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Original qualitative research

Exploring the contextual risk factors and characteristics of individuals who died from the acute toxic effects of opioids and other illegal substances: listening to the coroner and medical examiner voice

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Abstract

Introduction: Substance-related acute toxicity deaths continue to be a serious public health concern in Canada. This study explored coroner and medical examiner (C/ME) perspectives of contextual risk factors and characteristics associated with deaths from acute toxic effects of opioids and other illegal substances in Canada.

Methods: In-depth interviews were conducted with 36 C/MEs in eight provinces and territories between December 2017 and February 2018. Interview audio recordings were transcribed and coded for key themes using thematic analysis.

Results: Four themes described the perspectives of C/MEs: (1) Who is experiencing a substance-related acute toxicity death?; (2) Who is present at the time of death?; (3) Why are people experiencing an acute toxicity death?; (4) What are the social contextual factors contributing to deaths? Deaths crossed demographic and socioeconomic groups and included people who used substances on occasion, chronically, or for the first time. Using alone presents risk, while using in the presence of others can also contribute to risk if others are unable or unprepared to respond. People who died from a substance-related acute toxicity often had one or more contextual risk factors: contaminated substances, history of substance use, history of chronic pain and decreased tolerance. Social contextual factors contributing to deaths included diagnosed or undiagnosed mental illness, stigma, lack of support and lack of follow-up from health care.

Conclusion: Findings revealed contextual factors and characteristics associated with substance-related acute toxicity deaths that contribute to a better understanding of the circumstances surrounding these deaths across Canada and that can inform targeted prevention and intervention efforts.

Keywords: *opioids, illegal drugs, substance-related harms, drug overdose, death, coroners and medical examiners, qualitative research*

Highlights

- People dying from substance-related acute toxicity came from all demographic and socioeconomic groups and had different histories of substance use, including first-time and occasional use, long-term use and management of chronic pain.
- Using substances alone and using in the presence of somebody who does not recognize the signs of an acute toxicity event or is unable to respond were identified as risks for substance-related acute toxicity death.
- People who died from a substance-related acute toxicity often had one or more of these contextual risk factors or characteristics: they consumed substances of unexpected potency or composition (e.g. contaminated substances); they had diagnosed or undiagnosed mental illness, history of trauma, history of substance use, history of chronic pain, decreased substance tolerance or experiences of stigma; and there was a lack of support or health care follow-up.
- Coroners and medical examiners are an underutilized source of expert information and can contribute to our understanding of opioid and other substance-related acute toxicity deaths.

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Introduction

Deaths from the acute toxic effects of opioids and other substances continue to be a significant public health concern in Canada and have largely been driven by "an interaction between prescribed, diverted and illegal opioids (such as fentanyl) and the recent entry into the illegal drug market of newer, more powerful synthetic opioids."[1,p.3] In April of 2016, British Columbia declared a public health emergency due to increasing rates of substance-related acute toxicity deaths. This increase had mainly been driven by illegal opioids, namely fentanyl and its analogues.[1]

Since April of 2016, the emergency has worsened and other Canadian provinces and territories have also reported an increase in deaths resulting from opioids and illegal substances.[2,3] Between January 2016 and March 2022, there were over 30 000 apparent opioid-related deaths (AORD) in Canada.[4] Since national surveillance began in 2016, the highest rate of AORDs was observed in 2021. The areas most impacted by AORDs continue to be Western Canada and Ontario, but other provinces have shown an increase.[4] There is also concern for the number of deaths that involve other substances; for example, stimulants were detected in approximately 60% of accidental opioid-related deaths in 2021.[5]

A number of studies have used coroner and medical examiner (C/ME) data or reports to shed light on acute toxicity deaths related to opioid and other substances. Contextual risk factors for substance-related acute toxicity death commonly identified in these studies included history of mental illness,[6,7] previous suicide attempts,[7] discharge from a treatment centre or health care facility,[8] recent nonfatal overdose,[9] recent release from jail,[10] use of multiple substances,[11] history of chronic pain[6] and a history of substance use.[6] However, these studies often focussed on a single province or territory, included only limited circumstances surrounding substance-related acute toxicity death and relied on the information recorded by the C/MEs in charts and reports.

Researchers have previously sought to understand the perspectives of people who experienced nonfatal overdose events[12-16] and friends and family of people who have died from overdose.[17-19] However, the perspectives of the C/MEs have not, to our knowledge, been published, with the exception of a preliminary, unreviewed report that was published online[20] based on data that were collected for the present study.

The high number of substance-related acute toxicity deaths in Canada represents a complex and multifaceted public health crisis, and national evidence on the contexts surrounding the deaths is needed to elucidate contributing factors and inform targeted responses. Investigating the perspectives of C/MEs on the contextual factors surrounding substance-related acute toxicity deaths may contribute novel evidence to enhance understanding of the circumstances and characteristics common across Canada, due to the C/MEs' experience with cases over time and the breadth and complexity of the information that they obtain from multiple sources during death investigations.

The purpose of this qualitative study was to obtain the perspectives of C/MEs on the deaths they investigated from the acute toxic effects of opioids and illegal substances, and to obtain in-depth evidence on common characteristics and contextual factors across Canada.

Methods

Ethical considerations and quality assurance

The Health Canada and Public Health Agency of Canada Research Ethics Board approved this study (certificate #REB 2017-0016). To ensure the trustworthiness of this study, its methodology contained steps to establish its credibility, confirmability and transferability.[21] Credibility was established by sharing the findings with all participants for review and feedback, which was then incorporated into the findings. The qualitative researchers (QRs) exchanged a selection of coded transcripts with the co-investigators to confirm the assigned coding and thematic analysis to corroborate findings and establish confirmability. To increase transferability, we have provided thick descriptions, wherever possible, of the participants' context and of the data collection procedure to facilitate evaluations of how the findings may transfer to other settings.

Study design

This qualitative study was conducted with C/MEs in eight provinces and territories across Canada. Through semistructured interviews, C/MEs were asked to reflect on the interplay of the common characteristics, contextual risk factors and opportunities for interventions in the investigations in which they had been involved.

This methodology values the experiences and perceptions of C/MEs, beyond what is documented in individual case files, and enables C/MEs to aggregate details across cases to provide insight into common characteristics and contextual factors. Practically, this methodology allows for the aggregation of national knowledge into a contextual, meaningful summary.

Recruitment

C/MEs were selected because of the breadth and complexity of information they obtain from numerous sources during their death investigations, and their mandated role in understanding deaths.

Provincial and territorial chief C/MEs were contacted to participate and assess interest in engaging in this study. Interested chief C/MEs prepared a letter of support and provided a list of potential regional and local C/MEs with consideration to achieving a broad geographic representation. Participant sampling was stratified by province or territory. Participating provinces and territories were allocated interviews based on their proportion of the Canadian population and their proportion of apparent opioid-related deaths at the national level.

Potential participants nominated by their chief C/ME received an email from Public Health Agency of Canada (PHAC) study coordinators inviting them to participate in the study. The email included a description of the study, a support letter from their chief C/ME, a short questionnaire and a consent form. The questionnaire contained questions about demographic information, the location where the majority of their cases occur (e.g. urban, rural, remote) and years of experience investigating deaths. Chief C/MEs were not informed which of their nominated staff participated in the study.

Interviews

A semistructured interview format was used to allow participants to share their own perspectives, while ensuring that answers informed the study purpose and enabled comparisons across respondents. The interview guide was pilot-tested with two C/MEs, and revisions were made to the interview questions as required.

Participants were anonymous to the interviewer with the exception of their province/territory. Interviews followed the semistructured interview guide (Table 1) and were conducted by telephone in the participant's preferred language (English or French). The interviews were audio recorded on a secure PHAC telephone line. Interviews ranged from 40 minutes to two hours. Each participant engaged in a single interview with one interviewer.[†] Only the participant and the researcher were present for the telephone interviews. There were no withdrawals from the study once participants were recruited. Participants were asked to reflect on the deaths from the effects of opioids and other illegal substances that they had investigated in the past two years. C/MEs were asked to describe characteristics and trends, rather than information on specific cases. The two QRs took field notes after each of the interviews was completed.

Data management

Study data were protected in accordance with PHAC's *Directive for the collection, use and dissemination of information relating to public health* (2013, unpublished document). The interview recordings were transcribed verbatim. French transcripts were translated to English by a professional translator, and a bilingual

TABLE 1
Study interview guide

Main interview questions	Probes/follow-up questions
What position do you currently hold with the coroner's/medical examiner's office and what experiences and education led you to this position?	What degrees or training do you have for your position? Can you describe your experience investigating deaths in vulnerable populations?
Can you give a short overview of the processes your office uses to investigate acute toxicity deaths?	Have there been any changes in the investigation, testing or reporting process that your office uses that may be influencing the rates or details of deaths reported from your jurisdiction? Are there any steps or tests that are missed or excluded that may influence your determination of the circumstances of death?
Can you tell me about the acute toxicity deaths that you have investigated over the last two years?	What interplay between social, demographic and economic factors have you observed? Do these differ depending on the substances involved? What are the most problematic substances or combinations of substances among the deaths that you have investigated? Can you describe any patterns of polysubstance use in the days leading up to death or any other problematic combinations that you have seen? Were there any differences in the individuals or circumstances depending on if they were personal pharmaceutical drugs, diverted pharmaceutical drugs, or illegal substances?
Based on your investigations, what do you feel are the key risk factors that lead to acute toxicity deaths and who is most impacted by these factors?	Have you noticed that risk factors are changing? Are you able to attribute the risk factors to populations you mentioned previously or do these risk factors cross all populations?
Have you noticed any changes in who is dying or the substances involved, particularly over the last two years?	You mentioned that [describe a group or drug that was mentioned in the last question] earlier. Have you noticed a change in the proportion of deaths with this characteristic or using this drug? What changes to the substances involved do you anticipate for the future?
In your investigations, have you noted any opportunities to prevent these deaths that may have been missed or underutilized?	Are there any overdose or acute toxicity prevention activities that you believe should be considered or prioritized for your jurisdiction? Now considering individuals that are at high risk of overdose or acute toxicities, are there more upstream interventions that you believe should be prioritized or implemented?
I will now ask you to review the provided opioid-related death statistics reported by your province/territory. What context do you feel is helpful to understand this data in order to compare to other jurisdictions?	Are there any differences with illegal vs. non-illegal drugs?
Is there anything else that you would like to share when considering how to address this issue?	Are there any other "takeaways" you think are important?

[†] The interviews were conducted by the first and fourth authors, both of whom have experience with qualitative methodologies, analysis and data collection. Both interviewers are female, hold PhD degrees, and, at the time of data collection, held assistant professor positions. There were no relationships established between interviewers and participants prior to data collection, and interviewers were introduced as qualitative researchers.

research team member (HO) compared the translated versions with the originals to ensure that meaning was not lost in translation.

To ensure confidentiality, all identifying information was removed from the interview transcripts and all interviews were assigned an identification number. The interview data were checked for accuracy, imported and managed with NVivo11.[22]

Data analysis

Braun and Clarke's[23] six-phase process for thematic analysis was utilized in this study, with a focus on the coding reliability approach to ensure accurate and reliable data coding and analysis.

Analysis of the data began with the QRs individually reading and re-reading the interview transcripts to become familiar with the depth and breadth of the data and develop a codebook with a list of codes. Codes are concepts that are used to provide a name to describe what the participant is saying. A code can be a word, phrase, sentence or paragraph that describes the phenomenon under study.[24] Following the initial coding of the interview data, the QRs began a process of iterative consensus building of the identified codes.

The QRs then categorized the codes into basic, organizing and global themes.[25] A theme is a broader constellation or category used to capture the more general phenomenon to which a code refers.[25] "Basic themes" are the simplest themes that come from the interview data and contribute to higher order themes.[25] When taken together, the basic themes constitute "organizing themes," which are middle-order themes that organize the basic themes into clusters of similar issues. A group of organizing themes, when taken together, then make up a "global theme," which is the highest order of themes and encapsulates the essential organizational concepts that work to provide a core interpretation or explanation of the text.[25]

Similarities and divergences detected in the coding and thematic process were discussed between the two QRs, and consensus was attained to validate the story of the data. Once the themes were finalized, a thematic map was developed and the story of the data was written by the QRs. A visual representation of global, organizing and basic themes is illustrated as a thematic network map in Figure 1.

Results

Thirty-six participants from eight provinces and territories were interviewed in the study. Table 2 provides the participant characteristics as well as the provinces and territories represented in this study.

The findings focus on the global theme contextual risk factors and characteristics of substance-related acute toxicity death. Four organizing themes were identified from the global theme: (1) Who is experiencing a substance-related acute toxicity death?; (2) Who is present at the time of death?; (3) Why are people experiencing a substance-related acute toxicity death?; and (4) What are the social contextual factors contributing to deaths? The global, organizing and basic themes are shown in Figure 2 as a thematic map.

Organizing theme 1: Who is experiencing a substance-related acute toxicity death?

Five themes for "Who is experiencing a substance-related acute toxicity death?" were identified: crossing demographic and socioeconomic groups, first time use, occasional use, chronic use and people with chronic pain.

C/MEs highlighted that the deaths they investigated were crossing all demographic and socioeconomic groups. For the most part, substance-related acute toxicity deaths have occurred historically among people with lower socioeconomic status; however, over the last two years of the study period, C/MEs across Canada noticed a change in the profile of acute toxicity deaths. Increasingly, they observed deaths involving individuals from a range of socioeconomic statuses and employment/occupations as well as a wider range of substance use histories, including first time substance use, occasional use and chronic use, as well as individuals who had a history of taking medications to treat chronic pain.

People consuming substances were noted as being at risk for an acute toxicity death if it was their first time use or they engaged in occasional use, potentially because they may have lacked awareness of the substances they were taking, including the source of the substances and the potential for them to be contaminated with undisclosed substances (e.g. fentanyl). First time or occasional use could also elevate risk due to low biological tolerance. Occasional use and first time use are illustrated by C/MEs here:

> From the cases that I've heard some of my colleagues having, it's the teenager who it's the first time s/he is using drugs, it's the rave, the more common parties that people are using drugs, and I think fentanyl is getting mixed with more and more common drugs that are not felt to be major drugs of [use] and stereotypically the drugs that people who are major [substance consumers] are using. (S019 ON)

> I had some cases involving young people who are always in party mode … they don't know what they're buying because they're getting them on the street. … They think they know what they're buying. But they really don't know. (S062 QC)

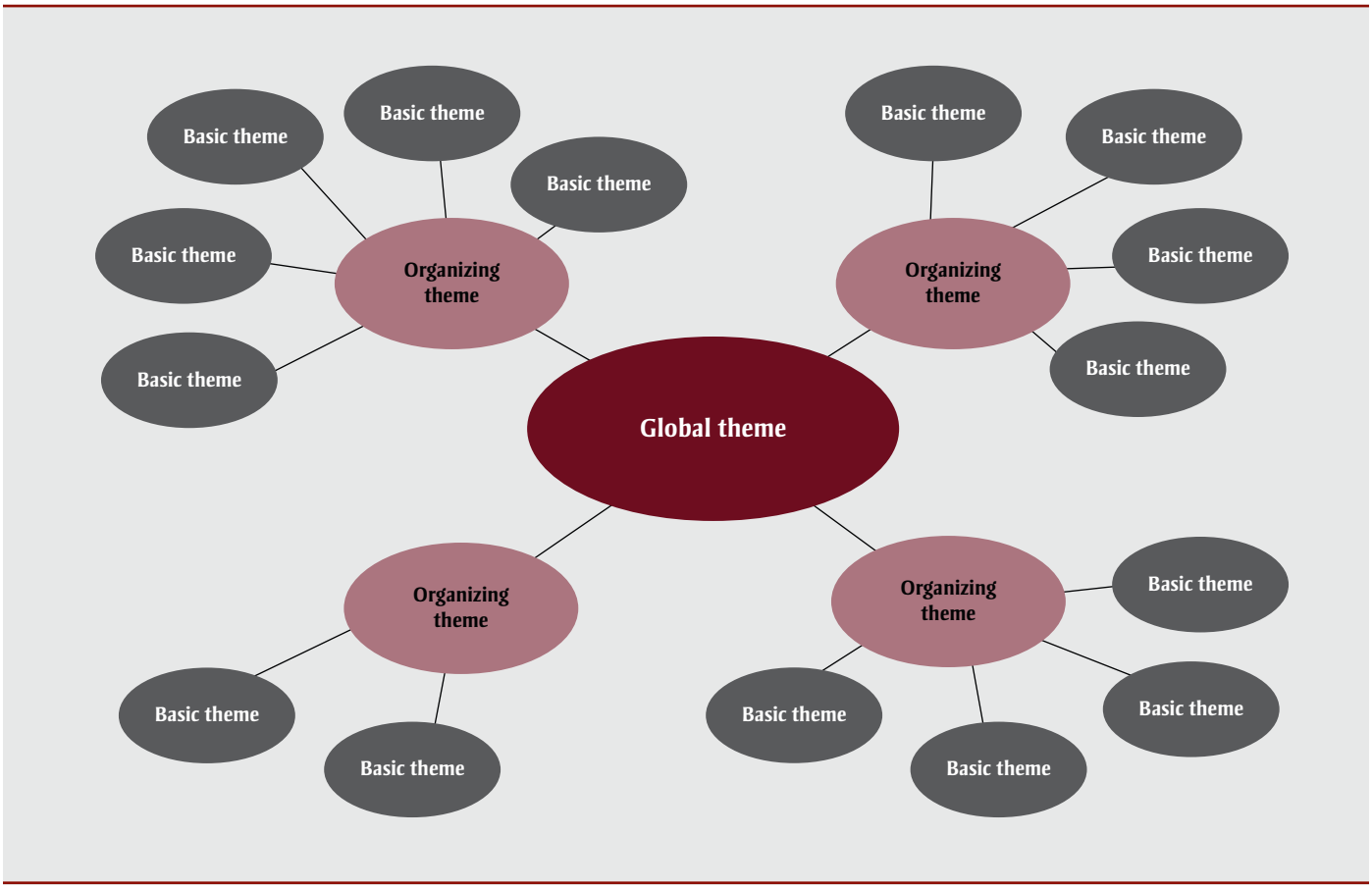
C/MEs talked about still seeing people who had a history of chronic use of opioids and illegal substances experiencing a substance-related acute toxicity death, as illustrated here:

> Not all of the cases that I've gone to are [people who had a history of] chronic long-term [substance use] … I'd say many are but not all of them. There are some where they manage to hold down jobs or they're kind of, you know, the [people who use occasionally] on the weekends … but most of them have got a history where—and when I say history it's not like, you know, they just have started using but it can go—depending on the age of the person, it goes back a few years. (S026 BC)

People with chronic pain as a result of surgery or work-related injuries were also noted as at risk of an acute toxicity death. One participant stated:

> Some of them are trades workers, I think there was construction workers … in some of the cases I'd say some of them were suffering from pain and they transitioned from painkillers possibly to more illegal substances. (S079 ON)

FIGURE 1
Structure of a thematic network



C/MEs noted some of the cases they investigated were among people who began taking medications because of a history of chronic pain but then became addicted and may not have been provided with or had access to alternatives for treatment.

Organizing theme 2: Who is present at the time of death?

The organizing theme "Who is present at the time of death?" consisted of two interrelated themes: consuming substances alone and consuming substances with/around others.

C/MEs talked about people consuming substances alone, including people who lived alone and may have been isolated or marginalized. One participant talked about people consuming substances alone with no one to respond or intervene in an acute toxicity event or death:

> Most of the people that I go to have died alone. They die in their bedroom or in their living room or in their bathroom, and the majority of them, there's no one there to call 9-1-1 and sound the alarm. (S026 BC)

The theme "people consuming substances with/around others" in medically supervised places or with other people they know was also identified frequently among the participants. Participants talked about the enhanced safety of people consuming substances in safe injection sites or supervised consumption facilities; however, they also expressed concern that these sites may not be nearby or accessible to all people who use substances. Participants also discussed instances of people consuming substances with or around other people who may be unaware of the signs of a substance-related acute toxicity event and therefore unable to identify and respond to those signs.

Organizing theme 3: Why are people experiencing a substance-related acute toxicity death?

Four themes were identified in "Why are people experiencing a substance-related acute toxicity death?"—unknown substances, substance use disorder, history of chronic pain and decreased drug tolerance.

C/MEs talked about people dying because they consumed unknown substances, and the substances consumed were contaminated with undisclosed components (e.g. fentanyl or carfentanil). One participant noted that no one was safe from substance-related acute toxicity deaths:

> My subjective feeling actually is that even the [people using substances] sometimes don't know what they are using because it is clear sometimes in the history that they certainly expected to be doing one kind of drug and they seemed to have others in their system that really ought not to have been there based on the expectation of the user. (S055 NS)

The theme "substance use disorder" focussed on cases that involved chronic use or a history of substance use. Some deaths had been preceded by one or more nonfatal

TABLE 2
Participant characteristics, n = 36

Characteristic	Frequency n (%)
Gender	
Women	23 (64%)
Men	13 (36%)
Age in years [median (range)]	49 (26–74)
Profession	
Coroner	31 (86%)
Medical examiner	2 (6%)
Chief coroner, medical examiner, or toxicologist	3 (8%)
Years participating in death investigations [median (range)]	9 (1–35)
Geographic region of deaths investigated[a]	
Urban	32 (89%)
Suburban	25 (69%)
Rural	25 (69%)
Remote	16 (44%)
Province or territory	
British Columbia	8 (22%)
Saskatchewan	4 (11%)
Ontario	10 (28%)
Quebec	8 (22%)
Nova Scotia	3 (8%)
Other provinces and territories	3 (8%)

[a] May include more than one category.

substance-related acute toxicity events. A participant noted:

> In all the cases that I've investigated either chronic drug use or drug use in their history is a contributing factor. Another risk factor … alcohol use … sometimes it's not found in the toxicology, we hear that in their history, we hear that from their families. … We also see … simultaneous use of the illicit drugs or the opiates, it may be fluctuating, so when they're not using the alcohol they're using the drugs, but I do see that in a lot of the cases, in their history, is alcohol use, and usually it's chronic. (S041 SK)

Acute toxicity deaths were also attributed to a history of chronic pain, with people who began taking medications because of an injury or previous surgery then struggling with chronic pain and pain management, or not being provided with alternatives when medications were discontinued, as illustrated below:

> You know for the chronic pain it has been … in the ones that you know had been prescribed medication prior for chronic pain, injuries, but then were taken off the medication. … And as the investigators we look in the records; it doesn't appear that they were offered another solution or another assistance, you know. (S023 NWT)

Decreased tolerance was identified as a significant theme associated with substance-related acute toxicity death. C/MEs talked about people experiencing a substance-related acute toxicity death after a recent release from a correctional facility, a treatment centre or health care facility because their drug tolerance was reduced from not using substances for a period of time. Some participants described decreased tolerance following a recent release from jail or not using for a while and then "testing the waters":

> The problem of a person getting out of [a correctional facility] … then using is kind of a consistent one. We don't get a huge number but we get … a half dozen a year pretty consistently which suggests to me at least a point of intervention. … And I think that the issue is that in [correctional facilities] access to their preferred drugs may have been somewhat limited. … But then they get out … the types and the numbers of drugs that they have access to obviously changes and that change in access is something lethal. … I don't think it is very numerous but it sort of sticks out in my head. (S055 NS)

Organizing theme 4: What are the social contextual factors contributing to deaths?

Four themes were identified in the organizing theme "What are the social contextual factors contributing to deaths?" including: mental health, stigma, lack of support and lack of coordinated health care follow-up. C/MEs across the country also noted that some of the deaths they investigated were of individuals who were experiencing more than one of these factors concurrently.

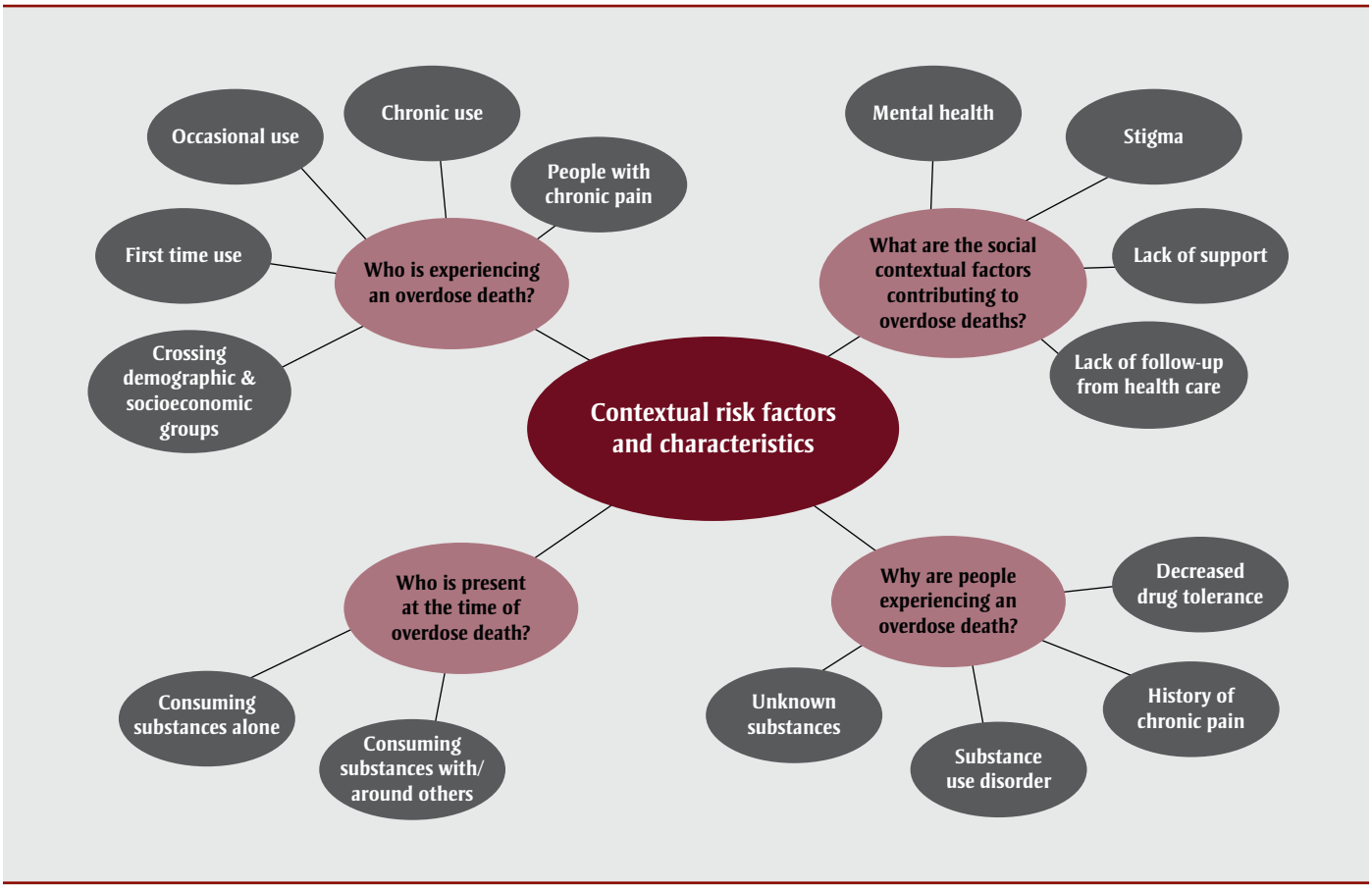
Within the theme "mental health," mental ill-health was a significant focus of discussion regarding the contextual risk factors and characteristics of people who experienced a substance-related acute toxicity death. These factors included diagnosed, undiagnosed and untreated mental illness.

> With respect to mental health problems, from what I can see … are the problems that are known and diagnosed … the person is seeing a psychiatrist or a psychologist or a family doctor … receives medication. … It can be depression. It can be psychosis. It can be a personality disorder. … It usually involves one of those things. … Or it's someone who obviously has a mental health problem, but who hasn't been diagnosed. Because the person hasn't seen anyone. (S062 QC)

Other participants talked about patterns of complex and interrelated factors, including the connections between mental ill-health, pain and medications, prescribed and not prescribed:

> People who are in pain … fibromyalgia, depression … there's like a pattern there … living all alone … often addicted to alcohol … have chronic pain … back pain or suffer from fibromyalgia … have had episodes of depression … you usually find them

FIGURE 2
Contextual risk factors and characteristics thematic map



with medications that were not prescribed. (S090 QC)

I had another death ... a man who ... was a truck driver ... he got into an accident ... went to emergency ... he was taking antidepressants and had symptoms of depression. ... But he wasn't taking narcotics, he didn't have substance [use] problems ... the doctor prescribed him ... he had never seen him, it was in emergency ... enough narcotic pills for him to commit suicide. And that is what happened. That very night, he took them all. (S084 QC)

Mental ill-health was also linked, for some, to previous sexual or physical trauma and thoughts of suicide or previous suicide attempts. Feelings of hopelessness and feelings of loss were illustrated in this quote:

Well, I think those that are struggling with hopelessness and sadness, and that's where the mental health picture comes in ... many of these folks that have been struggling with drug use ... alienated from their families either by choice or by their family members' choice because they're tired of having things stolen and jewelry pawned. ... They've had their children removed ... lost jobs, partners ... they've just lost ... so with that comes a sense of hopelessness. When you're struggling with perhaps some childhood trauma issues on top of that, what's the easiest thing to do? It's just to keep using because it's so overwhelming for that person to see a light. (S026 BC)

Within the theme "stigma," C/MEs described how people were struggling with multiple stressors and may have been at a higher risk of experiencing a substance-related acute toxicity death. One participant talked about the stress that people deal with when they are struggling and trying to navigate the stigma associated with substance use and accessing care:

So now they are out on the street and they are trying to find the drugs they need because of the addiction and it is a complicated ... there's no harm reduction and there's so much stigma in health, and I still see it today ... it is one of the things that really concerns me. (S023 NWT)

Lack of support was highlighted as a risk for an acute toxicity death because the deaths the C/MEs investigated were often of people who were estranged from their families or did not have access to programs or services, which increased their risk of experiencing death. One participant stated:

For some of these folks who want to access trauma counselling, do you have any idea what the waits are like? They are ridiculous, and these folks, many are on income assistance, don't have means of paying for counselling

> services, so they go on these ridiculous waits, like months of waiting. (S026 BC)

C/MEs identified a lack of follow-up from health care as a contextual risk factor for a substance-related acute toxicity death. Participants described cases in which people had not received or been able to access coordinated follow-up care after having contact with the health care system, such as emergency room visits, repeated visits for pain control to their physician or another physician and requests to refill medications early. As noted by one participant:

> I think there's been a number of cases where they had psychiatric involvement and there perhaps was a loss of follow-up or maybe … the patient didn't attend or they lost contact with their psychiatrist and so were not on their usual medications. (S079 ON)

Other participants noted repeated emergency room visits were a possible pattern in substance-related acute toxicity death, such as in this quotation referring to emergency room release:

> They're brought in by ambulance and there is no one there for them. What do they do? … You're putting a small band-aid on somebody coming in, making sure that they're still breathing, giving them their naloxone injection, then away you go. Well, what have you done to prevent that person from coming back in tomorrow? (S026 BC)

C/MEs also stated that lack of coordination between social and health services and barriers related to fees could be contextual risk factors for substance-related toxicity death.

Discussion

C/MEs observed increases in the numbers of people experiencing acute toxicity deaths and identified that deaths occurred across a wider range of profiles compared to prior years, including among people who used substances on occasion, on a regular or chronic basis, for the first time or to manage chronic pain. These changes were largely attributed, by C/MEs, to changes in the composition and potency of the substances consumed. C/MEs described how substances may have been contaminated with fentanyl, fentanyl analogues and other novel synthetic opioids that were not disclosed, which aligns with the literature from the US context[26] and from drug-checking services' analyses in Vancouver, Canada.[27]

Consistent with analyses from provincial and international data sources, which have shown that many cases of acute toxicity deaths involved people using alone,[19,28] these findings also tell us that people consuming substances alone are at risk of death because there may be no one to respond or call for help. C/MEs discussed how people who consumed substances alone often lived alone and may have been isolated or marginalized. These themes align with studies conducted in British Columbia that have reported that common factors associated with using alone include having no one to use with or no other choice; comfort and convenience; safety; material or resource constraints; lack of secure housing; and experiencing stigma or not wanting others to know about drug use.[29-31] However, most studies on this topic have focussed on people who access harm reduction or supervised injection services and may not generalize to people who are not connected with these services and who may be more likely to use alone.

In addition to using alone, participants mentioned that using with others may also contribute to risk, if they are not able to respond or to recognize the signs of overdose. A study of peer witnesses to substance-related acute toxicity events in Wales described how peers had the capacity to respond, but that contextually specific factors could prevent or delay a response; such factors would include, for example, signs going unnoticed (e.g. a peer mistakenly assuming an unconscious person was asleep).[32]

Our findings illustrated several interrelated themes concerning the contextual factors that may have contributed to deaths, including contaminated substances, diagnosed or undiagnosed mental illness, history of substance use, history of chronic pain, decreased substance tolerance, lack of support from family or friends or inability to access programs or support services, and stigma associated with substance use.

The theme of stigma, which emerged from the complex and broad range of information obtained across C/MEs' death investigations, further corroborates previous research that has highlighted stigma as an important factor in the context surrounding acute toxicity deaths.[33-35] There are multiple dimensions of stigma associated with substance use (internalized, enacted, structural, public and anticipated) that can contribute to negative outcomes, including increased stress, concealing substance use, isolation and decreased access to or engagement with health services.[35,36] C/MEs discussed how people may have experienced isolation, stress, limited support (e.g. from friends, family or targeted programs and services), and may have lacked access to coordinated health services and follow-up after repeated contacts (e.g. multiple emergency room visits).

Several of the circumstances and contextual factors identified by C/MEs are also consistent with previous qualitative studies conducted with family or friends of people who died from the acute toxic effects of opioids or other substances in the United States and in the United Kingdom, including history of substance use,[18,19] diagnosed or undiagnosed mental illness,[17-19] lack of support,[18] history of chronic pain,[17,18] repeated visits for pain control to physicians[17] and decreased substance tolerance.[19] Many of these factors may occur in combination; for example, Yarborough et al.[18] found that mental illness, unstable social support, history of chronic pain and lack of adequate pain management were common factors among people who experienced an acute toxicity event. Quantitative research has demonstrated that many of these factors (e.g. decreased tolerance after release from a correctional, health care or treatment facility,[37-39] mental illness and substance use disorders[40]) are associated with the risk of acute toxicity events; however, these analyses have typically been limited to one or two of these factors. Our findings illustrate that there are often multiple contextual factors and how these may intersect, which highlights the need for a better understanding of patterns of factors that may increase risk of fatal acute toxicity events.

Strengths and limitations

Previous literature that has characterized substance-related acute toxicity deaths in

Canada has largely been limited to quantitative analyses with limited data on contextual factors or analyses involving a single province or region. This study builds upon previous literature by providing an in-depth exploration of the multifaceted contextual factors that are common across the country from an underutilized source of expert information. To our knowledge, this is the first qualitative study including most provinces and territories in Canada that explores the perspectives of C/MEs to enhance understanding of the circumstances surrounding deaths from the acute toxic effects of opioids or illegal substances.

There are several limitations to this research. Not all C/MEs were interviewed in each participating province or territory, and not all Canadian provinces and territories were represented in this study. Thus, the views presented here represent only a small subset of the Canadian death investigation community. It is acknowledged that the perceptions of participating C/MEs may differ from those of nonparticipating C/MEs.

Because C/MEs were asked to informally aggregate information from multiple cases together, recall bias may have been a result, since the most acute, proximal or disturbing cases may be more memorable than others. Similarly, responses may be biased regarding changes over time, as opioid information has recently become plentiful and highly publicized, potentially influencing responses. Personal bias related to interventions and risk factors may have influenced the responses offered; however, professionalism may have mitigated this limitation. Finally, this study is a snapshot of the risk factors and characteristics of those who died at the time when the interviews took place, between December 2017 and February 2018. As circumstances evolve, including the impact of the COVID-19 pandemic on the context surrounding drug toxicity deaths, more research will be needed to shed light on how these contextual risk factors and characteristics may change.

Conclusion

Our study provides the perspectives of C/MEs across Canada on the contextual risk factors and characteristics surrounding deaths from the acute toxic effects of opioids or illegal substances. There is limited pan-Canadian evidence on these factors, and the use of C/MEs to describe this context is not well documented in the literature. C/MEs highlighted the changing epidemic and identified a range of interrelated characteristics and circumstances that appear to be associated with substance-related acute toxicity deaths. These findings offer a national snapshot of the multifaceted factors that surround such deaths, which allows for triangulation with previous analyses that have focussed on a single province or quantitative analyses that included limited factors and contextual description. The themes presented in this study offer a more in-depth understanding of the complex circumstances that contribute to substance-related acute toxicity deaths and can provide insight into targeted prevention and intervention efforts designed to mitigate these events and deaths.

Future research should focus on further collaboration and investigations with C/MEs to advance our understanding of substance-related acute toxicity deaths and inform action in this area. Moreover, further studies should examine the lived and living experiences and perspectives of those most affected by or involved with people who consume opioids or illegal substances. Understanding their experiences and perceptions of what actions could be taken may help to provide a broader picture of the context surrounding an individual's life and address priority information needed to help inform education, awareness and interventions to prevent substance-related acute toxicity events and deaths.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Authors' contributions and statement

JR and JH designed and conceptualized the study and critically revised the paper.

TT conducted interviews, analyzed and interpreted the data and drafted and revised the paper.

JL conducted interviews, analyzed and interpreted the data and critically revised the paper.

JMH, DH, LL and MK were involved in the study design and critically revised the paper.

HO and AE analyzed and interpreted the data, drafted and revised the paper.

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Original quantitative research

Opioid-related deaths in Kingston, Frontenac, Lennox and Addington in Ontario, Canada: the shadow epidemic

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This article has been peer reviewed.

Abstract

Introduction: In the Kingston, Frontenac, Lennox and Addington (KFL&A) health unit, opioid overdoses are an important preventable cause of death. The KFL&A region differs from larger urban centres in its size and culture; the current overdose literature that is focussed on these larger areas is less well suited to aid in understanding the context within which overdoses take place in smaller regions. This study characterized opioid-related mortality in KFL&A, to enhance understanding of opioid overdoses in these smaller communities.

Methods: We analyzed opioid-related deaths that occurred in the KFL&A region between May 2017 and June 2021. Descriptive analyses (number and percentage) were performed on factors conceptually relevant in understanding the issue, including clinical and demographic variables, as well as substances involved, locations of deaths and whether substances were used while alone.

Results: A total of 135 people died of opioid overdose. The mean age was 42 years, and most participants were White (94.8%) and male (71.1%). Decedents often had the following characteristics: being currently or previously incarcerated; using substances alone; not using opioid substitution therapy; and having a prior diagnosis of anxiety and depression.

Conclusion: Specific characteristics such as incarceration, using alone and not using opioid substitution therapy were represented in our sample of people who died of an opioid overdose in the KFL&A region. A robust approach to decreasing opioid-related harm integrating telehealth, technology and progressive policies including providing a safe supply would assist in supporting people who use opioids and in preventing deaths.

Keywords: *opioid overdose, people who use drugs, people who use substances, harm reduction, Ontario*

Highlights

- Opioid-related deaths have been steadily increasing in KFL&A, from fewer than 13 deaths per year before 2016 to 42 deaths in 2020.
- 135 people died of opioid overdose from May 2017 to June 2021. The following characteristics were present in a large proportion of decedents: a history of incarceration, use of opioids while alone, not accessing opioid substitution therapy treatment, and mental health diagnoses or chronic pain.
- To prevent further harm, a robust approach based on evidence gathered from local trends is needed.

Introduction

Opioid-related deaths have been increasing in Canada for over a decade as an ongoing and significant national public health crisis, with overdose deaths the highest ever recorded in the first six months of 2021.[1] Between January 2016 and June 2021 in Canada (the last available data at the time of writing), there were 24 626 deaths, including 1720 deaths between April and June 2021 (19 deaths per day), a 66% increase from the period April to June 2019, and the highest quarterly count ever reported at that time.[1] The reasons for this increase are multifactorial. For one, the COVID-19 pandemic likely played a role in this increase in overdose deaths by creating an increase in toxic drug alteration due to a decrease in supply, as well as reduced capacity or closing of harm reduction sites.[1-3] However, overdose deaths were increasing well before the pandemic, and more inquiry into the factors causing these deaths, and how they can be prevented, is necessary.

Studies from various jurisdictions in Canada point to specific factors as contributing to overdose deaths. For example, using substances while alone is consistently reported as an important risk factor.[4] Other risk factors reported in the literature include living in a rural area, lack of access to take-home naloxone kits and lack of access to opioid agonist therapy.[5-7] Overdose prevention sites (OPS), on the other hand, are an effective strategy to prevent overdose deaths. British Columbia (BC), the frontrunner in implementing OPS, has evaluated them at length, and there is a plethora of evidence supporting their effectiveness in reducing mortality from overdose of substances.[8]

Academic studies of overdose deaths in Ontario are more sparse,[9] and the general

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epidemiology of the opioid crisis in that province, including influencing and protective factors such as those described above, is less well understood than in more studied jurisdictions such as Vancouver. Yet, Ontario was not spared from increasing overdoses: over 1414 people lost their lives to overdose from January to June 2021 (the latest available data at the time of writing).[1] It is thus urgent that we understand the factors specific to this province that contributed to the increase in death rates. For example, in Ontario, the implementation of OPS continues to be controversial, and it is not known whether this is influencing opioid-related deaths.[10,11] There is also less willingness to provide a safe supply to people who use substances.[12,13] In light of the alarming recent increase in opioid-related deaths in Ontario, better understanding of the specific context in this province and inquiry into the factors causing and preventing such deaths is necessary to inform any actions.

The public health systems in Ontario are administered by 34 independent public health units, each with its particular catchment region and population make-up. In the Kingston, Frontenac, Lennox and Addington (KFL&A) public health unit in southeastern Ontario, hospital visit data reflected a record-high number of opioid-related overdoses for late April and early May 2021,[14] and opioid-related deaths have been steadily increasing from 12 cases or fewer per year before 2016 to 42 cases in 2020. The KFL&A region differs from larger urban centres in its size and culture, and the current overdose literature that is focussed on these larger areas is less well suited to enhance understanding of the context within which overdoses take place in regions such as KFL&A. Accordingly, the objective of this study was to describe the population who died of opioid overdose to delineate the local factors driving the overdose crisis in this smaller community.

Methods

Ethics approval

Ethics approval was obtained from Queen's University Research Ethics Board (# 6033165).

Study design

This was a retrospective study of the opioid-related deaths that occurred in KFL&A between 1 May 2017 (the day the Coroner's Opioid Investigative Aid [OIA] was launched) and 30 June 2021 (latest available data at the time of writing).

The OIA is a standardized database of information regarding the circumstances surrounding opioid-related deaths in Ontario. The OIA contains exhaustive information on the decedent and the circumstances around their death. This information is gathered by the investigating coroner using a multitude of sources including health records, toxicology results, and collateral information from family and people present at the time of death.

We analyzed data of people who experienced death caused by opioid overdose as per the OIA, defined as "an acute intoxication/toxicity death resulting from the direct contribution of consumed substance(s), where one or more of the substances was an opioid, regardless of how the opioid was obtained."[3,p.4] Opioid overdose deaths were further stratified as accidental deaths or suicides.

Decedents' data collected for analysis were clinical (comorbid diagnosis), demographic (age, sex, ethnicity, marital status, employment status, history of incarcerations) and location of death (home, public space, correctional facility). We also included other factors that might help explain the increase in opioid-related deaths, including substances involved and whether substances were used alone. The variables were selected based on conceptually relevant variables from the literature, and from discussion with local experts.

Data analysis

Because the objective of this study was to provide a description of the situation related to opioid-related deaths in KFL&A, descriptive analyses were appropriate. Number and percentage were conducted on demographic and clinical characteristics of the population. For transparency, we added missing data as "undetermined." In addition, we performed subanalyses on whether relevant characteristics were changed before and after the beginning of the COVID-19 pandemic. To do so, we considered years prior to 2020 "pre-pandemic" years, and 2020 and 2021 "post-pandemic" years, with deaths pooled into pre- versus post-COVID time periods. Chi-square tests were conducted to determine the significance of any variability between characteristics pre- and post-pandemic. Analyses are presented in text and tables. To prevent identifiability, counts less than 5 have been supressed; we also suppressed some numbers greater than 5 that would permit participant identification of other cells by subtracting. However, we left numbers less than 5 for "undetermined" cells, since there is no risk of identification for this category. All data analyses were verified by a data analyst at Queen's university. All statistical analyses were conducted using R Version 4.0.2 (R Foundation for Statistical Computing, Vienna, AT).

Results

A total of 135 people died of opioid overdoses in the KFL&A health region from May 2017 to June 2021. Of those, 93.3% of deaths were deemed accidental, 5.2% were ruled suicides and the remaining were undetermined. The mean age was 42 years, with people as young as 17 and as old as 78 dying of opioid overdoses. The OIA captures both sex and gender identity, with gender identity being determined with the sources available to the coroner, including interviews with decedents' friends or family. Sex and gender identity were the same for all people who died. The majority (71.1%) of participants were male. The majority of participants (94.8%) were White (note that ethnicity data for other ethnicities are not shown to preserve confidentiality due to small numbers). Most were unemployed at the time of death (59.3%), and only 5.9% had no stable housing. The majority (57.8%) were neither married nor living common-law. Table 1 highlights demographic characteristics of the people who died of opioid overdoses over time.

The majority of people died in a private home (79.3%) and were alone at the time of overdose death (69.3% of known). A total of eight (5.9%) of people died in a correctional facility, while 32 (23.7%) had a prior history of incarceration. Of those, five (15.6%) were released in the four weeks before death. The majority of people (89.4% of known) had used opioids for more than five years. Of the participants with known prior diagnoses gathered by the coroner from medical records, 26.7% had a chronic pain diagnosis, 35.6% were diagnosed with depression and 18.5% were diagnosed with an anxiety disorder. Six (4.4%) people who died

TABLE 1
Summary statistics of people who died of an opioid overdose in KFL&A, by year (2017–2021)

	2017 (n = 21)	2018 (n = 23)	2019 (n = 33)	2020 (n = 42)	2021 (n = 16)	Total (N = 135)
Age (years)						
Mean (SD)	44 (15.5)	44 (12.3)	39 (12.1)	41 (12.5)	43 (13.4)	42 (12.9)
Range	22–78	18–64	25–74	17–67	22–62	17–78
Sex and gender identity						
Female	5 (23.8%)	8 (34.8%)	9 (27.3%)	11 (26.2%)	6 (37.5%)	39 (28.9%)
Male	16 (76.2%)	15 (65.2%)	24 (72.7%)	31 (73.8%)	10 (62.5%)	96 (71.1%)
Marital status						
Married or common-law	[a]	[a]	[a]	[a]	[a]	20 (14.8%)
Not married or common-law	12 (57.1%)	16 (69.6%)	19 (57.6%)	22 (52.4%)	9 (56.2%)	78 (57.8%)
Undetermined	[a]	[a]	[a]	[a]	[a]	37 (27.4%)
Housing						
Housed	21 (100.0%)	16 (69.6%)	25 (75.8%)	39 (92.9%)	14 (87.5%)	115 (85.2%)
No stable housing	[a]	[a]	[a]	[a]	[a]	8 (5.9%)
Correctional facility	[a]	[a]	[a]	[a]	[a]	8 (5.9%)
Undetermined	0 (0.0%)	2 (8.7%)	1 (3.0%)	0 (0.0%)	1 (6.2%)	4 (3.0%)
Employed						
Yes	[a]	[a]	[a]	[a]	[a]	13 (9.6%)
No	12 (57.1%)	17 (73.9%)	19 (57.6%)	26 (61.9%)	6 (37.5%)	80 (59.3%)
Undetermined	[a]	[a]	[a]	[a]	[a]	42 (31.1%)
Location of death						
Private home	17 (81.0%)	18 (78.3%)	25 (75.8%)	34 (81.0%)	13 (81.2%)	107 (79.3%)
Public space	[a]	[a]	[a]	[a]	[a]	9 (6.7%)
Correctional facility	[a]	[a]	[a]	[a]	[a]	8 (5.9%)
Undetermined	2 (9.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.2%)	3 (2.2%)
Used substances alone						
Alone	14 (66.7%)	12 (52.2%)	16 (48.5%)	20 (47.6%)	8 (50.0%)	70 (51.9%)
Others present	[a]	[a]	[a]	[a]	[a]	31 (23.0%)
Undetermined	[a]	[a]	[a]	[a]	[a]	34 (25.2%)
Past incarceration						
Yes	[a]	[a]	[a]	[a]	[a]	32 (23.7%)
No	[a]	[a]	[a]	[a]	[a]	35 (25.9%)
Undetermined	18 (85.7%)	17 (73.9%)	10 (30.3%)	16 (38.1%)	7 (43.8%)	68 (50.4%)
Opioid use disorder diagnosis						
Yes	11 (52.4%)	16 (69.6%)	26 (78.8%)	32 (76.2%)	12 (75.0%)	97 (71.9%)
Undetermined	10 (47.6%)	7 (30.4%)	7 (21.2%)	10 (23.8%)	4 (25.0%)	38 (28.1%)
Previous overdose						
Yes	[a]	[a]	5 (15.2%)	9 (21.4%)	[a]	23 (17.0%)
No	[a]	[a]	28 (84.8%)	33 (78.6%)	13 (81.2%)	91 (67.4%)
Undetermined	15 (71.4%)	[a]	[a]	[a]	[a]	21 (15.6%)
Duration of substance use						
< 5 years	[a]	[a]	[a]	[a]	[a]	7 (5.2%)
> 5 years	11 (52.4%)	8 (34.8%)	13 (39.4%)	20 (47.6%)	7 (43.8%)	59 (43.7%)
Undetermined	[a]	[a]	[a]	[a]	[a]	69 (51.1%)

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TABLE 1 (continued)
Summary statistics of people who died of an opioid overdose in KFL&A, by year (2017–2021)

	2017 (n = 21)	2018 (n = 23)	2019 (n = 33)	2020 (n = 42)	2021 (n = 16)	Total (N = 135)
Chronic pain						
Yes	[a]	[a]	[a]	[a]	[a]	36 (26.7%)
No	13 (61.9%)	12 (52.2%)	23 (69.7%)	33 (78.6%)	13 (81.2%)	94 (69.6%)
Undetermined	[a]	[a]	[a]	[a]	[a]	5 (3.7%)
Depression						
Yes	8 (38.1%)	11 (47.8%)	12 (36.4%)	10 (23.8%)	7 (43.8%)	48 (35.6%)
No	10 (47.6%)	10 (43.5%)	21 (63.6%)	32 (76.2%)	8 (50.0%)	81 (60.0%)
Undetermined	3 (14.3%)	2 (8.7%)	0 (0.0%)	0 (0.0%)	1 (6.2%)	6 (4.4%)
Anxiety disorder						
Yes	[a]	[a]	8 (24.2%)	8 (19.0%)	[a]	25 (18.5%)
No	[a]	[a]	25 (75.8%)	34 (81.0%)	11 (68.8%)	88 (65.2%)
Undetermined	16 (76.2%)	[a]	0 (0.0%)	0 (0.0%)	[a]	22 (16.3%)
Schizophrenia						
Yes	[a]	[a]	[a]	[a]	[a]	10 (7.4%)
No	16 (76.2%)	20 (87.0%)	30 (90.9%)	39 (92.9%)	13 (81.2%)	118 (87.4%)
Undetermined	[a]	[a]	[a]	[a]	[a]	7 (5.2%)
Bipolar disorder						
Yes	[a]	[a]	[a]	[a]	[a]	10 (7.4%)
No	16 (76.2%)	20 (87.0%)	31 (93.9%)	39 (92.9%)	12 (75.0%)	118 (87.4%)
Undetermined	[a]	[a]	[a]	[a]	[a]	7 (5.2%)
Naloxone used						
Yes	[a]	[a]	10 (30.3%)	17 (40.5%)	5 (31.2%)	42 (31.1%)
No	16 (76.2%)	14 (60.9%)	15 (45.5%)	18 (42.9%)	8 (50.0%)	71 (52.6%)
Undetermined	[a]	[a]	8 (24.2%)	7 (16.7%)	3 (18.8%)	22 (16.3%)

Data source: Opioid Investigative Aid.

Abbreviations: KFL&A, Kingston, Frontenac, Lennox and Addington region; SD, standard deviation.

Notes: Percentages were calculated by column for each variable.
Sex and gender identity were the same for all people who died.

[a] Suppressed to prevent participant identification.

were known to have previously attempted suicide.

All decedents received the same toxicology screening. Fentanyl and carfentanil were the most common opioids causing death (n = 103, 76.3%). Seventy (51.9%) people also used methamphetamines, and the use of methamphetamines increased significantly in 2019 and 2020 when compared to previous years. Nearly one-fifth (28, 20.7%) had cocaine in their blood at the time of death, and the number of people with cocaine in their blood at the time of death was highest in 2020 compared to previous years. Benzodiazepine, hydromorphone and oxycodone were present in the blood of less than 15% of people. Few people had naloxone, buprenorphine or methadone in their blood at time of death. Table 2 describes the toxicology results over time.

Interestingly, there were no differences in characteristics for the pre- and post-COVID-19 pandemic years, including in whether substances were used alone (p = 0.762). There were also no differences in whether decedents had opioid substitution therapy (OST) in their blood at time of death (p = 0.086). Tables 3 and 4 present the pre-and post-pandemic results.

Discussion

In this study, we describe the characteristics of people who died of opioid overdoses in KFL&A, and the circumstances surrounding their deaths. A large proportion of people who died of opioid overdoses had a history of incarceration. This issue is particularly important for Kingston, as the region hosts four prisons, and over 2000 prisoners use Kingston health services. Numerous studies have identified a high risk of opioid overdose in the 14-day period following discharge from prison, and the substance-related mortality rate for prisoners and ex-prisoners is 32 times higher than in the age- and sex-matched general population.[15-17] In light of the relatively high number of deaths both in prison and upon release, strategies to address this vulnerable population are urgently needed. High-quality studies have already suggested approaches for addressing opioid overdoses in incarcerated populations and those newly released from jail, including robust OST programs,

TABLE 2
Toxicology findings, by year (2017–2021)

	2017 (n = 21)	2018 (n = 23)	2019 (n = 33)	2020 (n = 42)	2021 (n = 16)	Total (N = 135)
Fentanyl and carfentanil						
Yes	13 (61.9%)	14 (60.9%)	26 (78.8%)	37 (88.1%)	13 (81.2%)	103 (76.3%)
No	8 (38.1%)	9 (39.1%)	7 (21.2%)	[a]	[a]	30 (22.2%)
Undetermined	[a]	[a]	[a]	[a]	[a]	2 (1.5%)
Morphine						
Yes	7 (33.3%)	6 (26.1%)	5 (15.2%)	[a]	[a]	23 (17.0%)
No	14 (66.7%)	17 (73.9%)	28 (84.8%)	38 (90.5%)	13 (81.2%)	110 (81.5%)
Undetermined	[a]	[a]	[a]	[a]	[a]	2 (1.5%)
Hydromorphone						
Yes	[a]	6 (26.1%)	5 (15.2%)	[a]	[a]	17 (12.6%)
No	17 (81.0%)	17 (73.9%)	28 (84.8%)	41 (97.6%)	13 (81.2%)	116 (85.9%)
Undetermined	[a]	[a]	[a]	[a]	[a]	2 (1.5%)
Oxycodone						
Yes	[a]	[a]	[a]	[a]	[a]	12 (8.9%)
No	17 (81.0%)	20 (87.0%)	29 (87.9%)	41 (97.6%)	14 (87.5%)	121 (89.6%)
Undetermined	[a]	[a]	[a]	[a]	[a]	2 (1.5%)
Methamphetamine						
Yes	9 (42.9%)	7 (30.4%)	20 (60.6%)	26 (61.9%)	8 (50.0%)	70 (51.9%)
No	12 (57.1%)	16 (69.6%)	13 (39.4%)	16 (38.1%)	6 (37.5%)	63 (46.7%)
Undetermined	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (12.5%)	2 (1.5%)
Cocaine						
Yes	5 (23.8%)	[a]	[a]	15 (35.7%)	[a]	28 (20.7%)
No	16 (76.2%)	20 (87.0%)	29 (87.9%)	27 (64.3%)	13 (81.2%)	105 (77.8%)
Undetermined	[a]	[a]	[a]	[a]	[a]	2 (1.5%)
Benzodiazepine						
Yes	5 (23.8%)	[a]	[a]	[a]	[a]	13 (9.6%)
No	16 (76.2%)	22 (95.7%)	30 (90.9%)	38 (90.5%)	14 (87.5%)	120 (88.9%)
Undetermined	[a]	[a]	[a]	[a]	[a]	2 (1.5%)
Naloxone						
Yes	[a]	[a]	[a]	[a]	[a]	2 (1.5%)
No	20 (95.2%)	23 (100.0%)	33 (100.0%)	41 (97.6%)	14 (87.5%)	131 (97.0%)
Undetermined	[a]	[a]	[a]	[a]	[a]	2 (1.5%)
OST (methadone, buprenorphine)						
Yes	[a]	[a]	[a]	[a]	[a]	17 (12.6%)
No	18 (85.7%)	21 (91.3%)	31 (93.9%)	35 (83.3%)	11 (68.8%)	116 (85.9%)
Undetermined	[a]	[a]	[a]	[a]	[a]	2 (1.5%)

Data source: Opioid Investigative Aid.

Abbreviation: OST, opioid substitution therapy.

Note: Percentages were calculated by column for each variable.

[a] Suppressed either due to small numbers or to prevent participant identification.

access to naloxone and linkage to care upon release; lessons from these studies can be implemented in Kingston correctional facilities.[15,16]

In KFL&A, the majority of people died in a private home and were alone at the time of overdose. This is consistent with the trend in Ontario as a whole and in BC.[3,18,19] It is well known that using substances alone is a significant risk factor for overdose death, due to the unavailability of someone else to administer naloxone, provide CPR and call emergency services. Interestingly, in our study, the COVID-19 pandemic had no influence on whether people who died of opioid overdoses used alone. There is minimal research on the social and structural conditions that influence individuals to use substances alone, but the existing (though scarce) evidence

TABLE 3
Comparisons of decedents' characteristics pre- and post-pandemic

	Pre-pandemic (n = 77)	Post-pandemic (n = 58)	Total (N = 135)	*p* value
Age (years)				
Mean (SD)	42 (13.2)	42 (12.6)	42 (12.9)	0.936
Range	18–78	17–67	17–78	
Sex and gender identity				
Female	22 (28.6%)	17 (29.3%)	39 (28.9%)	0.925
Male	55 (71.4%)	41 (70.7%)	96 (71.1%)	
Marital status				
Married or common-law	13 (16.9%)	7 (12.1%)	20 (14.8%)	0.259
Not married or common-law	47 (61.0%)	31 (53.4%)	78 (57.8%)	
Undetermined	17 (22.1%)	20 (34.5%)	37 (27.4%)	
Housing				
Housed	62 (80.5%)	53 (91.4%)	115 (85.2%)	0.250
No stable housing	[a]	[a]	8 (5.9%)	
Correctional facility	[a]	[a]	8 (5.9%)	
Undetermined	3 (3.9%)	1 (1.7%)	4 (3.0%)	
Employed				
Yes	6 (7.8%)	7 (12.1%)	13 (9.6%)	0.605
No	48 (62.3%)	32 (55.2%)	80 (59.3%)	
Undetermined	23 (29.9%)	19 (32.8%)	42 (31.1%)	
Location of death				
Private home	60 (77.9%)	47 (81.0%)	107 (79.3%)	0.422
Public space	[a]	[a]	9 (6.7%)	
Correctional facility	[a]	[a]	8 (5.9%)	
Other	1 (1.3%)	3 (5.2%)	4 (3.0%)	
Undetermined	2 (2.6%)	1 (1.7%)	3 (2.2%)	
Used substances alone				
Alone	42 (54.5%)	28 (48.3%)	70 (51.9%)	0.762
Others present	17 (22.1%)	14 (24.1%)	31 (23.0%)	
Undetermined	18 (23.4%)	16 (27.6%)	34 (25.2%)	
Past incarceration				
Yes	16 (20.8%)	16 (27.6%)	32 (23.7%)	0.091
No	16 (20.8%)	19 (32.8%)	35 (25.9%)	
Undetermined	45 (58.4%)	23 (39.7%)	68 (50.4%)	
Opioid use disorder diagnosis				
Yes	53 (68.8%)	44 (75.9%)	97 (71.9%)	0.369
Undetermined	24 (31.2%)	14 (24.1%)	38 (28.1%)	
Previous overdose				
Yes	12 (15.6%)	11 (19.0%)	23 (17.0%)	< 0.001
No	45 (58.4%)	46 (79.3%)	91 (67.4%)	
Undetermined	20 (26.0%)	1 (1.7%)	21 (15.6%)	
Duration of substance use				
< 5 years	[a]	[a]	7 (5.2%)	0.193
> 5 years	32 (41.6%)	27 (46.6%)	59 (43.7%)	
Undetermined	[a]	[a]	69 (51.1%)	

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TABLE 3 (continued)
Comparisons of decedents' characteristics pre- and post-pandemic

	Pre-pandemic (n = 77)	Post-pandemic (n = 58)	Total (N = 135)	*p* value
Chronic pain				
Yes	25 (32.5%)	11 (19.0%)	36 (26.7%)	
No	48 (62.3%)	46 (79.3%)	94 (69.6%)	0.095
Undetermined	4 (5.2%)	1 (1.7%)	5 (3.7%)	
Depression				
Yes	31 (40.3%)	17 (29.3%)	48 (35.6%)	
No	41 (53.2%)	40 (69.0%)	81 (60.0%)	0.124
Undetermined	5 (6.5%)	1 (1.7%)	6 (4.4%)	
Anxiety disorder				
Yes	13 (16.9%)	12 (20.7%)	25 (18.5%)	
No	43 (55.8%)	45 (77.6%)	88 (65.2%)	< 0.001
Undetermined	21 (27.3%)	1 (1.7%)	22 (16.3%)	
Schizophrenia				
Yes	5 (6.5%)	5 (8.6%)	10 (7.4%)	
No	66 (85.7%)	52 (89.7%)	118 (87.4%)	0.271
Undetermined	6 (7.8%)	1 (1.7%)	7 (5.2%)	
Bipolar				
Yes	[a]	[a]	10 (7.4%)	
No	67 (87.0%)	51 (87.9%)	118 (87.4%)	0.171
Undetermined	[a]	[a]	7 (100.0%)	

Data source: Opioid Investigative Aid.

Abbreviation: SD, standard deviation.

Notes: Percentages were calculated by column for each variable.
Sex and gender identity were the same for all people who died.
Pre-pandemic refers to 2019 and earlier. Post-pandemic refers to 2020 and 2021.

[a] Suppressed either due to small numbers or to prevent participant identification.

points to motivations such as hiding one's substance use from others for fear of being stigmatized, fear of criminalization and unwillingness to share due to limited resources.[20] In our study, there were no differences in characteristics of people who died while using alone versus those who had someone present when they died, including in terms of age, sex, or year or location of death (data not shown). Qualitative studies are needed to elucidate the motivations behind using substances alone for people who use substances but do not access harm reduction services in the KFL&A health region.

In our study, less than 13% of decedents had OST in their blood at time of death, and there was no difference in OST use before or after the COVID-19 pandemic. Optimistically, this could mean that people who use OST do not die of opioid overdoses. Alternatively, this could indicate that there is limited access to OST in the KFL&A region. More investigation is needed to elucidate OST access and barriers in the KFL&A region.

In our study, the main substances found in the toxicity screen were fentanyl, carfentanil and methamphetamines, with fentanyl and carfentanil causing the highest number of deaths. The greatest number of deaths of people with a combination of fentanyl, carfentanil and methamphetamines in their blood occurred in 2020. This is consistent with the rest of Ontario, and with other jurisdictions such as BC, which also noted an increase in the number of people who had used opioids and methamphetamines around the time of death.[19,21]

The rise in fentanyl and methamphetamine use is correlated with a similar rise in overdose deaths. While we acknowledge that correlation does not necessarily imply causation, this is nonetheless an intriguing trend. While the co-use of opioids and methamphetamines at the same time (or in immediate succession) is an increasing trend among people who use substances,[22,23] the unpredictability of the supply means we cannot truly ascertain if the multiple substances detected at the time of death were taken simultaneously or sequentially or simply were all contained within a single substance consumed at the time of death.

There is room for future studies, ideally qualitative in nature, to explore whether people who use substances are aware of the nature of the substances they are taking, as well as to explore the motivations leading people to co-use opioids and methamphetamines, and the mechanism by which the use of both substances might lead to an increased susceptibility to overdose death. While understanding this pattern of use may not stop deaths in the near term, such studies may gather evidence to target harm reduction and education programs to prevent harms that arise from polysubstance use.

TABLE 4
Toxicology findings pre- and post-pandemic

	Pre-pandemic (n = 77)	Post-pandemic (n = 58)	Total (N = 135)	*p* value
Fentanyl and carfentanil				
Yes	53 (68.8%)	50 (86.2%)	103 (76.3%)	
No	24 (31.2%)	6 (10.3%)	30 (22.2%)	0.005
Undetermined	0 (0.0%)	2 (3.4%)	2 (1.5%)	
Morphine				
Yes	18 (23.4%)	5 (8.6%)	23 (17.0%)	
No	59 (76.6%)	51 (87.9%)	110 (81.5%)	0.025
Undetermined	0 (0.0%)	2 (3.4%)	2 (1.5%)	
Hydromorphone				
Yes	[a]	[a]	17 (12.6%)	
No	62 (80.5%)	54 (93.1%)	116 (85.9%)	0.007
Undetermined	[a]	[a]	2 (1.5%)	
Oxycodone				
Yes	[a]	[a]	12 (8.9%)	
No	66 (85.7%)	55 (94.8%)	121 (89.6%)	0.012
Undetermined	[a]	[a]	2 (1.5%)	
Methamphetamine				
Yes	36 (46.8%)	34 (58.6%)	70 (51.9%)	
No	41 (53.2%)	22 (37.9%)	63 (46.7%)	0.074
Undetermined	0 (0.0%)	2 (3.4%)	2 (1.5%)	
Cocaine				
Yes	12 (15.6%)	16 (27.6%)	28 (20.7%)	
No	65 (84.4%)	40 (69.0%)	105 (77.8%)	0.051
Undetermined	0 (0.0%)	2 (3.4%)	2 (1.5%)	
Benzodiazepine				
Yes	[a]	[a]	13 (9.6%)	
No	68 (88.3%)	52 (89.7%)	120 (88.9%)	0.178
Undetermined	[a]	[a]	2 (1.5%)	
Naloxone				
Yes	[a]	[a]	2 (1.5%)	
No	76 (98.7%)	55 (94.8%)	131 (97.0%)	0.253
Undetermined	[a]	[a]	2 (1.5%)	
OST (methadone, buprenorphine)				
Yes	7 (9.1%)	10 (17.2%)	17 (12.6%)	
No	70 (90.9%)	46 (79.3%)	116 (85.9%)	0.086
Undetermined	0 (0.0%)	2 (3.4%)	2 (1.5%)	

Data source: Opioid Investigative Aid.

Abbreviation: OST, opioid substitution therapy.

Notes: Percentages were calculated by column for each variable.
Pre-pandemic refers to 2019 and earlier. Post-pandemic refers to 2020 and 2021.

[a] Suppressed either due to small numbers or to prevent participant identification.

Our toxicology results indicate that most of the substances in decedents' blood at the time of death were obtained from street supply as opposed to prescribed medications. This opens the question as to whether decedents died due to a toxic or unpredictable supply, since most of the deaths were accidental. It is well known that offering people who use substances a safe supply has a tremendous impact on reducing the number of lives lost to opioid overdoses and on promoting safe injection patterns.[22-36] Other jurisdictions, such as BC, Switzerland and the Netherlands, offer prescription opioids as part of a harm reduction approach.[30] While some bigger urban centres in Ontario have programs

that offer safe supply to people who use substances,[37] these programs may not be available to people living in smaller and rural communities. Telehealth may prove an excellent tool to increase access to these programs for people living in smaller communities. In the longer term, implementing progressive policies such as decriminalizing or legalizing substances would support a safe substance supply. While we acknowledge that substance decriminalization and legalization is a bigger discussion that is beyond the scope of this paper, it is worth reflecting on how such policies may support people who use substances in using safely, and thus decrease the burden of morbidity and mortality associated with opioid use on society as a whole.

Strengths and limitations

This study paints an important and much needed picture of overdose-related deaths in a smaller region in southeastern Ontario, and reports foundational issues that future studies can further explore. However, it also has some limitations. First, the study used administrative data, and some variables had missing data. On the other hand, the OIA captured all suspected opioid-related deaths, and is unlikely to have missed a case, since a coroner must attend all deaths that are sudden, unnatural or not the result of an illness treated by a doctor. Second, the study period ended in June 2021; therefore, we did not capture more recent trends in opioid-related deaths in the region. In addition, 2017 and 2021 were not full years of data, which may have impacted results, including the results of the pre- and post-COVID-19 pandemic subanalyses, and our findings should be interpreted with this limitation in mind. Third, as with any administrative dataset, some of the variables may have been inappropriately coded. Fourth, since there was no control group, it was not possible to determine odds or risk ratio.

Conclusion

This study highlighted at-risk groups for opioid-related deaths based on trends gathered from the analysis of the OIA database. People who had been incarcerated and people using alone were some of the most represented groups, and interventions to better support these two populations may contribute to reducing the number of opioid-related deaths in the KFL&A region. A robust approach to reducing opioid-related harm integrating telehealth, technology and progressive policies decriminalizing substance use would go a long way in supporting people who use opioids and in preventing deaths.

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Conflicts of interest

The authors declare no conflicts of interest.

Authors' contributions and statement

SP conceptualized and designed the study, interpreted and analyzed the data and drafted the manuscript; SB conceptualized the study, provided contributions and critically revised the manuscript; JP conceptualized the study, provided contributions and critically revised the manuscript; KM conceptualized the study.

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Original quantitative research

Examining the use of decision trees in population health surveillance research: an application to youth mental health survey data in the COMPASS study

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Abstract

Introduction: In population health surveillance research, survey data are commonly analyzed using regression methods; however, these methods have limited ability to examine complex relationships. In contrast, decision tree models are ideally suited for segmenting populations and examining complex interactions among factors, and their use within health research is growing. This article provides a methodological overview of decision trees and their application to youth mental health survey data.

Methods: The performance of two popular decision tree techniques, the classification and regression tree (CART) and conditional inference tree (CTREE) techniques, is compared to traditional linear and logistic regression models through an application to youth mental health outcomes in the COMPASS study. Data were collected from 74 501 students across 136 schools in Canada. Anxiety, depression and psychosocial well-being outcomes were measured along with 23 sociodemographic and health behaviour predictors. Model performance was assessed using measures of prediction accuracy, parsimony and relative variable importance.

Results: Decision tree and regression models consistently identified the same sets of most important predictors for each outcome, indicating a general level of agreement between methods. Tree models had lower prediction accuracy but were more parsimonious and placed greater relative importance on key differentiating factors.

Conclusion: Decision trees provide a means of identifying high-risk subgroups to whom prevention and intervention efforts can be targeted, making them a useful tool to address research questions that cannot be answered by traditional regression methods.

Keywords: *decision trees, population health, survey methods, mental health, youth*

Highlights

- Decision trees can be used within population health research to address important research questions that cannot be answered by traditional regression methods.
- A key advantage of decision trees over regression models is the ability to examine complex interactions among risk factors.
- Decision trees can be used to identify high-risk groups to whom prevention and intervention efforts can be targeted.
- While regression models may have higher prediction accuracy in some settings, decision trees place greater emphasis on key differentiating factors.

Introduction

Population health surveillance research is often carried out using large-scale survey studies that attempt to assess the impacts of wide-ranging social, economic and environmental factors on various health outcomes. The relationship between these factors and health outcomes is often characterized by complex interactions that make it impractical to identify any single factor as causal. In the context of youth mental health, outcomes have previously been associated with socioeconomic status,[1] weight status,[2] dietary behaviours,[3] physical activity and sedentary behaviours,[4] sleep habits,[5] cannabis use,[6] bullying,[7] school connectedness[8,9] and peer and family relationships,[10,11] among other factors. However, most research studies focus on examining the impact of any given factor or domain of factors in isolation; in reality, the underlying interrelationships are likely more complex.

Associations are often examined using regression models, which estimate the association between a predictor and an outcome while controlling for other factors. However, these models are rarely used to estimate complex interactions between factors, due to computational limitations and difficulty in interpretation. Additionally, the resulting model estimates do not

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allow for the development of risk profiles, that is, separating subjects into subgroups based on certain combinations of risk factors. The identification of high-risk subgroups is important to efficiently target resources and interventions. Decision trees comprise a different class of models that are ideally suited for segmenting populations and examining complex interactions among factors.[12]

Decision trees are commonly used in clinical research that focusses on screening and diagnostics,[13] with emphasis on prediction. Decision trees are less common in population health research, where the focus is on understanding associations and identifying subgroups for targeting behavioural interventions, though their use is increasing. Within the domain of mental health, recent studies using decision trees have primarily examined associations with depression[14-19] and suicide risk.[15,20-28]

Two studies examined depression outcomes in youth populations specifically. Hill et al.[16] found that, among students with subclinical depressive symptoms at baseline, friend support was protective against developing major depressive disorder by age 30, with anxiety disorder and substance use disorder increasing risk among those without friend support. Seeley, Stice and Rohde[18] found poor school functioning to be a primary risk factor for major depressive disorder onset among girls with elevated depressive symptoms at baseline, with parental support acting as a protective factor only among girls with low levels of baseline depressive symptoms. Three studies examined suicide ideation in youth populations and found that mediating factors such as family relationships[22,26] and social support[22,24] were only protective among students that did not have high levels of depression.

Among the studies mentioned above, few included direct performance comparisons between tree and regression methods. Smaller studies by Burke et al.,[21] Mitsui et al.[15] and Handley et al.[27] found regression models had higher predictive accuracy than corresponding tree models; however, these studies had small sample sizes (ranging from 359 to 2194 participants). Conversely, two larger studies—one by Dykxhoorn et al.[23] examining a longitudinal sample of 11 088 children, and another by Batterham et al.[17] examining a longitudinal study of 6605 adults—found decision trees to outperform corresponding logistic regression in terms of sensitivity and overall predictive accuracy. Thus, while there is some evidence to suggest that decision trees may have advantages over traditional regression methods in the case of larger sample sizes, there is an overall lack of available evidence within the domain of mental health.

Despite growing use of decision trees, regression models remain commonplace in the population health literature. This results in a missed opportunity to understand the complex interactions among risk factors and to identify high-risk subgroups to which prevention and intervention efforts can be targeted. The aim of this study was therefore to examine the use of decision trees in the analysis of large-scale population health surveillance data. In this paper, we first provide an overview of two popular types of decision tree, the classification and regression tree (CART) and the conditional inference tree (CTREE) techniques. Next, the performance of decision tree models is compared to traditional linear and logistic regression models through an application to youth mental health outcomes in the COMPASS study.[29] Tree and regression methods are evaluated based on prediction accuracy and parsimony, with additional considerations given to relative variable importance and model interpretability.

Methods

Background on decision trees

Decision trees are statistical models that examine an outcome of interest by partitioning the sample into distinct subgroups based on predictor variables. The subgroups are determined using a series of binary splits that resemble a tree structure. Various types of decision tree algorithms have been developed;[30] this analysis focusses on two popular types of decision tree: CART and CTREE. Methodological overviews of CART and CTREE in the context of epidemiological research have been previously published;[12,13] a summary of important features follows.

Classification and regression trees

CART is a widely used class of decision tree for categorical (classification) and continuous (regression) outcomes. Originally developed by Breiman et al.,[31] CART methods find optimal splits of the sample into subgroups[32] such that subjects within a subgroup are similar and subjects across subgroups are as different as possible. Optimal splits are determined by recursively choosing the variables and cut-off levels that produce maximum separation among subgroups and minimal within-group variability with respect to the outcome.[32] Continuous and categorical variables may be split multiple times throughout the tree on different cut-points. Splitting occurs until a stopping rule is reached, typically based on minimum subgroup size.[12,32,33] Through this recursive process, the predictor space is divided into a final set of subgroups, for which the mean outcome value (regression trees) or the percent of the subgroup having the outcome (classification trees) is calculated.[33]

A large tree grown by recursively splitting the predictor space tends to overfit the sample data, resulting in poor generalizability. Overfitting is mitigated using tree pruning and a cross-validation procedure, in which the large tree is pruned leading to a sequence of nested subtrees from among which an optimal tree is selected. The most commonly used pruning method is cost complexity pruning, in which an increasing sequence of complexity parameters corresponds to a sequence of nested subtrees with decreasing sizes.[33,34] The optimal subtree that minimizes the average error based on cross-validation[33] is then chosen. When working with larger samples, the "1-SE" rule is often used to choose the smallest subtree that has an average error within one standard deviation of the overall minimum error.[12,13]

Conditional inference trees

CTREE is an alternative to CART developed by Hothorn et al.[35] While CART chooses the optimal split at each step among all potential variable and splitting points simultaneously, CTREE separates the splitting determination into two steps. First, the optimal variable to split on is chosen based on the strongest association to the outcome. Association to the outcome variable is measured using regression models appropriate for the outcome, for example, linear regression for continuous outcomes and logistic regression for binary outcomes.[12,35] The covariate with the smallest p value is chosen for splitting. Second, the optimal splitting point for that variable is determined.[12,35] This approach mitigates the selection bias

toward variables with many splitting points often found in CART.[12,35] This splitting process continues recursively among each subgroup until a stopping rule is reached. As with CART, continuous and categorical variables can be split more than once throughout the tree at different cut-points.

The stopping rule for CTREE is based on a global null hypothesis: the algorithm stops splitting when no covariates have a significant association to the outcome based on a prespecified significance level (alpha; α).[12,35] For large samples, additional stopping criteria based on minimum subgroup sizes can also be used. No pruning is required in CTREE; the global test for significance acts as a means to prevent overfitting.[12,35]

Application

The relative performance of decision trees and regression methods was compared in the context of population surveillance research using youth mental health data from the COMPASS study.[29]

Ethics approval, study design and sample

COMPASS is a prospective cohort study designed to collect hierarchical health data from Canadian secondary school students.[29] COMPASS has received ethics clearance from the University of Waterloo Research Ethics Board (ORE 30118). Additional details about the COMPASS host study are available in print[29] and online (https://uwaterloo.ca/compass-system).

We used student-level data from Year 7 (2018/19) of the COMPASS study. The sample consists of 74 501 students from 136 schools in Ontario (61 schools), Alberta (8 schools), British Columbia (15 schools) and Quebec (52 schools). COMPASS uses purposeful sampling to recruit whole-school samples based on their use of active-information, passive-consent parental permission protocols. The participation rate for 2018/19 was 81.9%, with the primary reason for nonparticipation being absenteeism or scheduled spare on the data collection date.

Measures

The COMPASS student questionnaire is a paper-based questionnaire completed by students during class time. The questionnaire is anonymous and self-administered, and students may decline to participate at any time. This study examined 5 mental health outcome measures related to depression, anxiety and psychosocial well-being (flourishing), as well as 23 core predictor measures related to demographics, body weight, healthy eating, movement behaviours, substance use, bullying, academics and school support, and perceived family and friend support.

Mental health outcomes

Depression

Depression is measured using the Center for Epidemiologic Studies Depression 10-item scale (CESD-10),[36,37] which has been validated in adolescent populations.[38] The CESD-10 is measured as a continuous score ranging from 0 to 30, with higher scores indicating greater degrees of depressive symptomatology and risk of unipolar depression. An additional binary measure of depression is used, with students scoring greater than or equal to 10 classified as having clinically relevant depressive symptoms.

Anxiety

Anxiety is measured using the Generalized Anxiety Disorder 7-item Scale (GAD-7),[39] which has been validated in adolescent populations.[40] The GAD-7 is measured as a continuous score ranging from 0 to 21, with higher scores indicating greater levels of anxiety. An additional binary measure of anxiety is used, with students scoring greater than or equal to 10 classified as having clinically relevant anxiety symptoms.

Flourishing

Flourishing is a component of psychological well-being and is measured using a modified version of Diener's Flourishing Scale (FS),[41] which has been validated in young adults.[42] The FS is a continuous score ranging from 8 to 40, with higher scores indicating greater levels of flourishing.

Predictor variables

Demographic predictor variables include age, sex, ethnicity and weekly spending money (a proxy for socioeconomic status). Body weight is measured using weight perception and body mass index (BMI) classification. Healthy eating is measured using a binary indicator of whether students eat breakfast daily, as well as the number of servings of fruits and vegetables consumed daily. Movement behaviours are assessed using minutes of average daily moderate-to-vigorous physical activity (MVPA), minutes of total daily screen time and daily minutes of sleep. Substance use is measured using binary indicators of past-month use of tobacco, e-cigarettes and cannabis, as well as past-month binge drinking. Bullying is measured using two indicators: whether a student was bullied or had bullied others in the past 30 days. Academics and school support are measured using a binary indicator of whether students expect to attend a postsecondary institution, the number of classes skipped in the past four weeks and a continuous school connectedness score (with higher scores indicating higher levels of connection to school). Perceived family and friend support are measured using binary indicators of having a happy home life, feeling able to talk about problems with family and feeling able to talk about problems with friends.

In addition to the student-level measures, additional school-level predictors include total school enrolment, province, school area median income and school urbanicity. Measures of income and urbanicity are taken from Statistics Canada's 2016 census and values linked by school forward sortation area.[43,44]

Analysis

Individual mental health scale items were person-mean imputed for students missing one or two items. While mean imputation may artificially reduce variance, more complex imputation methods were not used given the primary focus of the analysis on performance rather than inference. Students with missing or outlier values on any variables were removed, resulting in a final complete case sample of 52 350 students. Sample characteristics are provided in Table 1. The sample was randomly split into training (41 795; 80%) and test (10 555; 20%) samples.

CART and CTREE were run for continuous (CESD-10, GAD-7, FS) and binary outcomes (depression, anxiety). CART pruning was performed using 10-fold cross-validation and the 1-SE rule. CTREE significance was set at $\alpha = 0.05$ with a Bonferroni adjustment for multiple testing. Given the large sample size, an additional stopping rule was included for both CART and CTREE to limit the minimum number of observations per bucket to 1% of the sample. Linear and logistic regression models were also run for continuous and binary outcomes including all main effects. Backward variable selection using the Akaike information criterion (AIC) was performed to mimic tree pruning.

TABLE 1
COMPASS Year 7 (2018/19) student sample characteristics

Category	Variable	Levels	n	%
Total			**52 350**	**100.0%**
Mental health outcomes	CESD-10 scale	Mean (SD)	8.50 (5.85)	
	GAD-7 scale	Mean (SD)	6.02 (5.31)	
	Flourishing scale	Mean (SD)	32.42 (5.39)	
	Depression	No	33 778	64.5%
		Yes	18 572	35.5%
	Anxiety	No	40 568	77.5%
		Yes	11 782	22.5%
Demographic factors	Sex	Female	27 483	52.5%
		Male	24 867	47.5%
	Age (years)	12	2 310	4.4%
		13	4 564	8.7%
		14	10 282	19.6%
		15	12 221	23.3%
		16	12 198	23.3%
		17	8 628	16.5%
		18	2 147	4.1%
	Ethnicity	White	37 370	71.4%
		Black	1 565	3.0%
		Asian	5 559	10.6%
		Latin American	1 235	2.4%
		Other/multi	6 621	12.6%
	Spending money	$0	8 099	15.5%
		$1–$20	12 701	24.3%
		$21–$40	5 796	11.1%
		$41–$100	6 469	12.4%
		More than $100	10 067	19.2%
		Don't know	9 218	17.6%
	Province	Alberta	2 222	4.2%
		British Columbia	7 298	13.9%
		Ontario	20 450	39.1%
		Quebec	22 380	42.8%
	Urbanicity	Large urban	28 684	54.8%
		Medium urban	5 044	9.6%
		Small urban/rural	18 622	35.6%
	School median income (in thousands CAD)	Mean (SD)	67.33 (17.47)	
	School size (in hundreds of students)	Mean (SD)	8.49 (3.52)	

Continued on the following page

TABLE 1 (continued)
COMPASS Year 7 (2018/19) student sample characteristics

Category	Variable	Levels	n	%
Body weight and eating behaviours	Weight perception	Underweight	8 300	15.9%
		About the right weight	31 877	60.9%
		Overweight/obese	12 173	23.3%
	BMI classification	Underweight	985	1.9%
		Normal weight	29 932	57.2%
		Overweight	6 465	12.3%
		Obese	2 843	5.4%
		Not stated	12 125	23.2%
	Eat breakfast daily	No	25 373	48.5%
		Yes	26 977	51.5%
	Servings of fruits and vegetables	Mean (SD)	2.98 (1.93)	
Movement behaviours	Average daily physical activity (min)	Mean (SD)	96.40 (62.14)	
	Screen time (min)	Mean (SD)	350.97 (178.28)	
	Sleep time (min)	Mean (SD)	451.94 (74.78)	
Current substance use	Tobacco use	No	49 349	94.3%
		Yes	3 001	5.7%
	E-cigarette use	No	38 570	73.7%
		Yes	13 780	26.3%
	Binge drinking	No	44 020	84.1%
		Yes	8 330	15.9%
	Cannabis use	No	46 683	89.2%
		Yes	5 667	10.8%
Bullying in the last 30 days	Was bullied	No	46 412	88.7%
		Yes	5 938	11.3%
	Bullied others	No	49 702	94.9%
		Yes	2 648	5.1%
Academics and school support	Expect to attend postsecondary institution	No	12 380	23.6%
		Yes	39 970	76.4%
	Classes skipped in past 4 weeks	0 classes	34 894	66.7%
		1 or 2 classes	10 634	20.3%
		3 to 5 classes	4 246	8.1%
		6 or more classes	2 576	4.9%
	School connectedness score	Mean (SD)	18.67 (3.14)	
Family and peer support	Happy home life	No	10 219	19.5%
		Yes	42 131	80.5%
	Talk about problems with family	No	20 770	39.7%
		Yes	31 580	60.3%
	Talk about problems with friends	No	12 748	24.4%
		Yes	39 602	75.6%

Abbreviations: BMI, body mass index; CAD, Canadian dollars; CESD-10, Center for Epidemiologic Studies Depression 10-item scale; GAD-7, Generalized Anxiety Disorder 7-item scale; min, minutes; SD, standard deviation.

Fitted models from the training sample were applied to the test sample. Predictive performance was compared using adjusted R^2 (R^2_{adj}) and root mean square error (RMSE) for continuous outcomes, and percent classification accuracy (pCA) and area under the receiving operator characteristic curve (AUC) for binary outcomes. R^2_{adj} is the amount of variation explained by the model, adjusted for the number of covariates, such that R^2_{adj} will decrease if inclusion of a given covariate does not substantially increase the explained variation. RMSE is the average of the squared difference between the actual and predicted outcome values.[33] The closer the predicted values are to the true values, the lower the RMSE. pCA simply measures the percentage of observations for which the model correctly assigns the outcome value. AUC (also known as the concordance statistic) is a more sophisticated measure of accuracy that accounts for both the sensitivity and specificity of the model.[32] Both measures range from 0 to 1, with higher values indicating higher model accuracy.

Parsimony was evaluated using the number of parameters and unique variables in the model. Relative variable importance measures were calculated based on the decrease in model fit resulting from removing a given variable from each model. For decision trees, this is measured by the sum of the goodness of split for all occurrences where the variable is used as a primary or surrogate split. For linear and logistic regression models, this is measured by the decrease to R^2_{adj} and AUC, respectively.

R version 4.0.3 (R Foundation for Statistical Computing, Vienna, AT) was used for all analyses. The functions "rpart" (package "rpart") and "ctree" (package "partykit") were used for CART and CTREE models, respectively. The functions "lm" and "glm" (package "MASS") were used for linear and logistic regression models, respectively.

Results

The average CESD-10 score in the sample was 8.50 (SD = 5.85) with 33.5% of the sample classified as having clinically relevant depressive symptoms. The average GAD-7 score was 6.02 (SD = 5.31) with 22.5% classified as having clinically relevant anxiety symptoms. The average FS score was 32.42 (SD = 5.39).

Decision tree and regression model comparison

As an illustrative example, the CART and logistic regression model results for the binary anxiety outcome are presented. The final fitted CART tree for the binary anxiety outcome is presented in Figure 1. The model identified 9 final subgroups using 5 unique variables. The primary splitting variable was whether students indicated having a happy home life. Both subgroups were then split based on school connectedness, though different cut-off points were used. Splits were also made for some subgroups on sex, sleep duration and whether the student was bullied. The largest final subgroup was of students who indicated having a happy home life and had school connectedness scores of 17.5 or greater, making up 61% of the sample. Within this group, the probability of having clinically relevant anxiety symptoms was 12.7%, which was the lowest of all groups. The highest-risk subgroup comprised females who indicated not having a happy home life and low school connectedness (< 16.25), with a 64.6% probability of having clinically relevant anxiety symptoms.

The logistic regression model result for anxiety is presented in Table 2. The final model after applying backward variable selection included 20 variables (33 parameters). Like the CART model, having a happy home life (odds ratio [OR]: 0.33; 95% CI: 0.31–0.34), male sex (OR: 0.33; 95% CI: 0.31–0.34) and school connectedness (OR: 0.88; 95% CI: 0.87–0.89) were found to be important predictors. Other factors including minority ethnicity, higher spending money, living in Quebec, small urban or rural urbanicity, "about right" weight perception, eating breakfast daily, higher sleep time and feeling able to talk about problems with family and friends were associated with lower odds of having clinically relevant anxiety symptoms. Older age, eating more fruits and vegetables, higher screen time, current tobacco use and e-cigarette use, being bullied, expecting to attend a postsecondary institution and skipping classes were associated with higher odds of having clinically relevant anxiety symptoms.

Prediction accuracy and parsimony

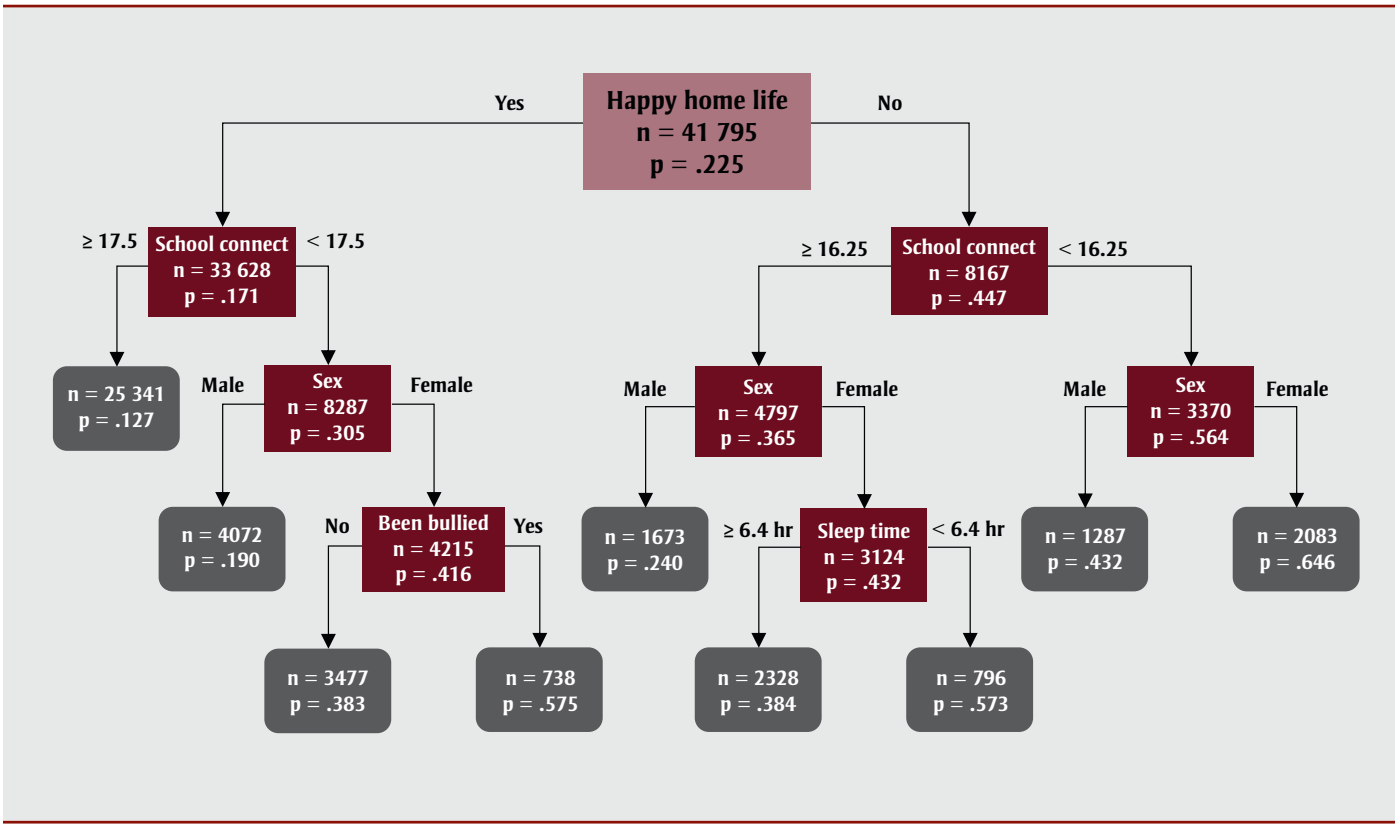
Prediction accuracy results for continuous outcomes (CESD-10, GAD-7, FS) are presented in Table 3. The linear regression models had the highest test set R^2_{adj} and lowest RMSE for all three outcomes. The R^2_{adj} and RMSE values were similar for CART and CTREE models, with R^2_{adj} consistently 4% to 5% lower than the linear regression results and RMSE 0.13 to 0.19 higher. The CART trees included the fewest unique variables, followed by CTREE, with linear regression models including over twice as many variables. However, the number of final parameters (corresponding to number of splits for tree models) was similar for CART and linear regression, and higher for CTREE models. The absolute value of the R^2_{adj} was relatively low for all models, indicating the predictors explain less than half of the variation in the outcome. Additionally, the R^2_{adj} and RMSE calculated on the test set were similar to the training set for all models, suggesting minimal overfitting.

Prediction accuracy results for binary depression and anxiety outcomes are presented in Table 3. CART produced more parsimonious models than CTREE and logistic regression, using only 9 splits on 6 variables for depression, and 8 splits on 5 variables for anxiety. CTREE produced more complex models, using over 50 splits. The larger difference between number of subgroups and variables used in the CTREE models compared to the CART models is partially due to the model splitting on the same variable multiple times using different cut-points. Logistic regression models included 22 unique variables for depression and 20 for anxiety. Despite the difference in model complexity, the test set pCA and AUC were very similar across models, with logistic regression performing only slightly better. The absolute value of the AUC was 0.71 for depression and ranged from 0.59 to 0.63 for anxiety, which suggests mediocre discriminatory ability. As in the continuous case, training and test set performances were similar, suggesting minimal overfitting.

Relative variable importance

Relative variable importance percentages for continuous outcomes (CESD-10, GAD-7, FS) are presented in Figure 2. For CESD-10 and GAD-7 outcomes, CART, CTREE and logistic regression all consistently identified school connectedness, having a happy home life and sex as the three most important variables. Sleep time also ranked fourth highest in relative importance in all except the anxiety linear regression model, which ranked bullying

FIGURE 1
CART tree for having clinically relevant anxiety symptoms (GAD-7 ≥ 10)



Abbreviations: CART, classification and regression tree; GAD-7, Generalized Anxiety Disorder 7-item Scale; hr, hours; school connect, school connectedness.

Note: n is the number of students in subgroup; p is the percentage of the subgroup with clinically relevant anxiety symptoms.

as fourth highest. However, the CART and CTREE models gave more weight to the highest ranked variables than the linear regression models. CART and CTREE attributed 78% to 87% of the total importance to the top four variables, while linear regression attributed only 47%, with the remainder split more evenly across other variables in the model.

Similar results are seen for FS, though sex is not identified as important in any of the models, while talking about problems with friends is ranked within the top four for all models, family was identified as important for CART and CTREE models, and spending money was identified as important for linear regression. Again, CART and CTREE attributed 86% to 93% of total importance to the top four ranked variables, while linear regression attributed only 43%.

Relative variable importance percentages for binary outcomes are presented in Figure 2. As was seen for continuous outcomes, school connectedness, happy home life and sex were consistently identified as the three most important variables across depression and anxiety models. Talking about problems with family was ranked as fourth highest for depression across all models, while having been bullied was ranked as fourth highest for all anxiety models. CART attributed 92% to 93% of total importance to the top four variables, while CTREE attributed 79% to 83% and logistic regression attributed 44% to 46%.

Discussion

This study provided a methodological overview and comparison of two types of decision tree, CART and CTREE, to traditional linear and logistic regression methods using a novel application to large-scale youth mental health survey data. This study adds to the limited existing evidence on decision tree performance in this domain[15,17,21,23,27] by examining a large sample of youth and wide breadth of predictors. This study also examines methodological considerations of decision trees in the context of population surveillance research, in which prediction accuracy must be weighed against model interpretability.

Beyond the subject matter knowledge gleaned from the results of this application to youth mental health, the implications discussed below can be used as a guide for researchers examining other large-scale survey datasets.

In the case of prediction accuracy, for linear scale outcomes linear regression outperformed CART and CTREE, with 4% to 5% higher R^2_{adj} values and 3% to 5% lower RMSE values. The number of model parameters was similar for CART and linear regression, while CTREE resulted in more complex models. However, while CART and linear regression had a similar number of parameters, CART identified far fewer unique variables as significant, with the high number of parameters due to multiple splits on the same continuous predictor variables. In contrast, regression models assumed a linear effect of continuous variables and provided only a single estimate representing the effect of a one-unit increase in the variable, regardless of the starting value.

In the case of binary outcomes, logistic regression models again had higher

TABLE 2
Logistic regression model for odds of having clinically relevant anxiety symptoms (GAD-7 ≥ 10)

Variable	Level	AOR (95% CI)
Sex (ref = female)	Male	0.33 (0.31–0.34)***
Age (years)	per year	1.05 (1.02–1.07)***
Ethnicity (ref = White)	Black	0.5 (0.43–0.59)***
	Asian	0.73 (0.66–0.81)***
	Latin American	0.83 (0.7–0.98)*
	Other/multi	1.01 (0.94–1.09)
Spending money (ref = $0)	$1–$20	0.93 (0.85–1.01)
	$21–$40	0.86 (0.77–0.95)**
	$41–$100	0.87 (0.79–0.96)**
	More than $100	0.94 (0.86–1.03)
	Don't know	0.87 (0.79–0.96)**
Province (ref = Alberta)	British Columbia	0.89 (0.77–1.03)
	Ontario	0.92 (0.81–1.05)
	Quebec	0.66 (0.58–0.76)***
Urbanicity (ref = large urban)	Medium urban	1.02 (0.93–1.12)
	Small urban/rural	0.86 (0.80–0.91)***
Weight perception (ref = underweight)	About the right weight	0.78 (0.72–0.84)***
	Overweight	1.03 (0.95–1.12)
Eat breakfast daily	Yes	0.76 (0.72–0.8)***
Servings of fruits and vegetables	per serving	1.03 (1.01–1.04)***
Screen time (hours)	per hour	1.05 (1.05–1.05)***
Sleep time (hours)	per hour	0.83 (0.83–0.83)***
Current tobacco use	Yes	1.12 (1.00–1.25)*
Current e-cigarette use	Yes	1.08 (1.01–1.15)*
Was bullied in last 30 days	Yes	2.03 (1.88–2.18)***
Expect to attend postsecondary institution	Yes	1.16 (1.09–1.24)***
Classes skipped in past 4 weeks (ref = 0 classes)	1–2 classes	1.06 (0.99–1.13)
	3–5 classes	1.16 (1.06–1.28)**
	6 or more classes	1.23 (1.10–1.39)***
School connectedness score	per unit	0.88 (0.87–0.89)***
Happy home life	Yes	0.50 (0.47–0.54)***
Talk about problems with family	Yes	0.73 (0.69–0.77)***
Talk about problems with friends	Yes	0.75 (0.71–0.8)***

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; ref, reference group.

*$p < 0.05$

**$p < 0.01$

***$p < 0.001$

predictive performance than CART and CTREE; however, overall performance was closer than for continuous outcomes, with 1% to 2% higher prediction accuracy and 0% to 3% higher AUC. In these cases, CART produced far more parsimonious models than both CTREE and logistic regression, both in terms of total parameters and number of unique variables. Previous small studies by Burke et al.,[21] Mitsui et al.[15] and Handley et al.[27] found AUCs ranging 4% to 8% lower for CART than logistic regression, while in contrast, a study by Batterham et. al[17] found AUC 2% higher for CART than logistic regression. While direct comparison of AUC findings from these studies is difficult given the differences in study samples, outcomes and model specifications, it is still noteworthy that across all studies performance between the two techniques did not drastically differ.

Thus, while linear and logistic regression may provide slight advantages in predictive ability, the simpler models generated by CART may be more desirable, particularly for knowledge translation in the context of population health research where the focus is on understanding associations and communicating results to a non-technical audience.

Decision tree and regression models consistently identified the same sets of most important predictors for each outcome, indicating a general level of agreement between methods. However, CART and CTREE weighted the relative importance of these top predictors much higher than the regression models, attributing more than three-quarters of total importance to the top four predictors, compared to regression models, which attributed less than half of total importance to the top predictors. This is in line with the greater parsimony seen in the CART and CTREE models and highlights the ability of decision trees to single out the most important factors.

Additionally, a common limitation of regression models is that factors with high multicollinearity tend to "wash out" when entered simultaneously, leading to inflated variance estimates or variable omission bias, which could cause factors to be overlooked.[45] This has been seen in past research comparing trees and regression,[23] suggesting that decision tree methods can offer a clearer representation of key factors to aid in decision making. This advantage of parsimony can be particularly beneficial in the domain of population-level disease prevention research, in which a myriad of competing risk factors and confounders may be present.

Higher levels of school connectedness and having a happy home life were consistently identified as key predictors and were associated with lower levels of depression and anxiety and higher flourishing. This is consistent with previous research linking family relationships to

TABLE 3
Prediction accuracy comparison for continuous and binary outcomes for CART, CTREE and regression models

Continuous outcome	Method	# Parameters	# Unique variables	Training R^2_{adj}	Training RMSE	Test R^2_{adj}	Test RMSE
CESD-10	CART	38	9	0.35	4.73	0.33	4.76
	CTREE	57	10	0.36	4.70	0.34	4.73
	Linear reg.	34	20	0.39	4.59	0.38	4.57
GAD-7	CART	39	11	0.28	4.50	0.27	4.55
	CTREE	63	15	0.29	4.49	0.27	4.55
	Linear reg.	40	23	0.32	4.39	0.31	4.42
FS	CART	43	9	0.47	3.94	0.46	3.97
	CTREE	70	12	0.47	3.93	0.46	3.96
	Linear reg.	40	24	0.51	3.79	0.51	3.78
Binary outcome	**Method**	**# Parameters**	**# Unique variables**	**Training pCA**	**Training AUC**	**Test pCA**	**Test AUC**
Depression	CART	9	6	0.75	0.71	0.74	0.70
	CTREE	53	14	0.75	0.71	0.74	0.70
	Logistic reg.	39	22	0.76	0.71	0.76	0.70
Anxiety	CART	8	5	0.80	0.60	0.79	0.59
	CTREE	52	11	0.80	0.61	0.79	0.61
	Logistic reg.	34	20	0.80	0.63	0.80	0.63

Abbreviations: AUC, area under the receiving operator characteristic curve; CART, classification and regression tree; CESD-10, Center for Epidemiologic Studies Depression 10-item scale; CTREE, conditional inference tree; GAD-7, Generalized Anxiety Disorder 7-item scale; FS, flourishing scale; pCA, percent classification accuracy; reg., regression; R^2_{adj}, adjusted R^2; RMSE, root mean square error.

adolescent anxiety[11] and school connectedness to emotional distress and depression in youth.[8,9] Additionally, previous classification tree analysis on adolescent girls found poor school functioning to be a major risk factor for depression onset, but found that parental support was only protective among subgroups with low depression at baseline.[18] The protective association to school connectedness highlights the role of the school environment in helping to shape youth mental health and highlights why schools are an appropriate context for intervening, given the ability to reach a large section of the youth population. The decision tree method highlighted in the current study is well suited to future research evaluating complex environmental characteristics and co-occurring interventions.

As previously mentioned, an advantage of decision trees is the ability to examine complex interactions between predictors and identify high-risk subgroups to whom prevention and intervention efforts can be targeted. In the illustrative example with anxiety, bullying was significantly associated with the odds of having clinically relevant anxiety symptoms in the regression model; however, in the CART model, bullying only appears as a risk factor for higher anxiety among the subset of female students with a happy home life and lower school connectedness.

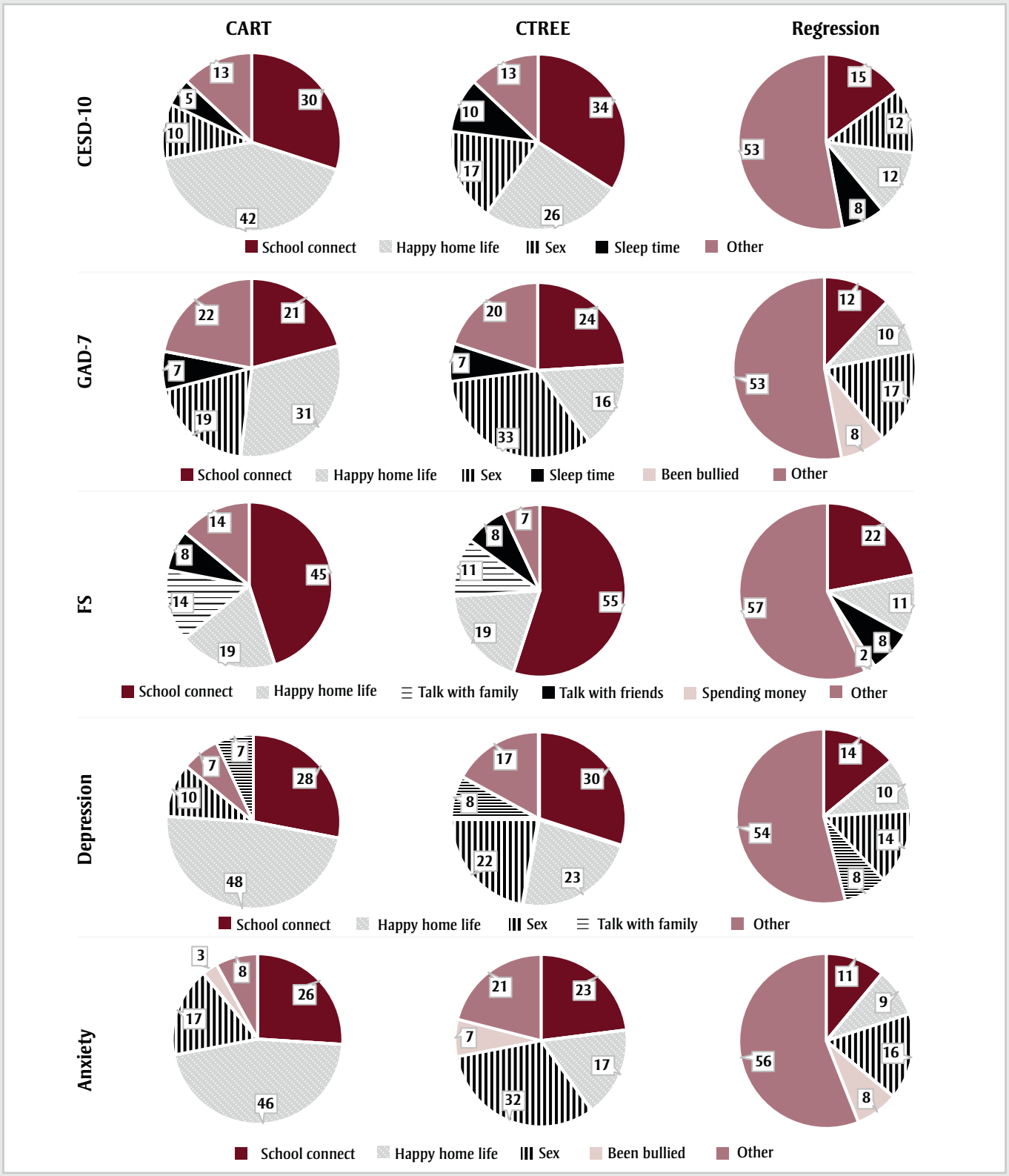
Similarly, sleep time was associated with greater odds of anxiety in the regression model, though the magnitude was small; in contrast, the CART model found sleep to be a protective factor among females without a happy home life and with high school connectedness. Estimates in the regression model correspond to the overall average association across the entire sample and do not provide any insight into the differential impacts on various subgroups. In this case, the low effect size for sleep time in the regression model masks its importance among a specific subgroup.

Studies by Handley et al.[27] and Batterham et al.,[28] which examined suicide ideation in adults, each found important factors present in decision tree analyses that were not significant in corresponding regression models. As noted by Handley, this suggests a multiplicative rather than independent impact of these factors, which would not be detected using a standard regression model of main effects. Thus, decision trees can be much more useful than regression models for researchers and practitioners seeking to identify unique characteristics of the highest risk groups to whom to tailor interventions.

Despite these findings, the stronger predictive performance of regression models compared to decision tree models seen in this study could suggest that the underlying nature of predictors is somewhat linear. In the illustrative anxiety example, school connectedness was found to be an important factor across both happy home life subgroups, while sex was found to be the next most important factor across three of four subsequent subgroups. This suggests that the effect of these factors is similar across the sample, meaning a regression analysis would adequately capture this effect through the single model estimate. Decision trees have a greater advantage over regression models when the true underlying relationships in the data are nonlinear.[12] Researchers should therefore carefully consider underlying data structures based on theory and descriptive exploration when contemplating the most appropriate analysis technique.

This study examined two types of decision trees: CART and CTREE. Both models segment the population into distinct subgroups by recursively choosing the variables and cut-off levels that produce

FIGURE 2
Relative variable importance percentages of top contributing predictor variables for CART, CTREE and regression models for continuous and binary outcomes



Abbreviations: CART, classification and regression tree; CESD-10, Center for Epidemiologic Studies Depression 10-item scale; CTREE, conditional inference tree; GAD-7, Generalized Anxiety Disorder 7-item scale; FS, flourishing scale; school connect, school connectedness.

maximum separation among subgroups and minimal within-group variability. While CART and CTREE performed similarly in terms of prediction accuracy, CART consistently produced more parsimonious models, including fewer total model parameters and unique variables. Both CART and CTREE models tended to include multiple splits on different values of the same variable, particularly for the continuous outcomes examined. Tendency to favour continuous predictors over categorical due to the greater number of potential splits is a commonly noted drawback of decision trees.[12,31] For binary outcomes, this limitation seems to be more of a concern for CTREE than CART.

Another commonly mentioned drawback of decision trees is the tendency for the models to overfit to the sample data,[35] which is partially mitigated by pruning in the case of CART and stopping rules based on tests of statistical significance in the case of CTREE.[35] In this study, similar model performance for training and test sets showed that overfitting is not a concern using either method, which may potentially be credited to the large sample size in this dataset. Interestingly, CTREE produced much more complex models than CART. CTREE models in this study used a standard statistical significance threshold of $\alpha = 0.05$ with Bonferroni correction, suggesting that perhaps more stringent criteria should be used with CTREE in the case of large sample size. Thus, while previous literature tends to favour CTREE,[12] this study suggests that researchers working with larger-scale health data should instead consider using CART when parsimony and interpretability are primary concerns.

Strengths and limitations

This study provides a novel application of decision trees using large-scale Canadian health survey data. In contrast to previous limited research, this study benefits from a large sample size that allows for more complex tree structures.

However, the resulting increased tree complexity makes interpretation difficult, which diminishes one of the primary benefits of tree analysis. While this study used standard stopping and pruning criteria, additional restrictions such as limiting the number of levels and using more stringent significance thresholds could produce smaller, more easily interpretable trees. The impact of varying restrictions on overall model fit should be tested in future work. Additionally, only main effects were included in the regression models for this study; inclusion of interaction terms could have increased the relative performance, though as previously noted this can lead to issues in computation and interpretation.

Another limitation of this study is the low overall model fit. Test set R^2_{adj} values for continuous outcomes ranged from 0.27 to 0.51, indicating that the included predictors explain less than half of the overall variation in the outcomes. AUCs for binary outcomes ranged from 0.59 to 0.70, indicating low to moderate discriminative ability. While it is not uncommon for behavioural studies to have lower model fits, this suggests that other intrinsic factors that are not captured in this study may play an important role in predicting mental health outcomes. Previous studies of suicide ideation outcomes have generally seen higher AUCs around 0.80;[15,21,27] however, these studies included baseline depression, which is already a well-established predictor.

Additionally, this study uses a cross-sectional, nonrandomized study design, meaning that neither decision trees nor regression models can show causal relationships between the predictors and mental health outcomes in this case. More broadly, decision trees are generally considered to be exploratory methods[12] used for hypothesis generation. Further, decision trees are not deterministic methods and are highly sensitive to the sample and parameter choices. Methods such as random forest, which grow multiple trees and aggregate the results into overall measures of variable importance, have been developed to overcome this instability,[46] though interpretability is sacrificed. Finally, the CART and CTREE methods used in this study do not account for the hierarchical nature of data (i.e. students clustered within schools). Newer tree methods such as RE-EM[47,48] and M-CART[49] have been developed to account for this nonindependence of observations and should be examined in future research.

Conclusion

Despite growing use in other domains, decision trees remain an underutilized analysis technique in population health research. While the predictive performance of decision trees was found to be slightly lower than that of traditional regression methods, trees provide a means of examining complex interactions between predictors, and present results in a form that is easily interpretable by nontechnical audiences, aiding in knowledge translation. The ability of decision trees to identify high-risk subgroups to whom prevention and intervention efforts can be targeted is particularly valuable to public health practitioners facing limited resources. Decision trees can be a powerful addition to population health researchers' methodology repertoire to address research questions that cannot be answered by traditional regression methods.

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Conflicts of interest

Scott Leatherdale is an Associate Scientific Editor with the HPCDP Journal but has recused himself from the review process for this paper. The authors declare there are no other conflicts of interest.

Authors' contributions and statement

KB conceived this work, conducted the statistical analysis and drafted the manuscript as part of her PhD dissertation at

the University of Waterloo. SL and JD supervised KB in conceptualizing this work and drafting the manuscript. LD supported the analyses and interpretation of the data. LD and KP provided ideas and thoughts for discussion and revised the manuscript for important intellectual content. SL is the principal investigator of the COMPASS study and led study implementation. KP conceptualized the COMPASS mental health module. All authors informed the analysis plan, provided feedback on drafts and read and approved the final manuscript.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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Original quantitative research

The trends and determinants of seasonal influenza vaccination after cardiovascular events in Canada: a repeated, pan-Canadian, cross-sectional study

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Abstract

Introduction: Annual influenza vaccination is recommended for individuals with a history of cardiovascular disease (CVD) events. We aimed to examine (1) the time trends for influenza vaccination among Canadians with a CVD event history between 2009 and 2018, and (2) the determinants of receiving the vaccination in this population over the same period.

Methods: We used data from the Canadian Community Health Survey (CCHS). The study sample included respondents from 2009 to 2018 who were 30 years of age or more with a CVD event (heart attack or stroke) and who indicated their flu vaccination status. Weighted analysis was used to determine the trend of vaccination rate. We used linear regression analysis to examine the trend and multivariate logistic regression analysis to examine determinants of influenza vaccination, including sociodemographic factors, clinical characteristics, health behaviour and health system variables.

Results: Over the study period, in our sample of 42 400, the influenza vaccination rate was overall stable around 58.9%. Several determinants for vaccination were identified, including older age (adjusted odds ratio [aOR] = 4.28; 95% confidence interval [95% CI]: 4.24–4.32], having a regular health care provider (aOR = 2.39; 95% CI: 2.37–2.41), and being a nonsmoker (aOR = 1.48; 95% CI: 1.47–1.49). Factors associated with decreased likelihood of vaccination included working full time (aOR = 0.72; 95% CI: 0.72–0.72).

Conclusion: Influenza vaccination is still at less than the recommended level in patients with CVD. Future research should consider the impact of interventions to improve vaccination uptake in this population.

Keywords: *cardiovascular diseases, influenza vaccines, utilization, secondary prevention, trend, determinants*

Highlights

- Vaccine uptake in the post-CVD Canadian population from 2009 to 2018 was found to be suboptimal and is a potential area for optimization of health outcomes in these patients.
- Factors associated with increased likelihood of vaccination include older age, having a regular health care provider and being a nonsmoker.

Introduction

Annual vaccination against influenza is recommended for all individuals with a history of an ischemic cardiovascular disease (CVD) event.[1-5] Seasonal influenza infection further elevates the already increased risk of recurrent CVD events and deaths in this particular population.[6-9] Although the exact mechanism is unknown, this increased risk from influenza infection is believed to be the result of viral particles activating inflammatory pathways, which can contribute to dysfunctions in arterial endothelium and lipid metabolism and lead to coronary atherosclerotic events such as myocardial infarction and stroke.[6,10,11] Empirical evidence supports the efficacy of influenza vaccine in the secondary prevention context.[12,13] In a systematic review of randomized clinical trials, influenza vaccination was associated with a 36.0% reduction in future CVD events, with a relative risk of 0.6 (95% confidence interval [CI]: 0.5–0.9).[12]

In Canada, annual influenza vaccines are widely available in pharmacies, physician offices and local public health units.[14] Public funding of the vaccine is also provided for those with chronic conditions, including CVD, in all 13 Canadian jurisdictions.[15] Despite this availability, the uptake of influenza vaccine among patients with CVD remains low.[15-18] Data from the 2019/20 influenza season revealed the proportion of vaccinated Canadian adults with one or more chronic conditions (including CVD) was 44.0%, well below the 80.0% target set by the National Advisory Committee on Immunizations (NACI).[18] However, time trends of vaccination rates in Canadians specifically with a previous CVD event history are unknown.[18]

There is also inadequate evidence pertaining to the determinants of vaccine uptake

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in patients with CVD. Studies usually focus on determinants either in the general population or in patients suffering from chronic conditions as a whole, but not CVD specifically.[19-23] Older age was found to be significantly associated with a higher rate of vaccine uptake in the general population of the United States, Canada, Italy and Portugal.[19-21,23] In countries such as the United States, where the cost of influenza vaccinations may not be covered by the government, individuals with higher occupational and educational status were more likely to be vaccinated than those with lower incomes.[22,24] Aside from cost, other factors such as systemic racism and a reduced degree of prioritization by clinicians and the health care system may hinder patients' access to the influenza vaccine. Although these factors may also exist in Canada, findings from the United States are not directly applicable to the Canadian population, due to differences in demographics and health care coverage.[19]

It is important to identify the time trend and determinants of influenza vaccination in Canadian patients after CVD events to inform effective strategies, to help determine whether current policies are sufficient and to what extent there is a need to further improve influenza vaccine uptake among these high-risk patients.[25,26] The aim of this study was to identify the trend for the period of 2009 to 2018, as well as the determinants of receiving influenza vaccine among Canadian patients with a previous CVD event. We hypothesized that influenza vaccine uptake is increasing in Canada.

Methods

Data source

We used data from the Public Use Microdata Files (PUMF) of the Canadian Community Health Survey (CCHS)[27] to conduct this study. We accessed the data through the Ontario Data Documentation, Extraction Service and Infrastructure ("odesi") tool.[28] The CCHS is a voluntary, cross-sectional survey of noninstitutional Canadian residents aged 12 years and older, used to obtain health-related information representative of different health regions across Canada.[27] The data are collected year-round. Subject areas of interest include various health conditions, utilization of health care services, lifestyle factors and mental health.[27]

The CCHS utilizes a complex, two-stage, stratified cluster design to sample those 18 years of age and over in the Labour Force Survey while using a simple, random sample to query children aged 12 to 17 years.[27] A letter from Statistics Canada inviting participation in the survey is mailed to respondents; those who agree are then directed to an online questionnaire.[27] Together, those excluded from the sample make up less than 3% of the Canadian population.[27] The PUMF from CCHS compiles responses from approximately 130 000 individuals over a two-year period, published as a microdata file biennially.[27,29]

For this study, we included CCHS data from the 2009–2010, 2011–2012, 2013–2014, 2015–2016 and 2017–2018 cycles. The variables concerning influenza vaccination and all exposure variables used in this study were core content in the CCHS documentation, signifying that the variables were asked in all Canadian provinces and territories.[27] We applied weights provided in the Statistics Canada datasets to all data analyzed and presented in this study.[27] As per Statistics Canada, the survey weights are determined by a combination of modelling probabilities of response at the household and person levels, and correlates to the number of persons in the Canadian population represented by each respondent.[27]

Study population

We included respondents from the 2009 to 2018 CCHS who indicated that they were 30 years of age or older, had experienced a CVD event and who answered questions pertaining to influenza vaccinations. CVD event history was assessed using the survey questions "Do you have heart disease?" and "Do you suffer from the effects of a stroke?" Respondents who answered "yes" to either one or both questions were included in the study. Although it was not established through hospitalization records that all respondents indicating presence of heart disease or stroke had in fact experienced an ischemic CVD event, it was considered a reasonable indicator to be used for this study. Individuals below 30 years of age were excluded from this study due to the extremely low prevalence of heart disease in this age group and differences in etiology compared to older adults (i.e. higher proportion of non-atherosclerotic causes of CVD).[30]

Vaccination status

Respondents were considered vaccinated for the influenza season if they have indicated "yes" to the question "Have you ever had a flu shot?" and have also indicated "< 1 year ago" to the question "When did you last receive the vaccine?" As the influenza vaccine is recommended annually, respondents who had had the flu shot but indicated "1–2 years ago" or "2 or more years ago" as the last time they received the vaccine, as well as those who had indicated "no" to the question "Have you ever had a flu shot?", were considered unvaccinated in this study. The remaining respondents who indicated "don't know" or "unsure" to any of the above questions, or refused to answer, were all considered unvaccinated.

Measurement and confounding variables

Various independent variables were chosen to identify potential determinants of the outcome of interest (i.e. being vaccinated). We included sociodemographic factors related to age, sex, marital status, income, education level, immigrant status and employment status, based on previous findings for their correlation to vaccination among the general population.[19-21,23] In addition, we included the cycle year and chronic diseases variables. We also included variables pertaining to smoking status and body mass index (BMI)—calculated by Statistics Canada—to study the impact of various health-related factors, as well as a variable assessing self-perceived health, with responses ranging from "poor" to "excellent."[31] Further, the variables of having a regular health care provider and requiring help with personal care were included to evaluate health care and external aid utilization. Whether or not respondents resided in provinces or territories allowing pharmacists to provide immunizations was also assessed, due to recent evidence showing that Canadian jurisdictions that had implemented this policy saw increased influenza vaccination rates.[32] Details about included variables are available in Appendix 1.

Data analysis

The weighted rate of respondents in the overall CVD population who received influenza vaccination (i.e. the proportion of respondents vaccinated) across the study period from 2009 to 2018 was first plotted, along with the confidence interval.

The same procedure was then repeated to plot the vaccination rate of respondents in the overall CVD population over time stratified by province. These data plots were then analyzed utilizing the linear regression analysis test in Microsoft Excel version 16.43 (Microsoft Corp., Redmond, WA, US) to determine the significance of any trends in receiving vaccination over the study years.

Next, descriptive statistics were calculated for patients who were vaccinated versus those who were unvaccinated. The association between each independent variable and receipt of influenza vaccine was examined using the chi-square (χ^2) test of independence. Similar to previous research, a weighted multivariable logistic regression model was then fitted using a stepwise forward-selection model.[33] The independent variables in the final model were included based on significance ($p < 0.05$) from the Wald statistic and goodness of fit using the Akaike information criterion. Selected variables—cycle year, age and sex—were included in the model regardless of statistical significance. Patients with missing data were dealt with first by listwise deletion approach (where only respondents with complete data in all variables were kept in the analysis).[34] In a sensitivity analysis, we used the educated-guessing approach, in which variables with missing values are replaced with "no" in binary variables or by the lowest level (in ordinal variables).

Using weighted results, a second sensitivity analysis was performed in order to evaluate the robustness of the study definition for vaccination status. In the main model, respondents were considered vaccinated only if they had indicated having received the flu shot less than one year ago. This definition, however, excludes those who received the flu shot exactly one year ago or just over one year ago but who would still go on to be vaccinated for the upcoming influenza season. Therefore, in this sensitivity analysis, we considered respondents vaccinated as long as they had received the influenza vaccine less than two years before the survey date. This is because influenza vaccination is recommended annually during the influenza season to protect against new strains of the influenza virus. However, because the CCHS collects data annually, the questions pertaining to vaccination status may be referring to either year of a two-year cycle.

Several subgroup analyses were also performed to identify any differences in determinants for vaccination based on age group and type of CVD event (e.g. stroke only). The same independent variables and statistical procedure applied to the main model were used to perform the subgroup analyses.

SAS University Edition (SAS Studio version 3.8, SAS version 9.4; SAS Institute Inc., Cary, NC, US) was utilized to analyze the survey data. Due to the fact that the data are publicly available through Statistics Canada,[27] there was no need for research ethics board approval to conduct this study. All numbers presented are rounded to the closest 100, as per Statistics Canada rounding guidelines.[35]

Results

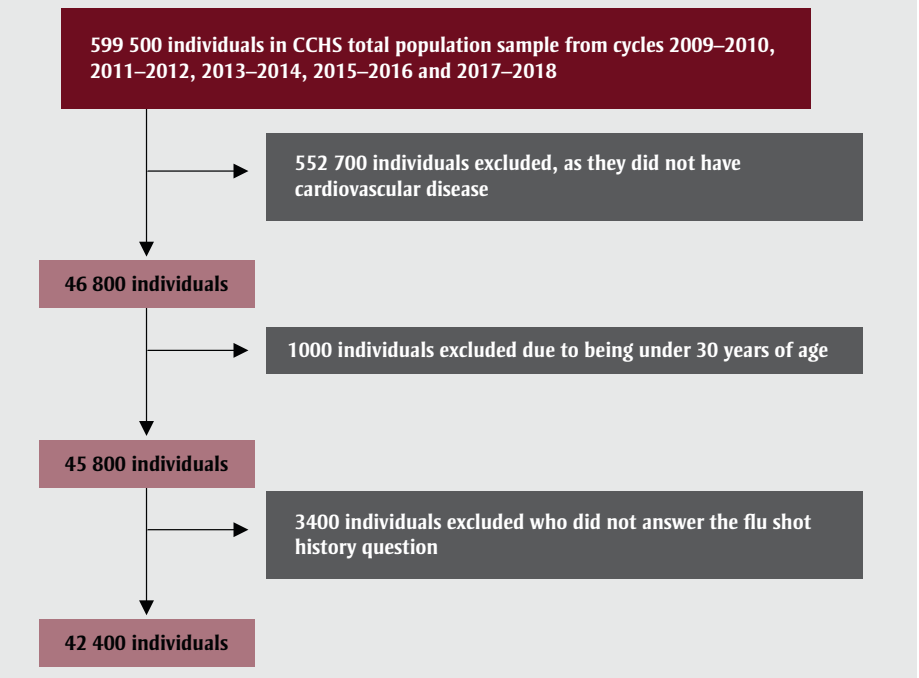
Descriptive statistics

The study sample included a total of 42 400 respondents, representing a weighted population of 7 148 500 Canadians, from the CCHS cycles 2009–2010 to 2017–2018, residing in all 10 Canadian provinces and 3 territories. Figure 1 illustrates the process taken to determine the final study sample. Most respondents (81.0%) had heart disease only, 13.0% had a history of a stroke and the remaining 6.0% had both. In the total weighted sample of 42 400 respondents, 58.9% had received influenza vaccination. More than half of the sample population (58.0%) were aged 65 and older, and 56.0% were males. Table 1 describes the baseline characteristics of the study weighted sample. Vaccinated individuals were generally older in age, were married and had other comorbidities. A low level of missingness was observed (Appendix 2) in all independent variables (< 3%) and most variables had less than 1% missingness.

Trends in vaccination

Figure 2 illustrates the weighted proportion of respondents with CVD events vaccinated against influenza from 2009 to 2018. Over the ten-year study period, there was a general downward trend in the proportion of vaccinated individuals with a history of a CVD event, from 59.3% (95% CI: 59.2–59.4) in the 2009–2010 cycle to 55.5% (95% CI: 55.4–55.6) in the 2017–2018 cycle. Vaccination rates peaked in the 2013–2014 cycle, with 61.5% (95% CI: 61.4–61.6) of respondents indicating vaccination against influenza. However, the trend line was not significant (p

FIGURE 1
Selection process of study respondents



Data source: Canadian Community Health Study (CCHS), 2009–2010 to 2017–2018.

TABLE 1
Characteristics of the weighted study sample

Respondent characteristics	Vaccination status[a]			*P* values from chi-square test of independence
	Unvaccinated n = 2 939 900 (column %)	Vaccinated n = 4 208 600 (column %)	Total N = 7 148 400[b] (column %)	
Age group (years)				< 0.0001
30–44	267 300 (9%)	107 200 (3%)	374 400 (5%)	
45–64	1 445 900 (49%)	1 163 200 (28%)	2 609 100 (36%)	
65 and above	1 226 700 (42%)	2 938 200 (70%)	4 164 900 (58%)	
Has heart disease only				< 0.0001
Yes	2 327 200 (79%)	3 475 800 (83%)	5 803 000 (81%)	
Suffers from effects of a stroke only				< 0.0001
Yes	426 600 (15%)	465 900 (11%)	892 500 (13%)	
Has heart disease and suffers from effects of a stroke				0.9829
Yes	186 200 (6%)	266 800 (6%)	453 000 (6%)	
Sex				0.0002
Female	1 239 700 (42%)	1 922 000 (46%)	3 161 700 (44%)	
Cycle year				0.0007
2009–2010	576 000 (20%)	837 700 (20%)	1 413 600 (20%)	
2011–2012	587 000 (20%)	877 900 (21%)	1 464 900 (20%)	
2013–2014	567 900 (19%)	906 800 (22%)	1 474 700 (21%)	
2015–2016	578 100 (20%)	799 600 (19%)	1 377 700 (19%)	
2017–2018	631 000 (21%)	786 600 (19%)	1 417 600 (20%)	
Requires help with personal care				< 0.0001
Yes	82 700 (3%)	172 900 (4%)	255 600 (4%)	
Smoking status				< 0.0001
Daily smoker	562 000 (19%)	441 500 (10%)	1 003 500 (14%)	
Occasional smoker	109 800 (4%)	95 000 (2%)	204 800 (3%)	
Former smoker	1 484 400 (50%)	2 416 000 (57%)	3 900 400 (55%)	
Never smoked	454 400 (15%)	756 000 (18%)	1 210 300 (17%)	
Self-perceived health				0.3403
Not poor	2 552 300 (87%)	3 633 100 (86%)	6 185 300 (87%)	
Poor	377 000 (13%)	565 200 (13%)	942 200 (13%)	
Has diabetes				< 0.0001
Yes	574 700 (20%)	1 129 000 (27%)	1 703 700 (24%)	
Has asthma				< 0.0001
Yes	287 100 (10%)	523 700 (12%)	810 700 (11%)	
Has COPD				< 0.0001
Yes	283 100 (10%)	558 000 (13%)	841 100 (12%)	
Has a regular health care provider				< 0.0001
Yes	2 663 300 (91%)	4 068 100 (97%)	6 731 500 (94%)	
Low-income group				0.4614
Yes	938 700 (32%)	1 316 100 (31%)	2 254 800 (32%)	

Continued on the following page

TABLE 1 (continued)
Characteristics of the weighted study sample

Respondent characteristics	Vaccination status[a]			*P* values from chi-square test of independence
	Unvaccinated n = 2 939 900 (column %)	Vaccinated n = 4 208 600 (column %)	Total N = 7 148 400[b] (column %)	
Marital status				0.0048
Single/widowed/divorced	1 073 000 (36%)	1 437 700 (34%)	2 510 700 (35%)	
Married	1 858 600 (63%)	2 764 400 (66%)	4 623 100 (65%)	
Highest educational attainment				0.0367
Secondary and lower	1 278 400 (43%)	1 916 600 (46%)	3 195 000 (45%)	
Postsecondary and higher	1 568 900 (53%)	2 169 800 (52%)	3 738 700 (52%)	
Pharmacist immunization in province of residence				< 0.0001
Yes	1 552 500 (53%)	2 497 400 (59%)	4 049 900 (57%)	
Province of residence				< 0.0001
British Columbia	334 400 (11%)	531 700 (13%)	866 000 (12%)	
Alberta	247 400 (8%)	346 300 (8%)	593 800 (8%)	
Saskatchewan	88 500 (3%)	124 700 (3%)	213 200 (3%)	
Manitoba	96 600 (3%)	125 500 (3%)	222 300 (3%)	
Ontario	1 024 800 (35%)	1 761 000 (42%)	2 785 800 (39%)	
Quebec	916 800 (31%)	901 800 (21%)	1 818 700 (25%)	
Atlantic provinces	223 700 (8%)	409 100 (10%)	632 800 (9%)	
Territories	7 600 (0%)	8 300 (0%)	15 900 (0%)	
BMI				0.9008
< 25	996 400 (34%)	1 429 800 (34%)	2 426 200 (34%)	
≥ 25	1 877 600 (64%)	2 680 300 (64%)	4 557 900 (64%)	
Immigrant status				0.8963
Yes	639 700 (22%)	925 200 (22%)	1 564 900 (22%)	
Full-time worker				< 0.0001
Yes	916 000 (31%)	651 000 (15%)	1 567 100 (22%)	

Data source: Canadian Community Health Study, 2009–2010 to 2017–2018.

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease.

[a] Respondents were considered vaccinated if they indicated having received the flu shot less than one year ago.

[b] Number has been rounded.

value = 0.12). Figure 3 illustrates the breakdown of vaccination trends within the Canadian provinces. Ontario, Quebec and British Columbia saw a general decrease in vaccination rates, while Alberta experienced an overall increase over the study period. Quebec consistently remained the province with the lowest percentage of respondents vaccinated.

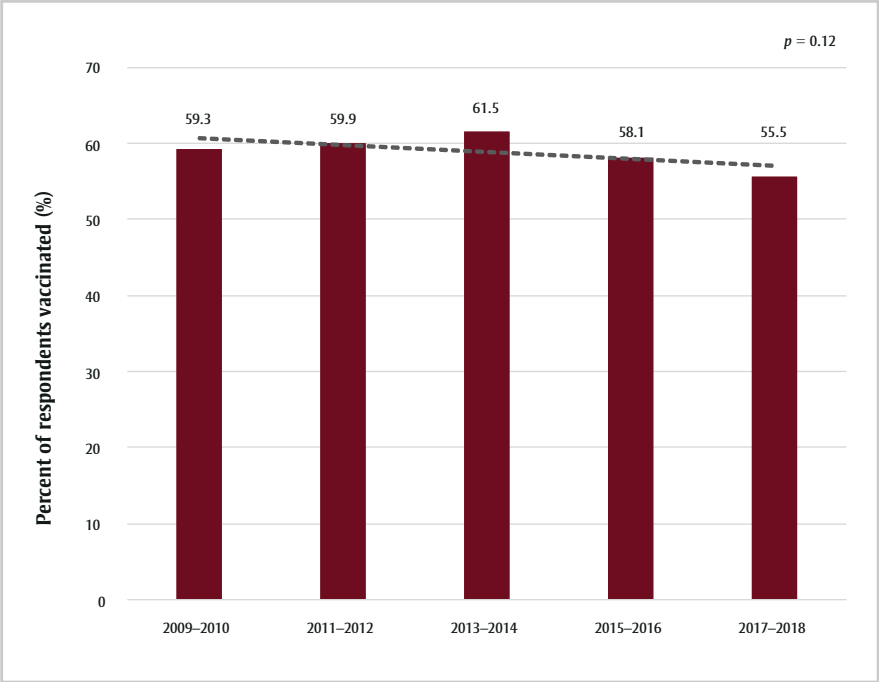
Determinants of receiving influenza vaccination

The variables that were retained in the multivariate logistic regression analysis, in addition to age, cycle year and sex, were smoking status, presence of comorbidities (diabetes, asthma and chronic obstructive pulmonary disease [COPD]), marital status, working status, highest educational attainment, requiring help for personal care and having a regular health care provider (Appendix 3). The adjusted odds ratios (aORs) of the variables controlled for in the final main model are listed in Table 2. Age of 65 years or older was associated with the greatest odds of receiving influenza vaccination, with an aOR of 4.28 (95% CI: 4.24–4.32) and having a regular health care provider was also associated with increased odds (aOR = 2.39; 95% CI: 2.37–2.41).

Subgroup analysis

Results of the subgroup analyses stratified by age revealed some differences in the aORs for the following variables: COPD, requiring help with personal care and working status. Respondents in the youngest age group (aged 30–44) were approximately four times more likely to receive the influenza vaccination if they had COPD than those without COPD (aOR = 4.6;

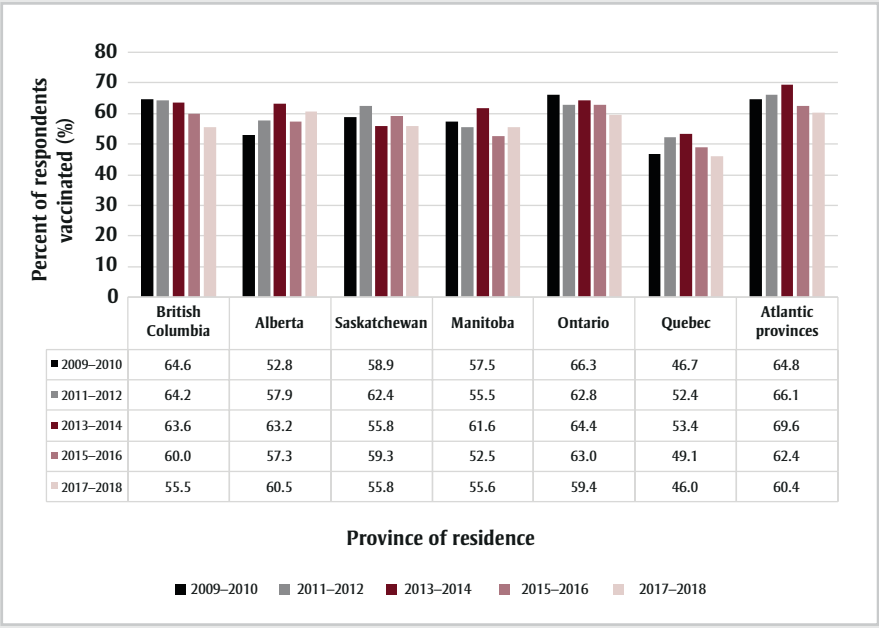
FIGURE 2
Weighted percentage of Canadians with a CVD event history vaccinated against influenza, from 2009 to 2018



Data source: Canadian Community Health Survey.

Abbreviation: CVD, cardiovascular disease.

FIGURE 3
Weighted percentage of Canadians with a CVD event history vaccinated against influenza, from 2009 to 2018, across various provinces[a]



	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	Atlantic provinces
2009–2010	64.6	52.8	58.9	57.5	66.3	46.7	64.8
2011–2012	64.2	57.9	62.4	55.5	62.8	52.4	66.1
2013–2014	63.6	63.2	55.8	61.6	64.4	53.4	69.6
2015–2016	60.0	57.3	59.3	52.5	63.0	49.1	62.4
2017–2018	55.5	60.5	55.8	55.6	59.4	46.0	60.4

Data source: Canadian Community Health Survey.

[a] Territories are not shown due to the very small number of respondents.

95% CI: 4.4–4.8), while respondents aged 45 and above with COPD had similar odds of vaccination as in the main model (aOR = 1.2; 95% CI: 1.1–1.2). Respondents in the youngest age group requiring help with personal care had an aOR of 2.7 (95% CI: 2.6–2.9), while requiring help with personal care was not associated with vaccination in respondents aged 45 to 64. The odds of vaccination were also increased in respondents working full time between 30 and 44 years of age (aOR = 2.5; 95% CI: 2.5–2.6) while respondents working full time older than 45 years of age had a decreased likelihood of vaccination (aOR = 0.8; 95% CI: 0.8–0.8). The remaining variables remained consistent with the results of the main model across all age groups (Table 3). In a second subgroup analysis on respondents suffering from the effects of a stroke only, findings were similar to the results of the main model (Table 4).

Sensitivity analysis

In the sensitivity analysis, in which respondents were considered vaccinated as long as they indicated vaccination less than 2 years ago, there were no extensive changes to the odds ratios compared to the main model (Appendix 4). Similarly, the educated-guessing approach for missing data yielded similar estimates (Appendix 5).

Discussion

We examined the trends and determinants of receiving influenza vaccination in individuals with a history of a CVD event in a representative sample from the Canadian population from 2009 to 2018. Over the study period, the percentage of respondents vaccinated each year remained generally stable (ranging from 55.5%–61.5%) and experienced no significant change (p = 0.12). Despite various attempts to improve vaccine uptake through national influenza vaccination campaigns and increased accessibility of vaccines through local pharmacies, vaccination rates remained below NACI's 80% target for Canadians with chronic conditions.[18,32] This is a concerning finding, as annual influenza vaccinations are an easily accessible and cost-effective measure to reduce morbidity and mortality from CVD events.[25,32] The data demonstrate that, as in other jurisdictions, not enough post-CVD patients are utilizing this cardioprotective strategy in Canada.[23] Therefore, while national influenza

vaccination campaigns distribute information for the general population, additional strategies to distribute information tailored to high-risk populations may be required.[36]

Within the study period, vaccination rates peaked in 2013/14. A possible reason may be attributed to the implementation of funding and policy allowing pharmacists to administer influenza vaccines in Manitoba and Atlantic provinces that year.[19,32] This is also supported by the finding that Quebec had the lowest rates of vaccination throughout the study period, potentially explained by the absence of universal funding and pharmacist immunization policy for influenza vaccinations in this province.[32] However, there was no significant improvement in vaccine uptake from 2009, and in none of the study years was the target of 80% reached.[18]

Consistent with previous studies, increasing age was associated with higher influenza vaccination rates.[19-21,23] Likewise, the presence of other comorbidities was another strong predictor for vaccination, and comorbidities also become more prevalent with age.[18] Older individuals and

TABLE 2
Adjusted odds ratios of being vaccinated[a] from multivariate logistic regression analysis (main model)[b]

Effect	Adjusted odds ratio (aOR) estimation	95% Wald confidence limits	
2011–2012 vs. 2009–2010	1.05	1.04	1.05
2013–2014 vs. 2009–2010	1.10	1.09	1.10
2015–2016 vs. 2009–2010	0.96	0.95	0.96
2017–2018 vs. 2009–2010	0.80	0.79	0.80
Sex: female vs. male	1.06	1.06	1.07
Age: 45–64 vs. 30–44	1.73	1.72	1.75
Age: 65 and older vs. 30–44	4.28	4.24	4.32
Require help with personal care: yes vs. no	1.11	1.10	1.11
Smoking: no vs. yes	1.48	1.47	1.49
Diabetes: yes vs. no	1.37	1.37	1.38
Asthma: yes vs. no	1.36	1.35	1.37
COPD: yes vs. no	1.32	1.31	1.32
Marital status: married vs. single/widowed/divorced	1.25	1.25	1.26
Work full time: yes vs. no	0.72	0.72	0.72
Has a regular HCP: yes vs. no	2.39	2.37	2.41
Educational attainment: postsecondary and higher vs. secondary and lower	1.10	1.09	1.10

Abbreviations: COPD, chronic obstructive pulmonary disease; HCP, health care provider.
[a] Respondents were considered vaccinated if they indicated having received the flu shot less than one year ago.
[b] All variables in the table were included in the multivariate model.

TABLE 3
Adjusted odds ratios of subgroup model stratified by age

Effect	Ages 30–44 y			Ages 45–64 y			Ages 65 y and above		
	Adjusted odds ratio estimation	95% Wald confidence limits		Adjusted odds ratio estimation	95% Wald confidence limits		Adjusted odds ratio estimation	95% Wald confidence limits	
2011–2012 vs. 2009–2010	0.38	0.37	0.40	1.10	1.09	1.11	1.36	1.35	1.38
2013–2014 vs. 2009–2010	0.68	0.66	0.70	0.98	0.97	0.99	1.24	1.23	1.25
2015–2016 vs. 2009–2010	0.94	0.92	0.97	0.92	0.91	0.93	1.00	0.99	1.00
2017–2018 vs. 2009–2010	0.44	0.43	0.46	0.70	0.69	0.70	0.91	0.91	0.92
Sex: female vs. male	1.48	1.46	1.51	1.11	1.10	1.12	1.02	1.01	1.02
Require help with personal care: yes vs. no	2.34	2.22	2.45	1.02	1.00	1.04	1.13	1.11	1.14
Smoking: no vs. yes	1.35	1.32	1.39	1.25	1.24	1.25	1.78	1.76	1.79
Diabetes: yes vs. no	2.02	1.97	2.08	1.44	1.43	1.45	1.27	1.26	1.28
Asthma: yes vs. no	1.19	1.16	1.22	1.58	1.57	1.60	1.16	1.15	1.17
COPD: yes vs. no	3.16	3.04	3.28	1.18	1.17	1.20	1.36	1.35	1.37
Has a regular HCP: yes vs. no	3.00	2.91	3.11	2.55	2.52	2.58	2.36	2.33	2.39
Marital status: married vs. single/widowed/divorced	0.99	0.98	1.02	1.16	1.16	1.17	1.30	1.30	1.31
Work full time: yes vs. no	1.53	1.50	1.56	0.79	0.79	0.80	0.47	0.46	0.47
Educational attainment: postsecondary and higher vs. secondary and lower	1.12	1.10	1.15	1.15	1.15	1.16	1.09	1.09	1.10

Abbreviations: COPD, chronic obstructive pulmonary disease; HCP, health care provider; y, years.

TABLE 4
Adjusted odds ratio of subgroup sample of respondents who had stroke only

Effect	Adjusted odds ratio estimation	95% Wald confidence limits	
Ages (yr): 45–64 vs. 30–44	1.60	1.56	1.63
Ages (yr): 65 and older vs. 30–44	3.68	3.60	3.77
2011–2012 vs. 2009–2010	0.67	0.66	0.69
2013–2014 vs. 2009–2010	0.79	0.78	0.80
2015–2016 vs. 2009–2010	1.06	1.05	1.08
2017–2018 vs. 2009–2010	0.68	0.67	0.69
Sex: female vs. male	1.20	1.19	1.21
Require help with personal care: yes vs. no	1.26	1.24	1.29
Smoking: no vs. yes	1.44	1.42	1.46
Diabetes: yes vs. no	1.55	1.53	1.57
Asthma: yes vs. no	1.64	1.61	1.66
COPD: yes vs. no	0.89	0.88	0.91
Has a regular HCP: yes vs. no	2.25	2.12	2.30
Marital status: married vs. single/widowed	1.28	1.27	1.29
Work full time: yes vs. no	0.52	0.51	0.53
Educational attainment: postsecondary and higher vs. secondary and lower	1.32	1.30	1.33

Abbreviations: COPD, chronic obstructive pulmonary disease; HCP, health care provider.

those with greater comorbidities are more readily perceived by health care providers to be at higher risk for complications from influenza, leading to greater frequency of recommendations and higher vaccination rates.[37] Increasing age may also be associated with increased self-perceived risk to complications of influenza infection, thereby influencing self-motivated vaccine uptake.[38]

Individuals with a regular health care provider were more than twice as likely as those without one to receive vaccination. This supports findings that health care utilization is an important determinant for vaccination.[21,39] Yet, while 94% of individuals in our study reported having a regular health care provider, almost 40% were not vaccinated against influenza. This suggests a potential gap in communication between health care providers and patients regarding the cardioprotective benefits of the influenza vaccine.[25] Considering the significant impact of health care provider recommendations on vaccine uptake as demonstrated by numerous studies, a greater focus on patient education on vaccine benefits during all points of contact with the health care system (e.g. hospitalizations, follow-up visits) is warranted.[40-42]

We also found that nonsmokers across all age groups were more likely to receive influenza vaccination than smokers (OR = 1.5; 95% CI: 1.4–1.5). While there are some discrepancies in the literature,[20,21,37] 57.0% of our vaccinated study population were noted to be former smokers. It is possible that former smokers who made the decision to quit smoking after a CVD event may be more inclined to take part in other preventative measures such as influenza vaccinations.[43] However, it is the current smokers who are at a higher risk for CVD events and have a higher incidence of CVD mortality than former smokers, and would therefore derive greater benefit from vaccination.[43]

We found that Canadians with a CVD event aged 65 and older with higher educational attainment were more likely to be vaccinated. This supports the findings of several Canadian studies showing that higher educational status is a determinant for vaccination in the elderly.[37,44] On the other hand, higher educational attainment was linked to a decrease in odds of vaccination for those under 65 years of age, which is in line with the findings from previous studies in other countries.[20,45] This can be potentially explained by the association between higher education status and greater likelihood of working, rendering these individuals busier and potentially less able to conveniently access vaccination than those who are not working.[39] Lastly, our results suggest that future vaccination campaigns could benefit from directing efforts to the working population. Working full-time was associated with a decreased likelihood of vaccination among middle-aged respondents aged 45 to 64. Full-time workers may potentially be busier than their unemployed counterparts, contributing to greater difficulties with booking health care appointments or taking part in vaccination programs.[39]

Strengths and limitations

Our study utilized representative data from the Canadian population collected over ten years. This enabled us to examine the trend determinants for vaccination and vaccine receipt in the past decade. However, some limitations should be noted.

First, CCHS relies on self-reporting, in which the responses may be subject to recall bias. Nevertheless, the CCHS questions pertaining to heart disease and stroke were validated and found to be robust. Lix et al. reported that these questions have very high specificity (> 96%) and negative predictive value (> 98%),[46] which would support the existence of heart disease in CCHS respondents who reported that they have heart disease. Regarding vaccination status, some respondents may have stated their last vaccination to be one to two years ago, when in actuality it was less than one year ago. This would have led them to be categorized as unvaccinated in the study, leading to an underestimation of the actual vaccination rate. It should be noted, however, that in the sensitivity analysis, expanding the window of vaccination to two years did not have an impact on the results.

Second, there were no specific questions asked in CCHS concerning history of CVD events. The question "Do you have heart disease?" encompasses many heart diseases, such as atrial fibrillation or heart failure, while the aim of this study was to look at only those with a history of an atherosclerotic cardiacvascular or cerebrovascular event.

Nevertheless, our results can be generalized to the Canadian public, as our sample was large, and the data collected over an extended period of time. In addition,

sample weights provided by Statistics Canada provide a robust estimation of vaccination level among patients with heart disease.

Conclusion

In spite of the morbidity and mortality benefits of the annual influenza vaccination in patients with a history of a CVD event, influenza vaccination rates among Canadians are still suboptimal, and were found to be overall stable over the ten-year study period from 2009 to 2018.[18] Major determinants associated with vaccine uptake include increasing age, having a regular health care provider, having concurrent comorbidities, requiring help with personal care and being a nonsmoker. Future influenza vaccination campaigns should include messages directed at post-CVD patients, as well as groups associated with lower odds of vaccination, such as those employed full-time in the workforce and individuals under 65 years of age. The results of this study also re-emphasize the important role clinicians play in patient education and the recommendation of influenza vaccinations for improved vaccine uptake and health outcomes in the Canadian CVD population.[1]

Conflicts of interest

None.

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Authors' contributions and statement

HC: data acquisition, data analysis, writing—original draft, writing—review and editing. SH: conceptualization, methodology, writing—review and editing. WA: conceptualization, methodology, data acquisition, data analysis, writing—review and editing.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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At-a-glance

Injuries among Canadian children and youth: an analysis using the 2019 Canadian Health Survey on Children and Youth

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Abstract

This work provides an overview of injury patterns in Canadian children and youth aged 1 to 17 years. Self-reported data from the 2019 Canadian Health Survey on Children and Youth were used to calculate estimates for the percentage of Canadian children and youth who experienced a head injury or concussion, broken bone or fracture, or serious cut or puncture within the last 12 months, overall and by sex and age group. Head injuries and concussions (4.0%) were the most commonly reported, but the least likely to be seen by a medical professional. Injuries most frequently occurred while engaging in sports, physical activity or playing.

Keywords: *children, youth, unintentional injuries, head injuries, concussions, fractures, punctures*

Highlights

- Overall, head injuries or concussions were the most commonly reported injury (4.0%), among the types of injuries surveyed.
- Serious cuts and punctures were most common among young children (aged 1 to 4 years), fractures were most common among children aged 10 to 14 years and head injuries or concussions were most common in youth aged 15 to 17 years.
- The most common activities that children and youth were partaking in when the injury occurred were playing and engaging in sports or physical activity.
- The majority of self-reported injuries led to a consultation from a medical professional.

Introduction

Childhood injuries are a major public health issue in Canada. Unintentional injuries are the leading cause of death, morbidity and potential years of life lost among Canadian children and youth.[1-5] During the 2018/19 fiscal year, there were 20 626 injury hospitalizations among those aged 0 to 19 years in Canada (excluding Quebec), 77% of which were unintentional.[6] Injury hospitalizations only reflect the most severe injuries, and less severe injuries can also impact quality of life and development.[6,7]

The majority of unintentional injuries in children and youth are preventable.[2,8] Understanding patterns in self-reported injuries, including injury types and activities leading to injury, is necessary to inform prevention efforts. This article provides a national overview of self-reported injuries and injuries leading to medical consultation over a one-year period using data from the 2019 Canadian Health Survey on Children and Youth (CHSCY). The 2019 CHSCY captured both severe and less severe injuries among children and youth, unlike hospitalization or emergency department data, which typically only capture severe injuries. The 2019 CHSCY collected data for a large sample of children aged 1 to 17 years, covering a broader age range of children compared to other national surveys such as the Canadian Community Health Survey (CCHS).

Methods

Data source and study population

This study used data from the 2019 CHSCY, a voluntary cross-sectional survey conducted by Statistics Canada. The 2019 CHSCY covered a national sample of the Canadian population aged 1 to 17 years living in all provinces and territories. Those living on First Nation reserves and other Indigenous settlements, those living in foster homes and the institutionalized population were excluded from the survey. The sampling frame for the CHSCY was the Canada Child Benefit file, which covers 98% of Canadians aged 1 to 17 years in the provinces and 96% in the territories. Data collection occurred between February and August 2019. The data used in this study were collected via questionnaires administered to the person most knowledgeable (PMK) about the selected child or youth, which was usually a parent. A total of 92 172 individuals were sampled for the 2019 CHSCY, with an overall response rate of 52%.[9] The sample for the current study was composed of 39 951 children and youth for whom injury data were available (43% of total sample).

Variables

Injury type

The 2019 CHSCY asked PMKs whether the child had (1) a head injury or concussion;

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(2) a broken or fractured bone; and (3) a serious cut or puncture during the past 12 months (response options: yes/no). Since these were the only categories used in the survey, this study is only able to present results based on these three injury categories.

Injury leading to a consultation from a health care professional

For each reported injury type, PMKs were asked whether a health care professional was consulted for that injury (response options: yes/no). For individuals who had multiple injuries of a single type, they were asked whether a health care professional was consulted for the most serious injury.

Activity during injury

For each reported injury type, PMKs were asked what the child was doing when the injury occurred. Responses were categorized as (1) riding a bike; (2) sports or physical activity other than riding a bike; (3) riding or driving an off-road or road motor vehicle; (4) playing; or (5) other, including household chores, outdoor yard maintenance or paid/unpaid work. Although these are not mutually exclusive activities, PMKs were only able to select one activity.

Statistical analysis

Descriptive statistics were used to calculate the weighted percentage and 95% confidence intervals for children who experienced each injury type in the past 12 months overall, and stratified by age (1–4, 5–9, 10–14, 15–17 years) and sex (male, female). Survey sampling weights were provided by Statistics Canada to generate nationally representative estimates, and 95% confidence intervals were estimated using the bootstrap method. Analyses were conducted in SAS EG 9.4 (SAS Institute Inc., Cary, NC, US).

Results

The percentages of self-reported injuries among children and youth are shown in Table 1. Among the surveyed injury types in children and youth, head injuries/concussions occurred most commonly (4.0%), followed by fractures (3.2%) and serious cuts/punctures (2.5%). Head injuries were most common among those aged 15 to 17 years and more common among males. Fractures were most common among those aged 10 to 14 years and more common among males compared to females. Serious cuts/punctures were most common in the youngest age group (aged 1–4 years), and were more common among males.

Table 1 also presents the percentage of injuries that led to a consultation from a health care professional. The majority of fractures (93.9%) led to a consultation, compared to 80.7% of serious cuts/punctures and 76.5% of head injuries or concussions. The percentage of head injuries or concussions that led to a medical consultation was highest in the oldest age group (15–17 years). The percentages of injuries that led to a consultation from a health care professional were similar between males and females for all injury types.

Among the injuries surveyed, the most common activities that children and youth were partaking in when the injury occurred were playing, sports or physical activity, and other (Table 2). Children aged 1 to 9 years were most frequently playing at the time of injury, whereas children and youth aged 10 to 17 years were more frequently engaging in sports or physical activity at the time of injury (data not shown). The percentage of injuries that led to a consultation from a health professional differed by type of activity and injury type. Among head injuries and serious cuts/punctures, riding an on- or off-road motor vehicle was the activity most likely to lead to a medical consultation, whereas sustaining a fracture while riding a bike or playing was most likely to lead to a medical consultation.

Discussion

This study provides an overview of the prevalence of self-reported injuries and injuries leading to a medical consultation among Canadian children and youth. Of the injuries examined, head injuries/concussions occurred most commonly, followed by fractures and serious cuts/punctures. Injuries tended to be more common in males, regardless of injury type. The percentage of head injuries/concussions and fractures increased with increasing age, while serious cuts/punctures decreased with increasing age. These findings are in line with hospitalization patterns, indicating that males have higher rates of head injury and fracture-related hospitalization,[10] and that head injuries and concussions are more common in older children.[11]

Notably, our findings differ from the results of the 2009-2010 CCHS, in which the most common self-reported, activity-limiting injuries in youth (aged 12–19 years) were sprains/strains, fractures and cuts, punctures or animal bites.[12] The 2009-2010 CCHS reported fewer concussions, brain injuries and head injuries, whereas our study suggests a relatively high rate of head injuries/concussions compared to the other injury types that were assessed (broken bones or fractures and serious cuts or punctures). This is to be expected based on the differences in injury types assessed by each survey. The rate of head injuries/concussions leading to medical consultation was relatively low in our study. Other studies have reported increasing trends of head injuries/concussions over the last several years, especially among sports, physical activity and playing injuries.[13-16]

The most frequently reported activities at the time of head injury leading to a medical consultation were related to sports or motor vehicles. Similarly, previous findings have shown that head injuries occur most commonly during sports, accounting for over 80% of traumatic brain injuries among youth in Canada.[17] Motor vehicle collisions are also a frequent cause of head injury hospitalizations in Canada and the US.[11,18,19] In our study, sports, physical activity and playing were the most common activities leading to fractures. Other studies have also shown that fractures are the most common type of sports-related injury in Canadian children and youth,[20] and also account for the majority (> 80%) of injuries sustained on a playground.[21] The most common activity leading to serious cuts/punctures was playing, likely because the majority of serious cuts/punctures occurred in children aged 1 to 4 years.

Most respondents sought medical consultation for their injury. Fractures were most likely to lead to a medical consultation (94% of injuries), likely due to the need for medical imaging or for the fracture to be set. Among head injuries/concussions, 77% of cases were seen by a health professional; this lower percentage is perhaps due to fewer physical symptoms or wearing a helmet at the time of injury.[22] Research from the US indicated that only

TABLE 1
Percentage of Canadian children and youth who had an injury and the percentage of injuries that led to a consultation from a health care professional, by injury type, in a 12-month period, overall and stratified by age and sex

Sex	Age (years)	Head injury or concussion % (95% CI)	Broken bone or fracture % (95% CI)	Serious cut or puncture % (95% CI)
Percentage of injuries				
Overall	1–17	4.0 (3.7–4.2)	3.2 (2.9–3.4)	2.5 (2.3–2.8)
Females	1–17	3.4 (3.0–3.8)	2.9 (2.6–3.2)	1.8 (1.6–2.1)
	1–4	2.6 (2.0–3.2)	1.2 (0.7–1.6)[c]	2.3 (1.8–2.8)
	5–9	2.6 (2.1–3.2)	2.1 (1.6–2.5)	1.7 (1.2–2.2)
	10–14	3.7 (3.0–4.5)	4.7 (3.9–5.5)	1.6 (1.1–2.0)[c]
	15–17	5.3 (4.3–6.3)	3.6 (2.7–4.6)	1.9 (1.0–2.8)[c]
Males	1–17	4.5 (4.1–4.9)	3.4 (3.1–3.8)	3.2 (2.9–3.5)
	1–4	3.3 (2.7–4.0)	1.1 (0.7–1.4)[c]	4.3 (3.5–5.0)
	5–9	3.9 (3.3–4.6)	2.3 (1.8–2.9)	3.3 (2.7–3.9)
	10–14	5.4 (4.5–6.2)	5.6 (4.8–6.5)	2.4 (1.9–3.0)
	15–17	5.8 (4.6–7.0)	4.8 (3.8–5.9)	2.8 (1.9–3.7)[c]
Percentage of injuries that required medical consultation				
Overall	1–17	76.5 (73.6–79.5)	93.9 (91.5–96.4)	80.7 (77.2–84.3)
Females	1–17	76.0 (71.2–80.8)	94.1 (91.0–97.2)	76.5 (69.7–83.2)
	1–4	70.8 (61.0–80.7)	98.6 (95.9–100.0)	84.9 (76.8–93.0)
	5–9	66.0 (55.5–76.5)	95.5 (90.8–100.0)	69.7 (55.3–84.1)
	10–14	74.6 (64.7–84.4)	92.0 (86.2–97.7)	65.6 (50.1–81.0)
	15–17	89.9 (84.3–95.5)	95.4 (89.5–100.0)	88.4 (75.0–100.0)
Males	1–17	77.0 (73.2–80.7)	93.8 (90.2–97.4)	83.1 (79.2–87.0)
	1–4	64.8 (55.8–73.8)	98.4 (95.2–100.0)	83.1 (76.1–90.2)
	5–9	67.5 (59.5–75.5)	95.2 (88.1–100.0)	86.4 (80.4–92.4)
	10–14	78.9 (71.6–86.1)	92.1 (86.1–98.1)	77.5 (68.7–86.3)
	15–17	94.6 (90.6–98.6)	94.7 (89.6–99.9)	84.7 (73.7–95.6)

Data source: 2019 Canadian Health Survey on Children and Youth.

Abbreviation: CI, confidence interval.

Note: Percentages and 95% confidence intervals are based on weighted data.

[c] High sampling variability (coefficient of variation between 15.0% and 25.0%).

25% of injuries were severe enough to require medical attention, whereas Canadian studies align with our work, reporting that the majority of injuries required medical attention.[23-25] The variation seen in seeking a medical consultation for the different types of injuries may be attributable to factors such as injury severity, general awareness, household income/education and health care access.[13,23,26,27]

Strengths and limitations

The 2019 CHSCY was a national survey covering Canadians aged 1 to 17 years from all provinces and territories, and injury estimates were weighted to be nationally representative of this population. However, this study was subject to several limitations. The sample size was insufficient to provide additional sociodemographic breakdowns (e.g. province/territory or socioeconomic status) that would provide further insight into injury patterns, considering that relatively few (< 5%) children in our sample reported an injury. Due to the survey design, only a few injury types were included, which reduces comparability to other research. Data were only collected at one time point, precluding the examination of self-reported injuries over time. Further, injuries were reported by PMKs, and may not have been clinically diagnosed. No definition of "serious" cut or puncture was provided in the questionnaire, likely resulting in subjective reporting. Data were also collected retrospectively, and may have been prone to response and recall biases.

Conclusion

Injuries among children and youth continue to be a public health concern in Canada. In our study, injuries most commonly occurred while playing or engaging in sports or physical activity, and injuries were more common among males. By capturing less severe injuries that are often missed in administrative databases, these results address a gap in Canadian injury surveillance. Understanding the variation in injuries across age groups and the activities taking place when the injury is sustained can help inform prevention efforts.

Conflicts of interest

The authors declare that they have no conflicts of interest.

TABLE 2
Percentage of injuries and injuries that led to a consultation from a health care professional, occurring during different types of activities, by injury type, in a 12-month period

Activity	Head injury or concussion % (95% CI)	Broken bone or fracture % (95% CI)	Serious cut or puncture % (95% CI)
Percentage of activities			
Riding a bike	2.0 (0.9–3.0)[D]	3.5 (2.1–4.8)[C]	7.0 (4.8–9.3)[C]
Sport or PA	44.8 (41.2–48.3)	51.9 (47.9–55.8)	13.2 (9.9–16.4)
Motor vehicle	2.7 (1.7–3.7)[C]	2.1 (1.0–3.2)[D]	—[E]
Playing	31.3 (28.2–34.5)	26.8 (23.3–30.2)	45.3 (41.1–49.6)
Other	19.3 (16.4–22.1)	15.8 (12.8–18.8)	31.6 (27.7–35.6)
Percentage of activities that required medical consultation			
Riding a bike	81.5 (59.9–100.0)	97.3 (93.6–100.0)	69.2 (53.3–85.0)
Sport or PA	83.3 (79.2–87.5)	93.1 (89.3–96.9)	77.3 (66.0–88.6)
Motor vehicle	93.2 (84.1–100.0)	89.4 (69.9–100.0)	100.0 (100.0–100.0)
Playing	65.4 (59.9–70.8)	97.3 (95.1–99.6)	83.1 (78.3–87.9)
Other	76.9 (70.1–83.6)	92.8 (86.1–99.4)	80.5 (74.3–86.6)

Data source: 2019 Canadian Health Survey on Children and Youth.

Abbreviations: CI, confidence interval; PA, physical activity.

Notes: Percentages and 95% confidence intervals are based on weighted data. "Sport or PA" refers to sports or physical activity other than riding a bike; "motor vehicle" refers to riding or driving an off-road or on-road motor vehicle; "other" refers to household chores, outdoor yard maintenance or paid/unpaid work.

[C] High sampling variability (coefficient of variation between 15.0% and 25.0%).

[D] High sampling variability (coefficient of variation between 25.0% and 35.0%).

[E] High sampling variability, unreportable (coefficient of variation greater than 35.0%).

Authors' contributions and statement

CW, ST, SZ, SRM and WT conceptualized the project and methodology. CW and ST conducted the analysis and led the writing of the manuscript. All authors provided feedback on the draft, and reviewed and approved the final manuscript.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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Call for papers: Social Prescribing in Canada

Guest Editors: Sandra Allison (Island Health Authority), Kiffer Card (Simon Fraser University), Kate Mulligan (University of Toronto)

HPCDP Journal Editors: Robert Geneau and Margaret de Groh (Public Health Agency of Canada)

Social prescribing (SP) is a practical tool for addressing the social determinants of health through supported referrals to community services. This globally spreading intervention aims to promote health and prevent chronic disease by supporting individual and community self-determination and connecting participants to nonclinical supports in their communities, such as food and income support, parks and walking groups, arts and cultural activities or friendly visiting.[1]

Global evidence demonstrates that SP can support individual and population health, build the evidence base on the impacts of social interventions for health promotion and chronic disease prevention and integrate health and social care at the community level.[2] However, while SP practices continue to scale and spread across Canada, and knowledge mobilization is underway through the new Canadian Institute for Social Prescribing,[3] there is relatively little published literature on this novel intervention in Canadian contexts and by Canadian researchers, practitioners and participants.

The objective of this special issue is to identify and share the most current research and practice on SP by and for residents of Canada, particularly those facing inequities in access to health and its social and structural determinants. *Health Promotion and Chronic Disease Prevention in Canada: Research, Policy and Practice* therefore seeks relevant qualitative and quantitative research articles, as well as commentaries, that present new findings, synthesize existing evidence or imagine new ways forward on (for example)

- applications of SP, including those for specific populations or specific types of social interventions;
- policies and systems changes relevant to SP uptake;
- expertise and experiences of SP actors, including participants (patients), health care workers, community organizations and caregivers;
- training, workforce development, collaboration and knowledge mobilization for SP;
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