs 0·82-0·86, combined 95% CI 0·69-0·99; max p=0·039; estimated effect of 30 less deaths in Stage 0). There was an excess of over 1,500 accidental drug-related deaths that occurred during 2020 (RR 2·5, 95% CI 2·4-2·7; p<0·001). This finding held up to 'interrupted time series' robustness testing, indicating that 2020 had substantially more drug-related deaths, even when accounting for the linear increasing trend over time. Although motor vehicle collision associated fatalities appeared to decrease slightly in 2020 (RR 0·89, 95% CI 0·81-0·96; p=0·0039; estimated annual effect of 78 less deaths), we could not conclude any lockdown-associated effect, particularly when compared to 2019 (RR 0·26, 95% CI 0·75-1·1; p=0·26).

Interpretation In Ontario, the short-term effects of the COVID-19 pandemic did not greatly increase homicide or suicide rates, nor decrease motor vehicle collision fatality rates; however, the longer-term impact of the pandemic remains to be elucidated and ongoing vigilance is warranted in the event that other trends emerge. Accidental drug-related fatalities substantially increased during all stages of the lockdown, marking an urgent need for consideration in policy. These results highlight the vital role of death investigation systems in providing high quality and timely data to inform public health recommendations.

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Keywords: COVID-19; pandemic; lockdown; manner; death; homicide; suicide; accident; drug; opioid; Ontario; Canada; motor vehicle; policy; public health

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Research in context

Evidence before this study

The authors considered all evidence available via online databases (e.g. PubMed) and internal (OCC-OFPS) publications, which analysed types and manners of sudden/unexpected deaths before, during, and after COVID-19-related lockdowns. The literature search (performed up to April 21, 2021) included various search terms, such as variations of COVID-19 (COVID, coronavirus, SARS-CoV), manners (suicide, homicide, natural, accident, undetermined) and types of death (e.g. stab, gunshot, collision, opioids), and was not limited by an exclusionary language or date of publication filter. References from each included publication were searched for additional applicable articles. Provincial and national reports concerning opioid death trends were also reviewed and incorporated.

Added value of this study

Our research uses an evidence-based, statistically robust approach to investigate the indirect consequences of the COVID-19 pandemic and related public health measures across multiple stages of provincially defined 'lockdown' measures as compared to the previous decade. The results are interpreted and reported reflecting the American Statistical Association's (ASA) current statement on statistical significance and p-values. This study offers a comprehensive data set regarding non-natural manners of death and their associated types of death. Our research is, to our knowledge, the single largest study worldwide that investigates all three non-natural manners of death (non-natural deaths= 77,655) that includes reporting of drug-related fatalities. We have shown the indirect effects of the pandemic and related public health measures on rates of homicide, suicides, and accidental deaths, as well as an estimated increase in over 1500 drug-related fatalities during the pandemic. Ontario has the largest death investigation system in North America and is composed of a large, culturally diverse collection of urban, suburban, and rural communities. This provides a study population that is generalizable to large administrative regions and countries. Further, this study examines multiple lockdown stages, including analyses of death trends during so-called 'reopening' phases.

Implications of all the available evidence

Our aim is to provide scientifically-sound data and trend analyses that will assist provincial, national, and international policy makers and public health professionals by highlighting key trends and areas in need of intervention. Ongoing study of the impact of the COVID-19 pandemic is warranted as time progresses in order to fully understand the long-term implications of the pandemic and related public health measures on manners and types of death in the world population. Additional stratification of data (such as by urban setting type, socioeconomic status, ethnography, etc.) could be of benefit to identify significant population subgroup-specific findings that may serve to inform best practice in public health efforts.

Introduction

A growing body of literature suggests that the COVID-19 pandemic has exacerbated the prevalence of mental illness, domestic violence, and substance use.[1-3] How the increased prevalence of these conditions translate into morbidity and mortality is of growing public health concern, especially in the context of prolonged and recurrent public health measures intended to protect the population by slowing the spread of COVID-19. Various countries and jurisdictions report differing trends when comparing pre-pandemic death data to during or post-lockdown death types. These include decreased,[4-10] increased,[7-9,11-13] and steady[8,13-22] suicide rates; as well as increased,[23] decreased,[10,24] and steady[21-23] homicide rates. Given the variation of the studies thus far, the indirect effects of the COVID-19 pandemic on the frequency of non-natural deaths are unclear. It has been suggested that the effects are likely to vary among countries and over time, possibly as a result of overall community disease burden, the impact of public health measures, the availability of mental health services, and the economic capacity to support the affected population.[4] Notwithstanding this heterogeneity, decreased motor vehicle collision-related fatalities[10,22,25,26] and increased substance use[3,27-33] manifested consistently across jurisdictions. Many countries have also documented a sudden decline in all or some death types at the onset of lockdowns, followed by an increase or return to average in the post-lockdown period.[26,34,35]

Lack of timely access to vital statistics data has hindered detailed analysis of trends in mortality during COVID-19. In the province of Ontario, the Office of the Chief Coroner and Ontario Forensic Pathology Service (OCC-OFPS) conduct death investigations for all non-natural deaths, natural deaths that are sudden and unexpected, and deaths that occur in specified circumstances under the *Coroners Act*. The OCC-OFPS maintains detailed data on death investigations and this data has been used in studies to support the goal of the OCC-OFPS: to improve the health and safety of the inhabitants of Ontario. Under the *Coroners Act*, each coronial investigation must answer five questions: who the deceased was; how the deceased came to their death (medical cause of death); when the deceased came to their death; where the deceased came to their death; and by what means the deceased came to his or her death (manner of death: natural, accident, suicide, homicide, or undetermined). The records of the OCC-OFPS provide data spanning the pre-COVID-era and throughout the pandemic to date, detailing death type, manner, and cause of death.

On March 17, 2020, the Government of Ontario invoked an emergency order in response to the COVID-19 pandemic and, in doing so, gained the necessary powers to impose restrictions such as legally requiring several facilities and businesses to close immediately and prohibiting organized public events. In this study,

we examine data from the OCC-OFPS to identify trends in manners of death and types of death across four provincially-defined 'lockdown' stages of the COVID-19 pandemic (March 17, 2020 to December 31, 2020) in comparison to the previous eleven years (March 17, 2009 to December 31, 2019). Our analysis highlights the importance of the death investigation system in mobilizing such data to best inform public health practice and policy recommendations.

Methods

The OCC-OFPS uses the Coroner's Information System (CIS) to manage case data for all death investigations conducted in Ontario (approximately 20,000 total investigations per year). For each case, the data recorded includes the manner of death and the death type, the latter of which refers to the category of the cause of death (e.g. hanging, blunt force trauma, etc.). Such data can identify broad trends in specific types of deaths over time.

As the CIS is a real-time case management database, we pulled data at multiple time points during the course of this study to assess data quality and completeness. All death investigation data for calendar years 2009 to 2020 was retrieved and the following specific data fields were included in the study: case number, status of case (open/closed), sex, age, manner of death, environment (e.g. residence, motor vehicle, hospital), and type of death.

A total of 197,966 deaths were investigated in Ontario between 2009-2020 for which data was pulled from the CIS (excluding 'unclear' deaths, see below). Of these, 77,655 had a manner of death that was homicide (n=2,443), suicide (n=16,425), or accident (n=58,787) and were included in the study. Deaths classified as natural (n=114,571), skeletal remains (n=682), or undetermined manner (n=5,058) were excluded. Cases resulting from Medical Assistance in Dying (MAiD) between June 17, 2016 - May 9, 2017 (n=437) were manually reviewed in the CIS, and the manner of death was assigned based on current practice (as there was a provincial change in practice in May, 2017 which updated the approach to manner classification of these deaths from universally classifying the death as suicide to the current practice of basing the manner of death on the nature of the inciting event/condition leading to eligibility to apply for MAiD). This resulted in 433 of these MAiD deaths being classified as natural in manner and 4 as non-natural in manner. This step was performed to ensure a consistent and current approach to manner classification in MAiD across the dataset.

With respect to all cases, for each category of manner of death and their associated death type (e.g. 'accident' and 'drug-related', or 'suicide' and 'drug-related'), crude rates were calculated per 100,000 Ontario yearly population as per Statistics Canada,[36] both for entire years and for specific date ranges that corresponded to provincially-defined lockdown periods: March 17 to May 18, 2020 (Stage 0), May 19 to June 11, 2020 (Stage 1), June 12 to July 16, 2020 (Stage 2), and July 17 to November 7, 2020 (Stage 3), and November 8 to December 31, 2020 (Stage 4), with the end date of December 31st representing the end of the calendar year and pre-defined study period, and not reflective of the end of the government mandated lockdown. The provincially-defined lockdown periods were selected as originally published online by the Government of Ontario.[37]

A proportion of the most recent death investigations included in the study (7.5% of all 2020 cases; see Figure 1) remained 'unclear' at the time of the most recent data retrieval from the CIS, meaning the manner and/or death type had not yet been formally assigned by the investigating coroner, and/or was 'undetermined', and the case could not be confirmed (i.e. was 'open' as quality assurance was not yet performed which would result in a 'closed' case). As excluding these cases could introduce unknown bias in the study results, we developed an approximation approach to estimate their final classification. As we had conducted multiple interval data retrievals from the CIS, we examined a set of cases that were unclear in one of the interval data retrievals (August 25, 2020), but were closed/finalized in a later data retrieval (March 30, 2021) and used this to determine what proportion of unclear cases were later resolved to each manner and type of death. We then used these proportions to compute a 95% confidence interval (indicated in the graphs by purple vertical lines) for the true total rates for each manner and type of death category.

For each category and each date range, we looked at linear trends over the interval 2009-2019, using standard linear regression tests, and report the corresponding slope, p-values and confidence intervals (in red text in the figures). We also investigated if the 2020 (pandemic year) rate is an 'outlier', i.e. higher or lower than would be expected based on all previous years (indicated in the figures by green dashes), using a two-sample Poisson statistical test in order to determine whether the 2020 death rate per 100,000 population was substantially different from the rate in previous years. We present (in green text within the figures) the estimated ratio of the 2020 rate over the 2009-2019 rate (rate ratio, RR), together with its 95% confidence interval (CI), p-value and estimated effect ('Diff') during 2020 (i.e. number of more or less deaths) with its 95% CI.

A finding that the 2020 rate is an outlier could be the result of pandemic effects, or of general trends over previous years. To clarify this, we also investigated the robustness ('rob') of our findings by computing the different p-values and confidence intervals as we a) varied the choices of comparison starting year ('robY') and b) tested the 'unclear' cases adjustments ('robU'). We then drew attention to a specific 2020 effect only when multiple such robustness p-values were small and when all

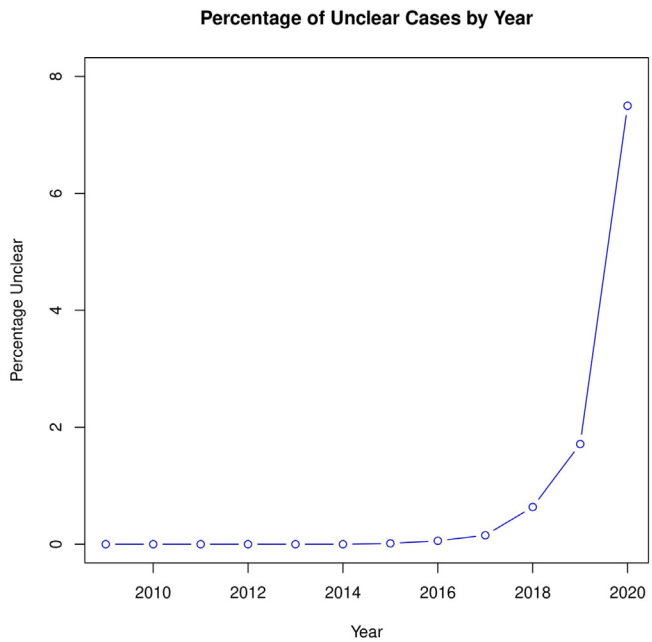

Figure 1. Percentage of Unclear Cases by Year.

the confidence intervals of the performed tests did not approach the value 1. That is, we ran statistical comparisons of 2020 to 2009-2019, 2010-2019, 2011-2019, and so on (displayed as 'robY', which is the largest of all the p-values over all possible choices of the comparison starting year). If 'robY' was small and its combined confidence interval did not approach the value 1, then the 2020 rate change is substantial regardless of which comparison year was used, thus demonstrating the robustness of the change. To evaluate the robustness of the 'unclear' correction, we re-computed the p-value after taking the rate for the comparison years to either its lower or upper confidence interval end point and simultaneously took the rate of 2020 to either its lower or upper confidence interval ('robU'). If 'robU' was small and its combined confidence interval did not approach the value 1, it was interpreted that the 2020 rate change is still substantial over a wide range of possible resolutions of the 'unclear' cases, thus again demonstrating robustness of the change. 'RobY' and 'robU' are presented in maroon text in the figures. In a separate analysis, we also considered an 'interrupted time series' (ITS) model, which performs a linear regression of the yearly death rates against both the year and an indicator variable for the special year 2020.[38] The resulting 'ITS' quantity measures the ratio of the observed 2020 rate to what would be expected if the linear trend from 2009-2019 had continued, with a corresponding p-value and confidence interval (presented as 'ITS' in red text in the figures). Full technical details of all of the categories, robustness tests, and adjustments that we considered are available in the Technical Supplement (please see corresponding *supplementary material*, also available at probability.ca/DmetrichukSupp).

The results are interpreted and reported reflecting the American Statistical Association's (ASA) statement on statistical significance and p-values and current recommendations (i.e. p-values interpreted as a spectrum versus dichotomous significance determined solely based on using a specified p-value).[39-42] This is of particular importance in the context of our study, as the ASA states that scientific conclusions and business or policy decisions should not be based only on whether a p-value passes a specific threshold (point 3 of the ASA Statement on Statistical Significance and p-Values).[39]

This study was approved by the University of Toronto Research Ethics Board (Protocol #00040433). Data that was digitally sent off-site for statistical analysis (to JR) was anonymised and password protected, and a confidentiality agreement was completed prior to analysis. A RECORD statement (REporting of studies Conducted using Observational Routinely-collected Data), which is an extension of STROBE guidelines (Strengthening the Reporting of Observational studies in Epidemiology) was completed.

Role of the funding source

This work received no funding.

Results

A total of 197,966 deaths were investigated in Ontario between 2009-2020 for which data was pulled from the

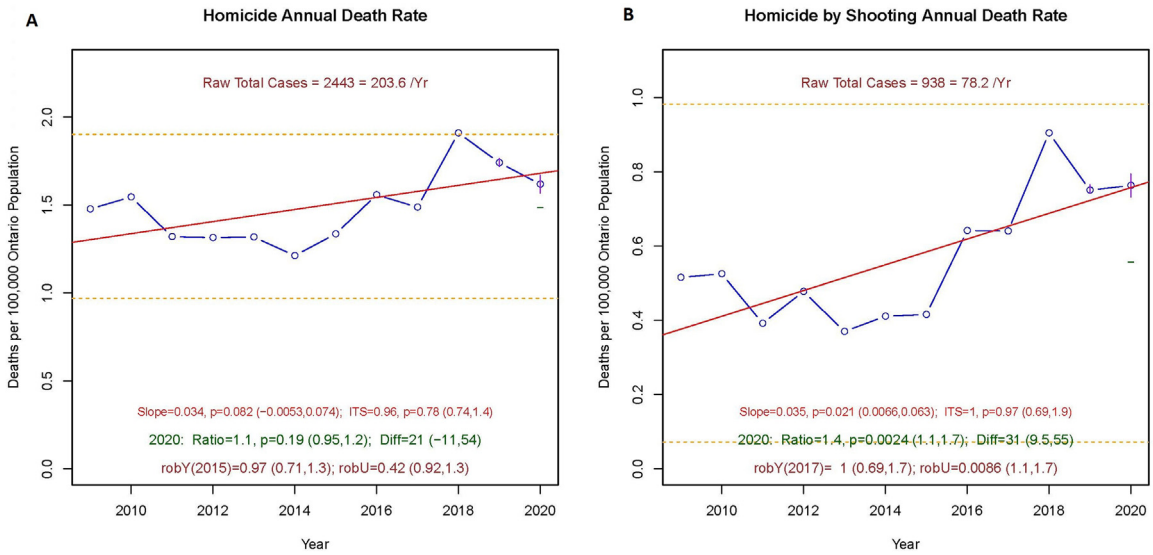

Figure 2. (A) Homicide and (B) Homicide by Shooting Annual Death Rates (per 100,000) in Ontario, 2009-2020.

CIS (excluding 'unclear' deaths, described above). The number of homicides (n=2,443), suicides (n=16,425), and accidental deaths (n=58,787) were extracted from the CIS database (total n=77,655) across four provincially defined stages of lockdown related to the COVID-19 pandemic (March 17 to December 31, 2020), and crude rates (per 100,000 people) were compared to the previous eleven years.

Homicides

The rate of homicides in Ontario has been slightly trending upwards over the past decade, with a particular peak in 2018 (slope=0·034, 95% CI -0·0053-0·074; p=0·082; Figure 2A). The homicide rate gradually increased from a low of 1·21 (per 100,000) in 2014 to a high of 1·91 in 2018, before decreasing to 1·74 in 2019 and then 1·62 in 2020. The 2020 rate is higher than the overall rate from 2009-2019 (RR 1·1, 90% CI 0·95-1·2; p=0·19) corresponding to 21 more deaths. However, considering just the most recent years (2018 and beyond), the 2020 rate is below the combined 2018-2019 rate of 1·82, corresponding to 30 less deaths in 2020 compared to the most recent two years. The decrease in 2020 compared to 2018-2019 has an estimated RR of 0·89 (95% CI 0·76-1·03; p=0·13). Further, there was no major change to the rate of homicides during any stage of lockdown (RRs 0·95-1·3, 95% CIs for ratios all include 0·95-1·25; p=0·18-1; total estimated annual effect = 21 more deaths). For homicide by shooting, the annual rate in Ontario appears to be increasing over the past decade (slope=0·035, 95% CI 0·0066-0·063; p=0·021; Figure 2B). Although in 2020 there was a total estimated annual increase of 31 homicidal deaths by shooting (RR 1·4, 95% CI 1·1-1·7; p=0·0024) this does not appear particularly notable when comparing to the 2017-2019 period (RR 0·99, 95% CI 0·79-1·2; p=1·0).

Suicides

The annual death rate by suicide in Ontario has overall increased over the interval 2009-2019 (slope=0·19, 95% CI 0·13-0·25; p<0·001; Figure 3). It increased from a low of 9·21 (per 100,000) in 2011, to a high of 11·07 in 2018, before decreasing to 10·82 in 2019 and then 10·19 in 2020.

Specific death by suicide methods with increases over the period 2009-2019 include suicide by hanging (slope=0·16, 95% CI 0·098-0·22; p<0·001), sharp force (slope=0·018, 95% CI 0·01-0·026; p<0·001), and descent from height (slope=0·029, 95% CI 0·013-0·044; p=0·0024) (Figure 4A-C).

Although these suicidal means seem to be generally increasing in Ontario, there did not appear to be a major change in rate for any of these means in 2020. For suicide by hanging, the rate gradually increased from a low of 3·70 (per 100,000) in 2011, to a high of 5·37 in 2018, before decreasing to 4·86 in 2019 and then 4·67 in 2020. Compared to 2009-2019, the 2020 rate of suicidal deaths by hanging had an estimated annual effect of 48 more suicides by hanging (RR 1·1, 95% CI 0·99-1·2; p=0·076), but this effect was not particularly beyond that expected when comparing only to more recent years (e.g. 2013-2019: RR 1·0, 95% CI 0·92-1·1; p=0·85). In fact, considering just the years 2018 and beyond, the 2020 suicide by hanging rate was well below the combined 2018-2019 rate of 5·12 (RR 0·91, 95% CI 0·83-0·99; p=0·048), corresponding to 60 less deaths. For suicidal deaths by sharp force, the estimated

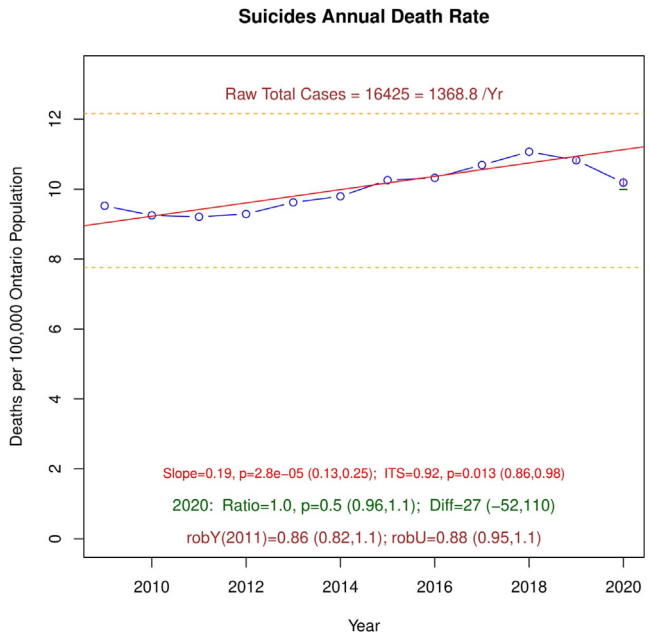

Figure 3. Death Rate by Suicide (per 100,000) in Ontario, 2009-2020.

2020 annual effect compared to 2009-2019 was just 3 less suicides (RR 0·93, 95% CI 0·67-1·3; p=0·71). For suicidal deaths by descent from height, the estimated 2020 annual effect compared to 2009-2019 was again just 3 less suicides (RR 0·97, 95% CI 0·81-1·2; p=0·82).

The 2020 rate of suicide was similar to the overall rate from 2009-2019 (RR=1·02, 95% CI 0·96-1·1; p=0·50; estimated annual effect of 27 more deaths), suggesting no major increases or decreases to suicide rate during the overall lockdown period. However, ITS analysis (which takes into account the increase in recent years) showed an estimated RR of 0·92 (95% CI 0·86-0·98; p=0·013), indicating a possible slight decrease in suicide rate during 2020. Furthermore, when considering just the years 2018 and beyond, the 2020 suicide rate was found to be below the combined 2018-2019 rate of 10·94 (RR 0·93, 95% CI 0·87-0·99; p=0·022) corresponding to 112 less deaths (95% CI 15-188). More specifically, in Stage 0 of lockdown (Figure 5), the suicide rate in 2020 is somewhat lower than in previous years (2009-2019), with an estimated effect of 30 less deaths by suicide (RR 0·88, 95% CI 0·77-1; p=0·081); this decrease appeared more substantial when compared to all combinations of recent years from 2013 onwards (combined 95% CI 0·69-0·99; max p=0·039). This apparent decrease in suicides during Stage 0 also

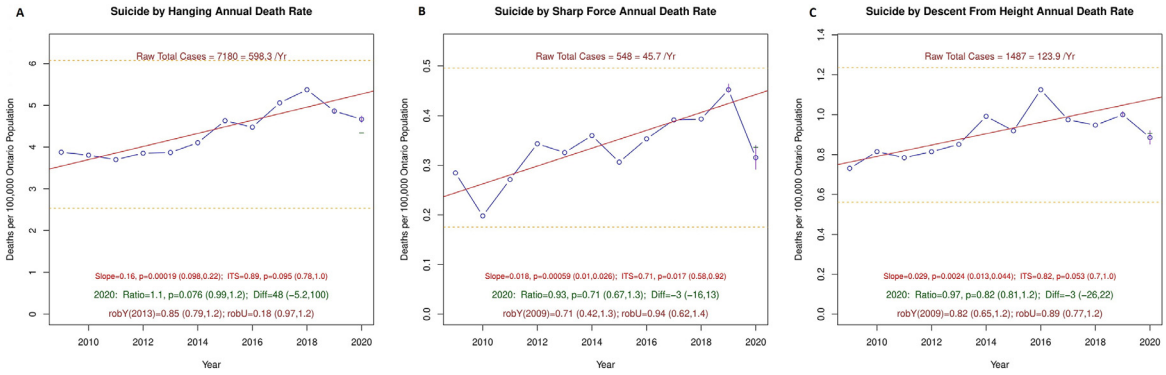

Figure 4. (A) Death Rate (per 100,000) According to Method by Means of Hanging, (B) Sharp Force Injury, or (C) Descent from Height in Ontario, 2009-2020.

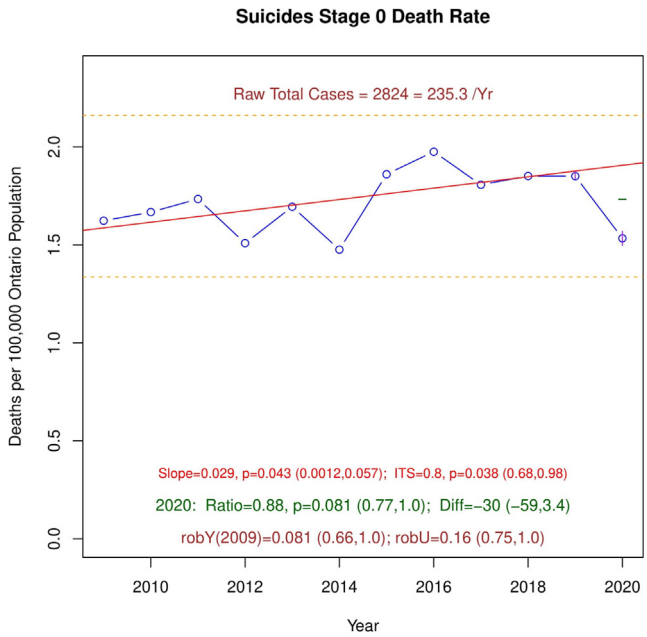

Figure 5. Death Rate by Suicide (per 100,000) in Ontario During Stage 0, March 17 - May 18, 2020.

appeared evident when using ITS analysis (RR 0·80, 95% CI 0·68-0·98; p=0·038). The greater decrease in Stage 0 than in the full year provides some evidence that the rate of deaths by suicide declined during the initial lockdown period. This decrease in suicide rate seen for Stage 0 (when compared to more recent years) does not hold up to tests of robustness when assessed in Stage 1 and disappears during Stages 2-4 (see the Technical Supplement), suggesting that death by suicide rates returned to near baseline in later stages of lockdown.

The combined rate of death by suicide by means of drugs, alcohol, substances, or poisons has been steady in Ontario from 2009-2019 (slope=-0·0093, 95% CI -0·022-0·0034; p=0·13; Figure 6A). However, the rate in 2020 is lower (RR 0·82, 95% CI 0·71-0·94; p=0·0044) and this finding is robust to choosing any starting year for the comparison group up to 2018 (combined 95% CI 0·71-0·99; max p=0·031), corresponding to an estimated 47 less suicides by toxic substances. This decrease was seen specifically in Stage 0 (RR 0·64, 95% CI 0·41-0·94; p=0·022; Figure 6B) although this finding does not hold up to tests of robustness, and less so in the other stages. When looking specifically at drug-related suicides (i.e. drugs and/or drugs and alcohol associated), the rate in 2020 is again lower (RR 0·78, 95% CI 0·67-0·90; p<0·001), which held up to all tests of robustness, corresponding to an estimated 54 less deaths (Figure 6C). Similarly, this finding was seen specifically in Stage 0 (RR 0·63, 95% CI 0·41-0·95; p=0·027; estimated 15 less deaths) although this does not hold up to tests of robustness (Figure 6D).

There were no major decreases in deaths by suicide overall in 2020 or during Stage 0 by means of hanging (2020: RR 1·1, 95% CI 0·99-1·2; p=0·076; estimated annual effect of 48 more deaths and Stage 0: RR 0·94, 95% CI 0·77-1·2; p=0·62; estimated effect of 6 less deaths), asphyxia by other means (2020: RR 0·81, 95% CI 0·65-1; p=0·059; estimated annual effect of 21 less deaths and Stage 0: RR 0·83, 95% CI 0·48-1·4; p=0·56; estimated effect of 4 less deaths), shooting (2020: RR 0·95, 95% CI 0·8-1·1; p=0·61; estimated annual effect of 8 less deaths and Stage 0: RR 0·82, 95% CI 0·51-1·3; p=0·47; estimated effect of 4 less deaths), sharp-force injury (2020: RR 0·93, 95% CI 0·67-1·3; p=0·71; estimated annual effect of 3 less deaths and Stage 0: RR 0·98, 95% CI 0·43-1·9; p=1·0; no change in estimated effect), blunt force trauma (2020: RR 1·5, 95% CI 1·1-1·8; p=0·0026; estimated annual effect of 26 more deaths and Stage 0: RR 1·5, 95% CI 0·81-2·6; p=0·14; estimated effect of 5 more deaths), or descent from height (2020: RR 0·97, 95% CI 0·81-1·2; p=0·82; estimated annual effect of 3 less deaths and Stage 0: RR 0·97, 95% CI 0·6-1·5; p=1·0; estimated effect of 1 less death; see the Technical Supplement).

Accident

Accidental deaths in Ontario have increased steadily since 2009 (slope=1·2, 95% CI 0·72-1·6; p<0·001; Figure 7), and, despite this trend, the 2020 rate is markedly higher than expected when compared with previous years (including overall robustness checks; combined 95% CI 1·05-1·47; max p<0·001 over all

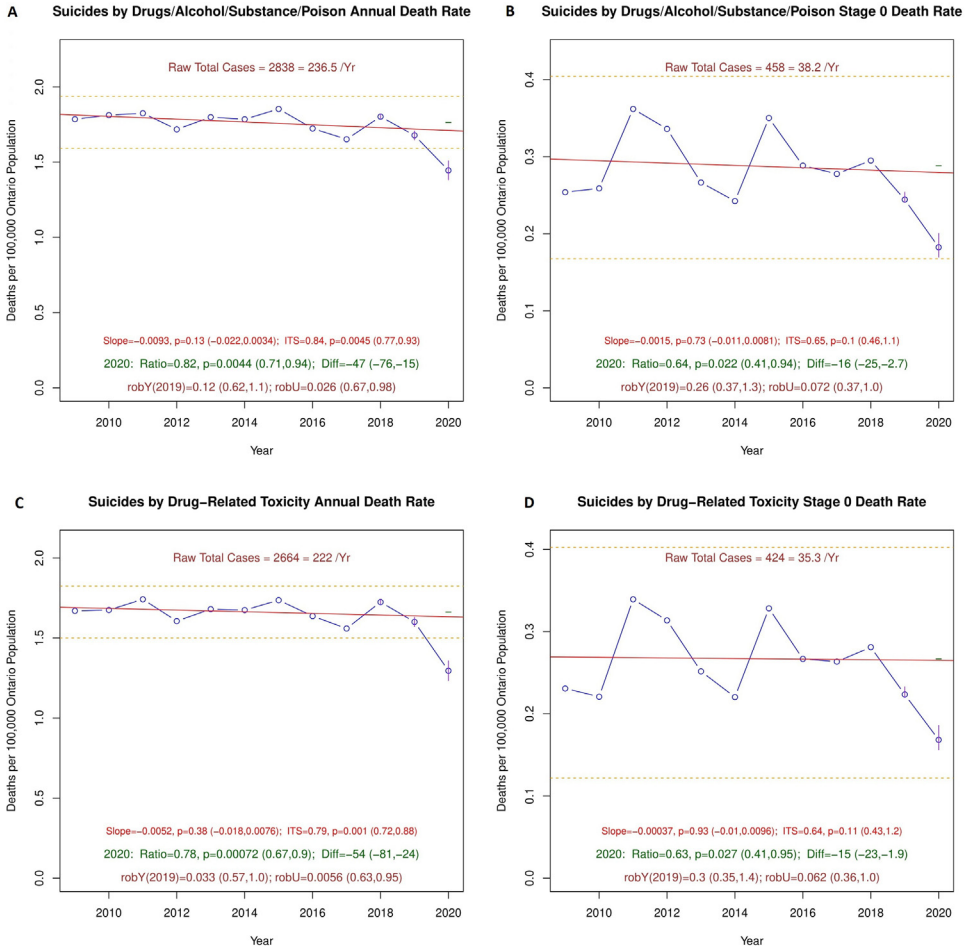

Figure 6. (A) Death Rate by Suicide by Drugs/Alcohol/Substance/Poison (per 100,000) in Ontario, and (B) During Stage 0, March 17 - May 18, 2020 or by (C) Acute Drug-Related Toxicity (only) (per 100,000) in Ontario and (D) Acute Drug-Related Toxicity (only) During Stage 0, March 17-May 18, 2020.

choices of comparison starting year and uncertainty corrections), corresponding to an estimate of over 2,100 additional accidental deaths in 2020.

Rates of death by accidental acute alcohol toxicity in Ontario have not greatly changed over the past decade (slope=-0·0018, 95% CI -0·012-0·0082; p=0·70) or specifically in 2020 (RR 1·1, 95% CI 0·82-1·4; p=0·52; estimated effect of 5 more deaths) (Figure 8A). By contrast, the rate of accidental drug-related death has increased steadily, with a positive slope from 2009-2019 (slope=0·84, 95% CI 0·58-1·1; p<0·001) and was dramatically higher in 2020 (max p<0·001 over all choices of comparison starting year and uncertainty corrections), corresponding to an estimate of over 1,500 additional drug-related deaths in 2020 (Figure 8B). Further, this finding held up to ITS robustness testing (RR 1·5, 95% CI 1·2-2·1; p=0·0041), indicating that 2020 had substantially more drug-related deaths, even when accounting for the linear increasing trend over time.

The drug-related death rate increase was also demonstrated in all the individual stages of the lockdown (estimated effect 285, 120, 144, 524, and 257 more deaths in Stage 0, 1, 2, 3 and 4 respectively; robust over all uncertainty corrections, ITS testing and all comparison starting years up to 2018; Figure 9). These findings include all drug-related deaths whether or not they also involved alcohol, but similar findings apply to drug-only deaths; see the Technical Supplement.

Accidental drug death data may intersect with suicide data insofar as some suicides by drug overdose may be misclassified as accidental drug deaths. In the literature, reports on the impact of the pandemic on suicide rates have been conflicting, with some reports indicating an increase or decrease and others showing no change in suicides. Given that one possible explanation for this discrepancy might be misclassification of some suicidal deaths as accidental drug overdoses, we also explored a composite self-injury mortality (SIM) model.

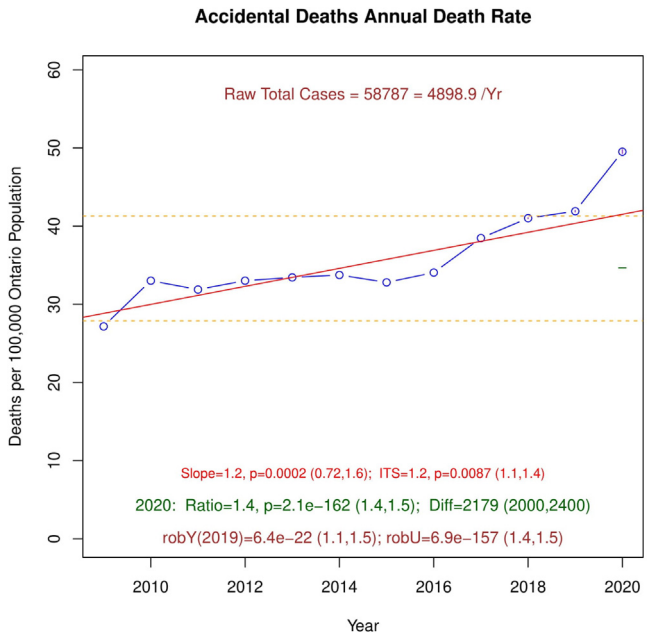

Figure 7. Accidental Annual Death Rate (per 100,000) in Ontario, 2009-2020.

Rockett *et al.* (2020) have proposed the use of this composite category that includes all suicides plus the accidental drug toxicity deaths.[43] We analyzed our data for SIM in the period 2009-2020. We found the SIM rate increased in 2020 (RR 1·6, 95% CI 1·6-1·7; p<0·001; estimated annual effect of 1628 more deaths), holding up to all tests of robustness including comparison starting years and uncertainty corrections and ITS (Figure 10A). When looking at Stage 0, although there was an increase in deaths in 2020 compared to the full 2009-2019 period (RR 1·5, 95% CI 1·4-1·7; p<0·001; estimated effect of 245 more deaths), this did not hold up to all tests of robustness since the 2019 and 2020 rates were similar (Figure 10B). Stages 1, 2, 3 and 4 all

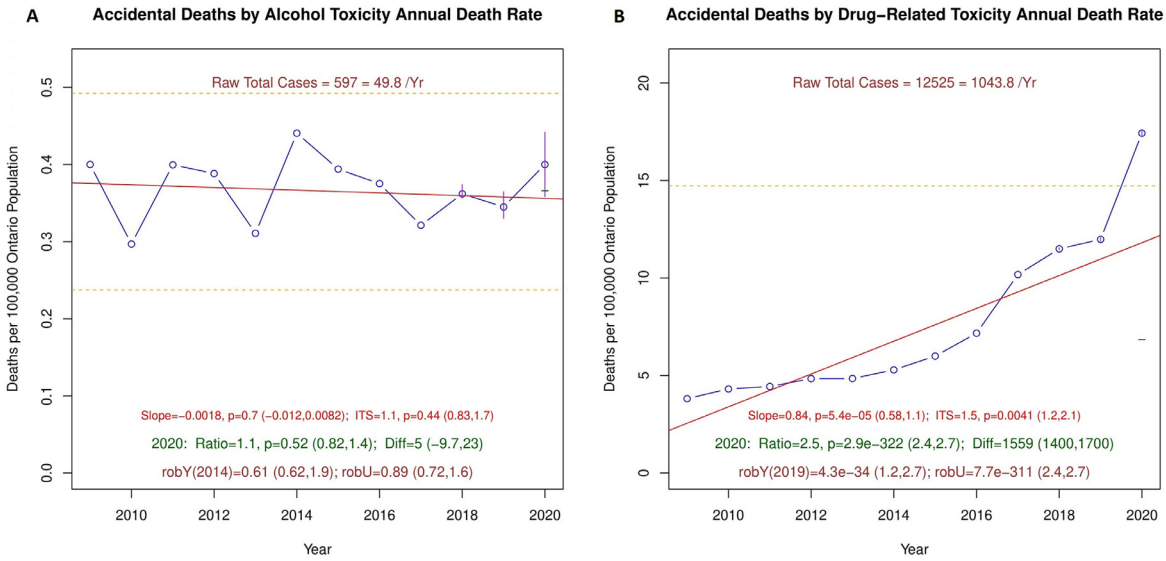

Figure 8. (A) Accidental Annual Death Rate Involving Deaths Associated with Acute Alcohol Toxicity or (B) Acute Drug-Related Toxicity (per 100,000) in Ontario, 2009-2020.

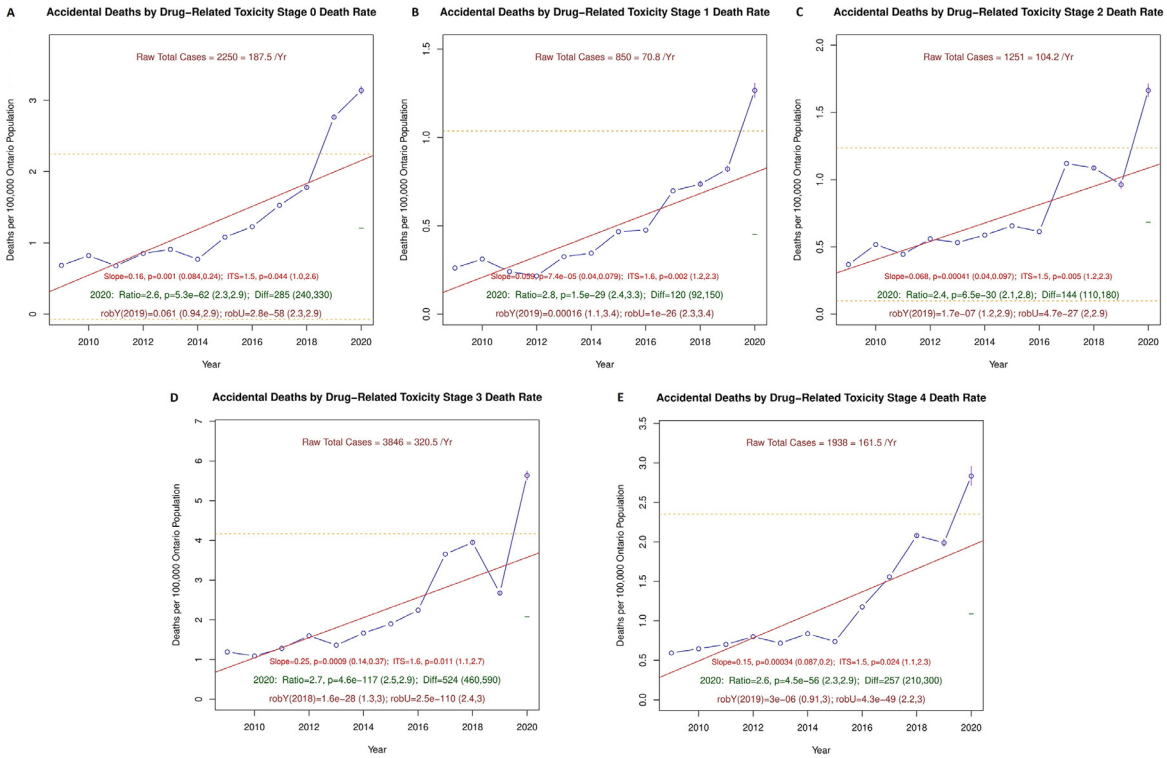

Figure 9. Accidental Drug-Related Death Rate (per 100,000) in Ontario for all Lockdown Stages.

showed an increase in the 2020 SIM rate (estimated effect of 111, 164, 560, and 304 more deaths respectively) (RR 1·6-1·8, combined 95% CI 1·4-1·9; max p<0·001) which held up with relatively strong robustness over all choices of comparison starting year and uncertainty corrections (see the Technical Supplement).

Motor vehicle collision-related death rates decreased slightly in recent years in Ontario (slope=-0·036, 95% CI -0·094-0·023; p=0·20; Figure 11A). The rate of deaths from motor vehicle collisions in 2020 (both annually and in Stage 0) is lower than in all previous years (2020: RR 0·89, 95% CI 0·81-0·96; p=0·0039; estimated annual effect of 78 less deaths; Figure 11A; and Stage 0: RR 0·77, 95% CI 0·59-0·99; p=0·038; estimated effect of 21 less deaths; Figure 11B), but not when compared only to 2019 (2020: 95% CI 0·75-1·1; p=0·26 and Stage 0: 95% CI 0·55-1·4; p=0·93) nor to the specific period 2018-2019 (2020: 95% CI 0·83-1·00; p=0·062 and Stage 0: 95% CI 0·65-1·17; p=0·40) nor from ITS (2020: RR 0·93, 95% CI 0·80-1·1; p=0·35 and Stage 0: RR 0·84, 95% CI 0·58-1·5, p=0·43). Hence, although there was a slight decrease in accidental motor vehicle collision-related deaths in 2020, we cannot infer any lockdown specific effect.

The main findings from our study have been summarized in a forest plot (Figure 12) which demonstrates the 2020 death rate ratios (i.e. the 2020 rate over the pre-2020 rate) and their respective p-values and confidence intervals.

Discussion

As the COVID-19 pandemic swept across the globe, public health authorities and governments have struggled to strike a balance between effective public health measures intended to curtail the spread of this novel disease and the unintended consequences that such measures may have on the population. There is obviously significant interest from the general public, media, academics, and government policy makers to understand and learn from these unintended consequences, so as to inform public health measures during the remainder of the current pandemic and future pandemics. These unintended consequences span across all manners of death. Reports of increases in domestic violence raise the question of whether homicides increased; economic impacts, job losses, and mandated stay-at-home orders prompt concerns for new onset and exacerbation of pre-existing mental health conditions and potential increases in death by suicide; the worrisome pre-pandemic trends in North American unregulated drug and opiate use queries whether these

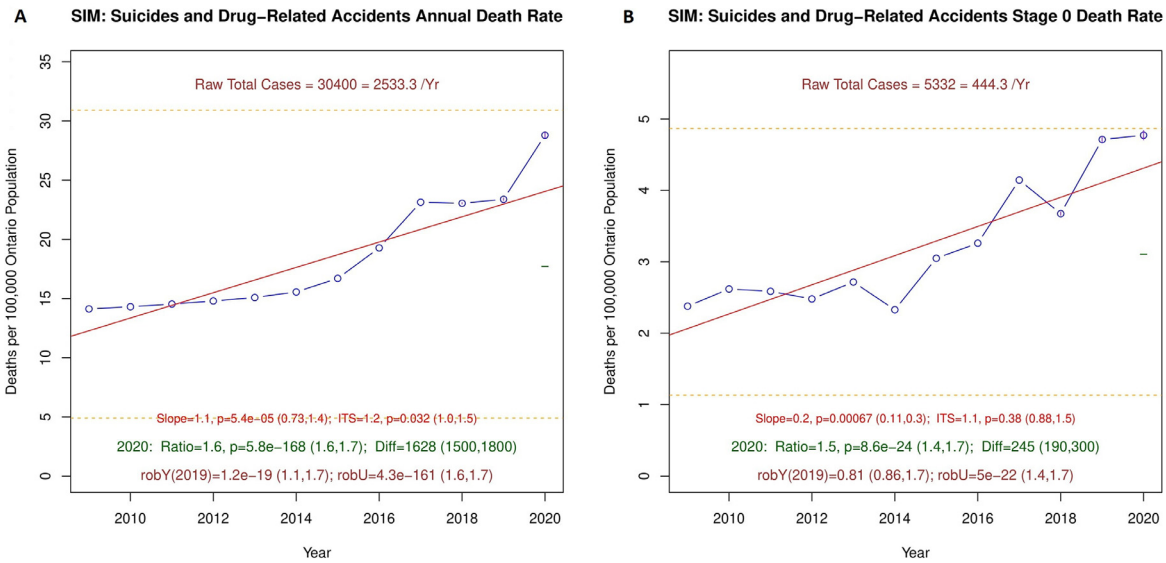

Figure 10. Combined Suicide and Accidental Acute Drug-Related Death Rate (per 100,000) in Ontario, and (B) During Stage 0, March 17 - May 18, 2020.

measures increased or decreased drug-related fatalities; and changes in routine traffic with mandatory stay-at-home orders raise considerations of the impact on motor vehicle collision-related fatalities.

Our study of 77,655 non-natural deaths is, to our knowledge, the largest study in the world to investigate all three non-natural manners of death including the effects of the COVID-19 pandemic on drug-related deaths (please see supplementary summary table of studies we identified which investigated manners of death during the pandemic). This is the first description in the literature reporting the effects of the COVID-19 pandemic and subsequent lockdown stages on all non-natural manners of deaths in Ontario. Additionally, we describe decade-long trends observed in the province that are valuable from a public health perspective.

Our data demonstrate that in Ontario, homicides are increasing slightly with a particular rise in firearm-associated deaths, highlighting the potential need for measures designed to reduce gun-related violence. We found minimal impact of the pandemic lockdown stages on homicides rates in Ontario, particularly when comparing to recent years. This contrasts with other reports that have documented homicide deaths to have increased[23] and decreased[10,24] and suggest reports of increased domestic violence rates in some jurisdictions following stay-at-home orders[1] may not translate into increased homicide rates in Ontario. Other studies have similarly found a consistent homicide rate in some regions.[21-23] The variability across jurisdictions may be due to differences in specific stressors across geographic, economic, political, and cultural boundaries and/or potential variability in the response of emergency medical services (e.g., police, ambulance, and/or hospital services). It remains important to consider public health interventions to not only decrease domestic violence, but also to prevent it from escalating to deaths in the coming years, and to continue to monitor death investigation system data for trends.

The annual death rate by suicide in Ontario has overall increased over the interval 2009-2019. More specifically, deaths by suicide by means of hanging, sharp force injury, and descent from height have increased in Ontario over the past decade. As such, studies investigating possible underlying associated risk factors, with subsequent targeted/specific suicide prevention strategies and/or allocation of additional mental health resources may be of benefit. In contrast, we found that the suicide rate decreased during the initial phase of the lockdown, Stage 0, compared to recent years (2013 onwards). There has been considerable variation in the literature with respect to death by suicide, with reports of rates decreasing,[4-10] increasing,[7-9,11-13] and remaining steady.[8,13-22] Other reports have shown death by suicide varied during the pandemic based on sex and ethnicity.[7-10,12,13] These include male and female death by suicide rates peaking at distinct stages during the pandemic,[12] decreased male death by suicide,[9,10] increased female death by suicide,[9,13] and increased death by suicide rates for racial minorities compared to Caucasian populations.[7,8] The explanation for death by suicides initially decreasing in our data, particularly those due to drug toxicity, is not clear, as pharmacies remained open during the lockdown stages. However, a potential interruption in the unregulated drug supply remains a possibility. Otherwise, initial positive mental

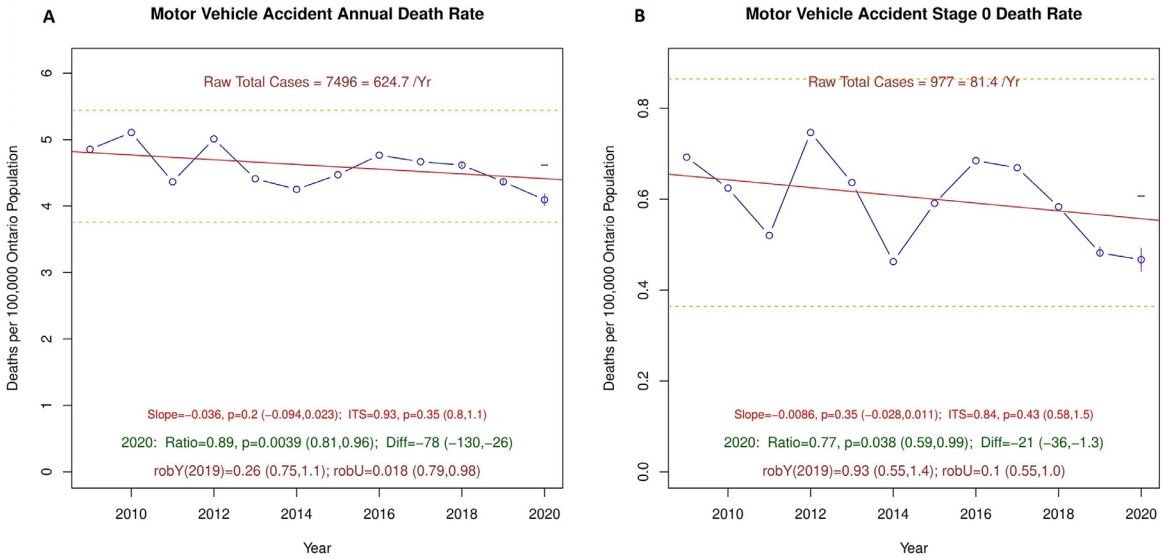

Figure 11. (A) Accidental Motor Vehicle Collision Associated Deaths (per 100,000) in Ontario, 2009-2020 and (B) and During Stage 0, March 17 - May 18, 2020.

health impacts of working from home and/or school closures also remain a possibility. Although an increase in death by suicide was not observed in the current study period, the long-term impacts of the COVID-19 pandemic and related lockdowns (e.g., impacts on income, unemployment, reports of increased mental illness) require ongoing monitoring.

Accidental deaths have increased in Ontario over the past decade, most likely driven by the opioid crisis and accidental drug-associated deaths. Taking this trend into account during analysis, we still found a substantial increase in the rate of acute drug-toxicity associated deaths in 2020 and during all pandemic stages. This finding is consistent with other published literature.[3,27-33] Our results suggest drug use is the main factor in accidental toxicity associated with death rather than use of alcohol. Potential reasons for this increase in drug-related deaths may include barriers to accessing harm reduction services and treatment, generally increased stressors during the pandemic with overall negative impacts on mental health driving increased drug use, and physical distancing mandates (possibly leading to more individuals using drugs alone). Our results suggest an excess of over 1,500 drug-related deaths occurred during the pandemic lockdown stages. Additional studies to best understand the principal drivers of these excess deaths during the pandemic are warranted. The results we show are of paramount importance to public health professionals and policy makers, highlighting the need to prospectively consider options to support and best protect the drug-using population when faced with whole population level stressors and necessary public health measures. More detailed analysis of the factors contributing to excess drug-related fatalities during the pandemic and related public health measures is important to best protect this segment of society from excess harm in any future large-scale public health threats and emergency responses.

Motor vehicle collision-related fatalities in Ontario show a slight decreasing trend over the past decade which may be due to law enforcement, safe driving campaigns, graduated licensing requirements, refined vehicle design, or improved roadways and signage. In Stage 0, we anticipated motor vehicle-related fatalities would decrease due to the stay-at-home order. Further, the literature has reported decreased fatal motor vehicle collisions associated with the pandemic.[10,22,25,26] Our findings demonstrate a similar trend, however the effect was less than might be anticipated, particularly when comparing to recent years. It is possible that fewer drivers in Ontario followed the stay-at-home order than expected or than compared with drivers in other jurisdictions that reported decreases. Alternatively, the assumed protective effect of having fewer vehicles on the road may have been offset by increases in motor vehicle related deaths secondary to unsafe driving practices, such as driving under the influence of drugs/alcohol or speeding and/or stunt driving.

Many countries have documented a sudden decline in all or some death types at the onset of lockdowns, followed by an increase or return to average in the post-lockdown period.[26,34,35] We note some possible similarities (please see Technical Supplement). However,

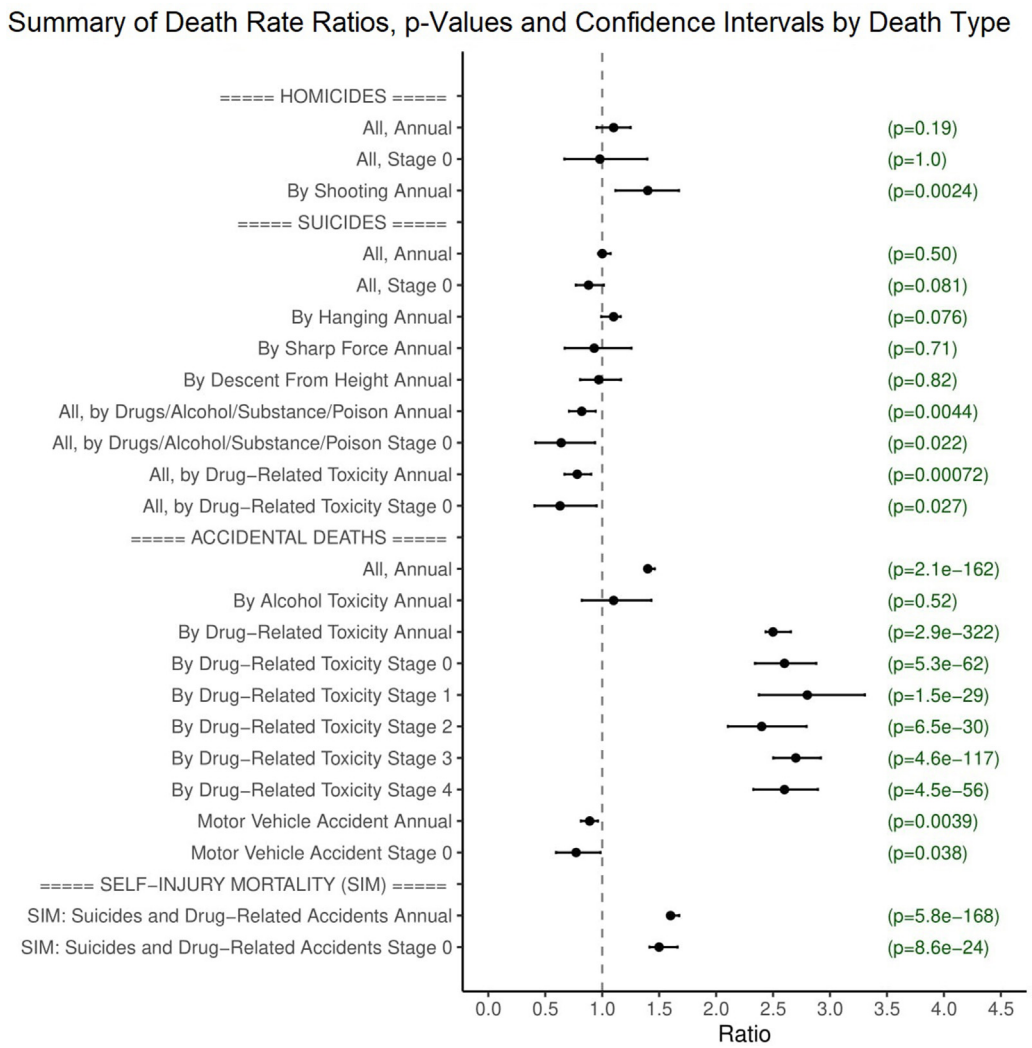

Figure 12. Summary of the Main Findings of this Study Presented as a Forest Plot, Demonstrating Death Rate Ratios for 2020 and their Respective p-Values and Confidence Intervals by Death Type.

Mason *et al.* (2020) report increased opioid overdose deaths during the stay-at-home order followed by a decline post-lifting of the stay-at-home order.[31] The findings reported herein reflect the impact during the defined pandemic stages that have been studied to date. For this study, the various trends identified may eventually increase, decrease, or return to average as the province relaxes pandemic-related public health measures.

Limitations

A limitation of this study is that not all cases were closed and finalized at the time of final data extraction. This was expected and unavoidable as death investigations can take several months to years to complete. Considering the timely dissemination of these results was of importance to the population of Ontario and international scientific community, data was extracted from open cases using preliminary data if it was provided by the coroner. With respect to this use of preliminary data from the coroner, an analysis comparing two data retrievals (August and October 2020) revealed that the rate of change in manners of death from open to closed cases is approximately 0·53% (17/3187) and is thus unlikely to have significantly impacted the results of the study. An additional limitation is how death types were classified, as multiple coroners input the data and there may be minor variation in classification/coding practices. Additionally, there was some variation in geographical areas that were re-opened in the province towards the later stages of the lockdown, however the lockdown dates for our study were selected based on the stage that reflected

the status of the majority of the province.[37] The conclusions drawn with respect to the later stages of the lockdown (e.g. accidental drug-related deaths) were seen across all stages, and, as such, mild variation in geographical location is unlikely to have impacted the main findings.

Although our analysis does take into account the small changes (increases) in Ontario's population over time, it does not specifically consider age-adjusted rates to reflect changes in Ontario's age distribution. We have conducted a preliminary investigation into those changes (please see corresponding supplementary material, also available at probability.ca/DmetrichukAges). Our findings indicate that suicide rates do indeed vary by age range. However, the percentages of Ontario's population in different age ranges have remained relatively constant over the period under investigation. Furthermore, what changes do remain do not appear to be large enough to substantially affect the corresponding yearly death rates. Thus, we feel that changes in population age distribution are unlikely to substantially affect our conclusions.

It is possible that a small percentage of deaths were unintentionally misclassified by cause and/or manner of death. For example, studies have suggested that suicides, in particular, are at risk of being underestimated due to misclassification, including unintentional (accidental) and/or undetermined manners of death.[44,45] As such, the manners in our study could potentially have been prefaced with 'suspected' as cautionary terminology. However, we have elected to use the officially determined manner of death as per the investigating coroner as recorded in the CIS. If there was considerable uncertainty with respect to manner determination, the coroner would likely have classified the death as 'undetermined'. Given the uncertainty surrounding undetermined deaths (in closed cases), this manner was excluded from our study as such analysis would be of very limited practical utility to public health and policy makers in the context of our study. In Ontario, all coroners' reports and conclusions are reviewed by a regional supervising coroner who performs a quality assurance check, ensuring multiple experts have reviewed the available information and agree on the cause and manner of death. Similarly, there is a rigorous quality assurance program in place in Ontario for forensic pathology reports for deaths where coroners order autopsies (which report the cause of death), including regular audits, and a peer review system to ensure appropriate testing and conclusions. We recognize that despite the rigorous quality assurance practices, there may still be misclassifications. However, within the recognized limitations of ascertaining manner of death based on the available information in any death investigation, we feel potential misclassification of the manner of death in a small percentage of cases is unlikely to have significantly impacted our analyses and findings. From a statistical point of view, the rate of misclassification is likely to have remained relatively constant from year to year, as coronial practices have largely remained the same, and is therefore unlikely to have affected comparisons between years.

Our SIM analysis of self-injury mortality showed when suicide and accidental drug-related deaths were combined, there was an increase in 2020. However, when looking at Stage 0 of the pandemic, this finding did not hold up to robustness testing. Based on our data, this is likely because drug-related suicides were found to decrease during Stage 0, suggesting that most of the self-injury burden is likely due to accidental drug-related deaths. However, there remains the possibility that some of these drug-related deaths were suicidal in nature due to possible manner of death misclassification due to limited investigative information.

We acknowledge that attempted homicides and suicides will not have been reflected in our study, as our data only includes the deceased population. Similarly, our accidental motor vehicle collision data only includes fatal collisions, and as such, we are not able to comment on motor vehicle collision rates (including non-lethal collisions).

Conclusions

The pandemic and these study results highlight the important role of death investigation systems in collecting, analysing, and mobilizing data related to manners of death in a timely fashion to best inform public health practices and policy recommendations. We show that homicide rates in Ontario were largely unaffected during the lockdown. Suicide rates slightly decreased during Stage 0, compared to recent years (2013 onwards). There was a substantial increase in the rate of drug-related fatalities during all stages of the lockdown. Accidental motor vehicle collision-associated fatalities decreased slightly in 2020, however an effect attributed to the lockdown was not clearly evident, particularly when compared to recent years. Future studies should analyze the impact of the COVID-19 pandemic and related public health measures over a longer time frame to fully understand the long-term implications on manners and types of death. Additional stratification of data (such as by urban setting type, socioeconomic status, or ethnography, etc.) could identify population subgroup-specific findings that may serve to inform best practice in public health efforts. The data in our study are inclusive for Ontario (for non-natural deaths) and therefore are representative of the situation in Ontario. Ontario's large, culturally diverse collection of urban, suburban, and rural communities provides a rich data set and generalizability, suggesting the results and recommendations may be widely applicable. Further, the opioid crisis is not specific to Ontario, affecting both the United States and Canada.[46] As such, our data (particularly regarding drug-related deaths) has implications applicable across North America and is key to future public policy development.

Contributors

JD conceptualized the study, gained REB approval, contributed to the study design and methodology, drafted and reviewed the manuscript. JR contributed to the study design and methodology, verified the underlying data, performed the statistical analysis and generated figures, drafted and reviewed the manuscript. JM contributed to the study design and methodology, coordinated extraction of the data, anonymized and secured the data, verified the underlying data, drafted and reviewed the manuscript. MC conducted the literature review, contributed to the methodology, and drafted and reviewed the manuscript. RW contributed to the methodology and reviewed the manuscript.

Funding

None.

Data sharing

Full technical details of the categories and robustness tests and adjustments that we considered are available in the Technical Supplement (please see corresponding supplementary material, also available at probability.ca/DmetrichukSupp). Our preliminary investigation regarding age-distribution, with data from Statistics Canada,[36] is available as supplementary material (available at probability.ca/DmetrichukAges). A summary table of the studies we identified that investigated manners of death during the COVID-19 pandemic is available as supplementary information. Requests for access to the data should be directed to The Office of the Chief Coroner.

Declaration of interests

This study adhered to scientific and medical standards of ethics and was approved by the University of Toronto Research Ethics Board (REB file #00040433). This study did not receive any funding. None of the authors declare any real or perceived conflicts of interest. All authors meet criteria for authorship per the ICMJE guidelines and all authors have approved the manuscript in its submitted form.

Acknowledgements

The authors thank Andrew Stephen and Daisy Chen for providing the CIS data for this study. We are grateful to Regan Murray and Dr. Andrew S. Williams for reviewing the manuscript. The authors thank Regan Murray, Dr. Emily Groot, Dr. Reuven Jhirad, Dr. Michael Pollanen, and Dr. Dirk Huyer for support and advice during this study. We are grateful to the coroners, forensic pathologists, technologists, assistants, technical and administrative staff, police and all other members of the death investigation team involved in these cases. We acknowledge the individuals and the loss experienced by families, friends and communities that are represented in these data. We thank the *Lancet Regional Health - Americas* and acknowledge the valuable feedback and suggestions we were provided during the peer review process.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lana.2021.100130.

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