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Original quantitative research

Determining the accuracy of the Canadian Hospitals Injury Reporting and Prevention Program for the representation of the rates of mild traumatic brain injuries in Quebec

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Abstract

Introduction: The recent rise in mild traumatic brain injuries (mTBI) in the pediatric population has been documented by many studies in Canada and the United States. The objective of our study was to compare mTBI rates from the Canadian Hospital Injury Reporting and Prevention Program (CHIRPP) in Montréal with population-based rates (Quebec mTBI rates).

Methods: We calculated CHIRPP's mTBI rates via two methods: (1) using all CHIRPP injuries as the denominator; and (2) using the number of children aged 0 to 17 years living within 5 km of either of two CHIRPP centres in Montréal as the denominator. We plotted CHIRPP's mTBI rates against the provincial rates and compared them according to sex and age.

Results: Whether using all CHIRPP injuries or the number of children aged 0 to 17 years living within 5 km of either CHIRPP centre in Montreal as the denominator, CHIRPP paralleled the fluctuations seen in Quebec's rates between 2003 and 2016. When stratifying by sex and age, CHIRPP was better at estimating the population-based rates for the youngest (0 to 4 years) and the oldest (13 to 17 years) age groups.

Conclusion: CHIRPP in Montréal proved a valid tool for estimating the variations in rates of mTBI in the population. This suggests that CHIRPP could also be used to estimate population-based rates of other types of injuries.

Keywords: *mild traumatic brain injury, epidemiology, children, adolescents, emergency primary care, surveillance, evaluation, Quebec*

Highlights

- The four distinct fluctuations in Quebec's mTBI rates (i.e. a sudden increase in 2009, then a drop, followed by a steady increase between 2010 and 2014 and another drop in 2015) were captured by CHIRPP Montréal.
- When compared with other studies of mTBI rates, CHIRPP Montréal reported similar results according to the years and age groups these studies used.
- CHIRPP proved to be particularly accurate in estimating the fluctuations in Quebec's mTBI rates in males aged 0 to 4 years.
- The average rates of mTBI between CHIRPP and Quebec were quite similar: 106.3 per 10 000 in CHIRPP and 98.2 per 10 000 for Quebec, when adjusting the provincial rates to compensate for repeat visits for the same mTBI.

Introduction

The collection of information on traumatic injuries for the purpose of creating a computerized database dates back to 1969, at the Cook County Hospital in Chicago, Illinois.[1] In Canada, before the 1990s, trauma databases only included the most severe injuries—those that caused mortality or required hospitalization. The Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) was created in August 1990 to provide a broader understanding of injuries, especially those occurring in the child population (under age 18 years), by gathering data about emergency room visits from 10 pediatric hospitals. As of 2018, CHIRPP has collected data from over 3.5 million injuries. It has been expanded to gather data from 19 hospitals: 11 pediatric and 8 general.[2]

One of CHIRPP's limitations is that it is not population-based, and only represents a sample of the injuries in Canada.[3-6] Yet, some have argued that CHIRPP data can be a useful tool in describing the injuries

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of the population. Kang et al.[7] and Pickett et al.[3] have hinted at the representativeness of CHIRPP for specific injuries, such as those related to sports and recreational activities. Macpherson et al.,[8] who compared the injuries captured by a CHIRPP centre in Ottawa with those seen in four other emergency departments in Ottawa, found that CHIRPP was better at capturing the injuries of younger children (< age 15 years) and those whose injuries required hospitalization. Keays et al.[9] found that the Canadian rates of injuries in youth football, calculated using CHIRPP data, mirrored those reported in the United States over a period of 20 years using data from the National Electronic Injury Surveillance System (NEISS).

The representativeness of CHIRPP regarding mild traumatic brain injuries (mTBI) has never been studied; we wanted to see if CHIRPP captured the increase of mTBI in recent years that has been reported by several studies.[10-15] We also wanted to take advantage of a recently published article[16] that estimated population-based mTBI rates in Quebec's children and see if variations in rates of mTBI in CHIRPP would mirror those of the population.

The specific goal of the present paper was to assess the representativeness of mTBI-related CHIRPP data from two provincially designated pediatric trauma centres in Montréal (The Montréal Children's Hospital at McGill University Health Centre, and Centre hospitalier universitaire mère-enfant Sainte-Justine [CHU Sainte-Justine]) by comparing it to population-based mTBI rates. Our hypothesis was that the fluctuations in yearly provincial mTBI rates in the child population demonstrated by Keays et al.[16] would also be captured by CHIRPP.

Methods

This study compared retrospective cohort data (CHIRPP) with population-based data from the Régie de l'assurance maladie du Québec (RAMQ).[16] As per CHIRPP protocol, patients or parents of patients who presented to the emergency department (ED) of either of the CHIRPP centres in Montréal for an injury were asked to fill out a one-page questionnaire and provide detailed information about the injury. In addition, clinical data such as nature of the injury, body part and type of treatment were extracted from the ED record by CHIRPP coordinators at each site. For cases for which there was no CHIRPP form filled out, information was extracted from the patients' medical records by the coordinator. In order to ensure full confidentiality, the patients' hospital medical record numbers were scrambled, and the day in their date of birth was rounded to 15 or 31 (depending on the day of the month of the actual birthday) prior to submission to the central CHIRPP data centre. In Montréal, both CHIRPP pediatric trauma centres capture over 97% of all ED injury-related visits at their site.

Because CHIRPP data are ED-based, we do not know with certainty how to determine the exact denominator for the population that presents to each site, as children with an mTBI can consult several other hospitals, not to mention private clinics, and thus not be recorded in CHIRPP. We thus opted to estimate the denominator for CHIRPP using two different methods. First, we chose the total number of CHIRPP-reported injuries in both hospitals, as this was thought to be the simplest method, considering that CHIRPP data are current and easy to access. Our second estimate was constructed using the total population of children under 18 years of age living within a 5 km radius of either hospital. The justification for this radius was that, since Montréal is an island, going further than 5 km north or south would have captured patients that have to cross a bridge to get to either hospital and patients from the South Shore and North Shore (suburbs located off of the island) are much more likely to consult the closest hospital. While there is no perfect way to estimate the best distance to use, one that would guarantee that all children living within this radius would visit one of the hospitals when injured, we are confident that a 5 km radius captured those most likely to come.

We structured the current study according to the same age groups and time period reported for the population-based mTBI rates in the province of Quebec,[16] where total numbers of medical services (billing information) for "concussion" (ICD-9 code 850.00) and "intracranial injury of other and unspecified nature without mention of open intracranial wound, unspecified state of consciousness" (ICD-9 code 854.00) were reported by year (2003–2016), and further broken down by age groups (0–4 years, 5–8 years, 9–12 years and 13–17 years) and sex. In CHIRPP, two codes are used for mTBI: 41, corresponding to ICD-9 code 854.00, and 42, corresponding to ICD-9 code 850.00.

For the first estimated denominator (all CHIRPP injuries), we calculated mTBI rates according to the sex and age of the patient. As an example, the rates of mTBI in females aged 13 to 17 years in 2003 were calculated using the number of mTBI for that year divided by the total number of injuries in females aged 13 to 17 years in CHIRPP in 2003.

For our second denominator, we set out to determine the population (by sex and age) of children living within 5 km of either hospital. We used Google Maps to determine the postal codes (the first three digits only) within a 5 km radius of either of the CHIRPP centres. Once we determined which postal codes to use, we obtained the population living in the area using data from Statistics Canada censuses[17] from 2001, 2006, 2011 and 2016, which break down the population by age and sex for each postal code (first three digits). For years for which there were no data, the average increase, or decrease, was evenly distributed between census years. We calculated the mTBI rates for each year as follows: number of mTBI cases in CHIRPP in patients living within 5 km of either hospital divided by the population living within 5 km of either hospital. As an example, the rates of mTBI in females aged 13 to 17 years in 2003 were calculated using the total number of mTBI in CHIRPP in 2003 for females aged 13 to 17 years who lived within 5 km, divided by the number of females aged 13 to 17 years who lived within 5 km of either hospital in 2003.

All results are presented as graphs in which CHIRPP mTBI rates are compared to the provincial population-based rates.[16] Since the provincial rates are nonlinear, we did not calculate regressions but rather looked at how CHIRPP mTBI rates paralleled the population-based rate, such as by comparing slopes (with confidence intervals) where increases and decreases occurred.

The Research Ethics Boards of the McGill University Health Centre and CHU Sainte-Justine approved this research.

Results

Between 2003 and 2016, a total of 340 241 injuries in children less than 18 years of age were recorded in the CHIRPP databases of the two child trauma centres in Montréal, averaging 24 300 injuries per year. Of these 340 241 cases, 60 635 were mTBI.

When we used all injuries as a denominator for CHIRPP rates, fluctuations in CHIRPP mTBI rates were similar to those of the provincial rates: a sudden increase in 2009, then a drop, followed by a steady increase between 2010 and 2014, and another drop in 2015 and 2016. For both CHIRPP and provincial rates, the lowest point was in 2008 and the highest point was in 2014. When we used the population of children living within 5 km of either hospital between 2007 and 2016 as the denominator, CHIRPP's rates again paralleled the provincial rates, and there were no statistically significant differences between the rate of increase (i.e. slopes 2007–2016) for CHIRPP (3.55; 95% CI: 1.27–5.83) and for the province (4.60; 95% CI: 2.56–6.64) (Figure 1).

Sex played an important role in the CHIRPP rates, as it did in the provincial rates. Rates in males were always higher than those in females (an average of 1.5 times more). For males, when using all CHIRPP injuries as a denominator, the rates of mTBI were similar to the published provincial rates over four distinct periods: a decrease from 2006 to 2008, a sudden increase in 2009, followed by a drop, then an increase from 2010 to 2014 followed by a decrease from 2015 to 2016. Interestingly, for males, the rates were the same as the provincial rates in 2009 and 2014. For our second denominator, the number of males aged 0 to 17 years living within 5 km of either hospital, there were no statistically significant differences between the rate of increase (i.e. slopes: 2007–2016) between CHIRPP (3.87; 95% CI: 1.58–6.16) and the provincial rates (3.80; 95% CI: 1.21–6.39) (Figure 2).

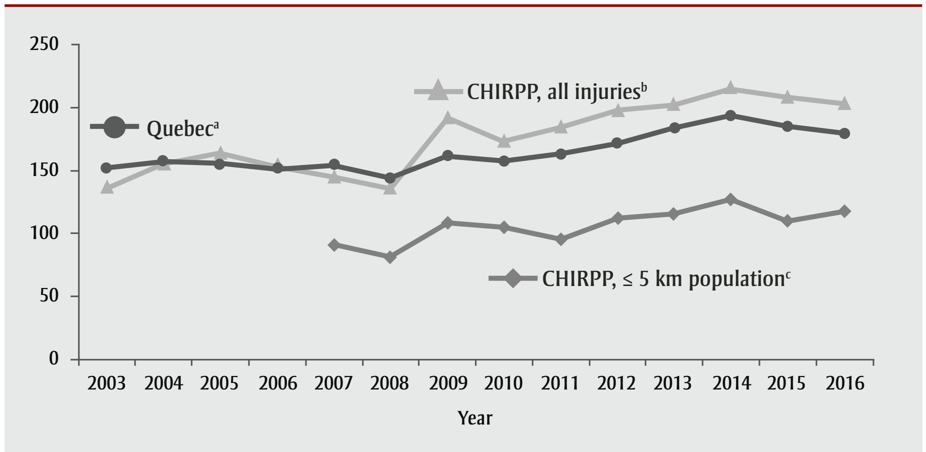
The same cannot be said for females. CHIRPP's rates (using all CHIRPP injuries as the denominator) did not parallel the published provincial rates between 2003 and 2008 but, similar to males, from 2008 onward, the rates paralleled one another. When using the number of females living within 5 km of either hospital as denominator for CHIRPP, the rate of increase (2007–2016) was smaller in CHIRPP (3.19; 95% CI: 0.42–5.96) than the published provincial rate (5.43; 95% CI: 3.51–7.35) (Figure 3).

When looking at all combinations of age and sex, the best fit between CHIRPP and the provincial rates was found in males aged 0 to 4 years using all CHIRPP injuries as denominator (Figure 4), where the rates paralleled one another from 2003 to 2016. Inversely, the greatest variations between CHIRPP and the provincial rates were found in the older groups, using the number of children aged 13 to 17 years living within 5 km of either hospital as denominator for CHIRPP (Figure 5).

Discussion

The population-based pediatric mTBI rates in Quebec[16] and CHIRPP Montréal's mTBI

FIGURE 1
Quebec provincial mTBI rates versus CHIRPP rates at two Montréal hospitals, in children aged 0 to 17 years, 2003–2016



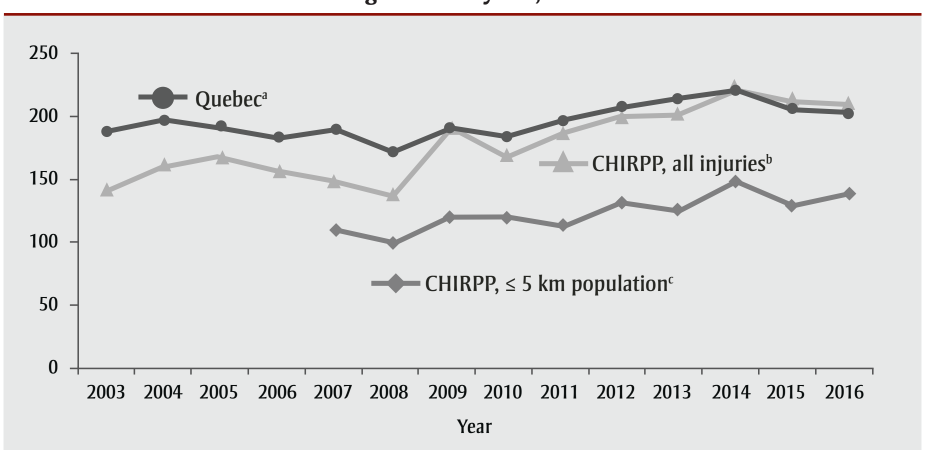
Abbreviations: CHIRPP, Canadian Hospitals Injury Reporting and Prevention Program; mTBI, mild traumatic brain injury.

[a] Quebec provincial mTBI rates per 10 000 children aged 0 to 17 years.

[b] Number of mTBI per 1000 CHIRPP injuries in children aged 0 to 17 years at The Montreal Children's Hospital and Centre hospitalier universitaire mère-enfant Sainte-Justine.

[c] Number of mTBI in children aged 0 to 17 years living within 5 km of either hospital per 10 000 children aged 0 to 17 years living within 5 km of either hospital.

FIGURE 2
Quebec provincial mTBI rates versus CHIRPP rates at two Montréal hospitals, in males aged 0 to 17 years, 2003–2016



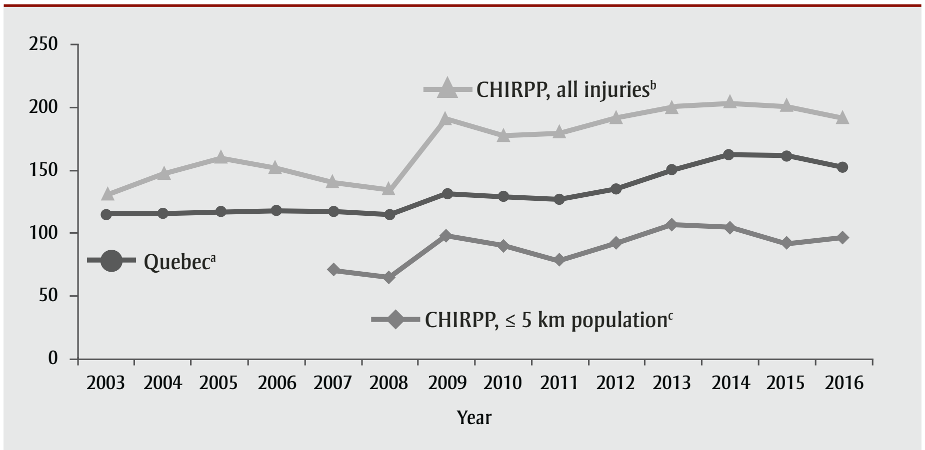
Abbreviations: CHIRPP, Canadian Hospitals Injury Reporting and Prevention Program; mTBI, mild traumatic brain injury.

[a] Quebec provincial mTBI rates per 10 000 males aged 0 to 17 years.

[b] Number of mTBI per 1000 CHIRPP injuries in males aged 0 to 17 years at The Montreal Children's Hospital and Centre hospitalier universitaire mère-enfant Sainte-Justine.

[c] Number of mTBI in males aged 0 to 17 years living within 5 km of either hospital per 10 000 males aged 0 to 17 years living within 5 km of either hospital.

FIGURE 3
Quebec provincial mTBI rates versus CHIRPP rates in two Montréal hospitals, in females aged 0 to 17 years, 2003–2016



Abbreviations: CHIRPP, Canadian Hospitals Injury Reporting and Prevention Program; mTBI, mild traumatic brain injury.

[a] Quebec provincial mTBI rates per 10 000 females aged 0 to 17 years.

[b] Number of mTBI per 1000 CHIRPP injuries in females aged 0 to 17 years at The Montreal Children's Hospital and Centre hospitalier universitaire mère-enfant Sainte-Justine.

[c] Number of mTBI in females aged 0 to 17 years living within 5 km of either hospital per 10 000 females aged 0 to 17 years living within 5 km of either hospital.

rates were similar in many regards. Whether using all CHIRPP injuries or the population of children living within 5 km of either child trauma centre in Montréal as the denominator in our calculations, CHIRPP Montréal's mTBI rates mirrored four distinct fluctuations of the population-based rates: a sudden peak in 2009, then a sudden drop in 2010, followed by an increase until 2014, then another drop in 2015.

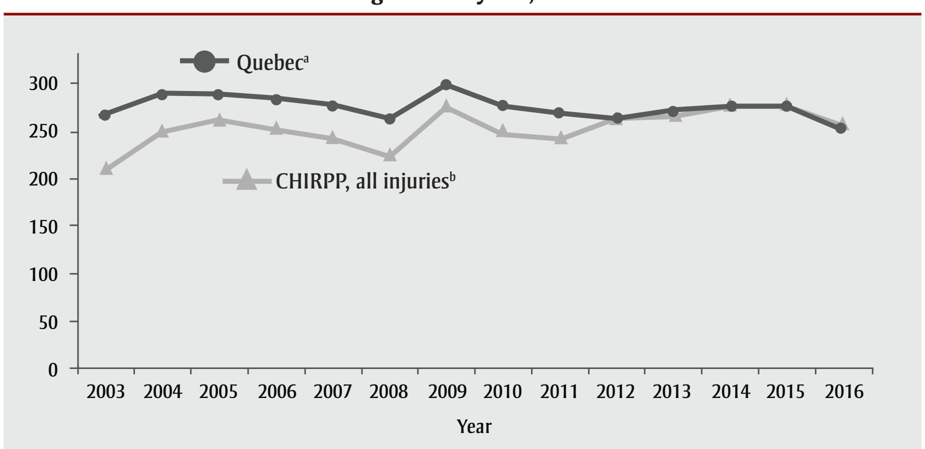
Several studies outside of Quebec have reported increases in mTBI rates in recent years, varying according to age and sex.[10-15,18] Within Quebec, mTBI rates increased 1.35-fold between 2008 (lowest rate) and 2014 (highest rate). Similarly, 2008 and 2014 were also the years of the lowest and highest CHIRPP rates, representing a 1.59-fold increase when using all CHIRPP injuries or a 1.56-fold increase when using the population living within 5 km. The drop in mTBI rates in Quebec from 2014 to 2016, a 1.08-fold decrease, was also observed in CHIRPP, with a 1.08-fold decrease using all CHIRPP injuries and a 1.06-fold decrease using population within 5 km.

Several studies have reported that the increases in rates of mTBI were more important in females than in males,[14,19-23] and that females had significantly higher odds of reporting concussions than males.[24] This phenomenon was also captured by our CHIRPP data. In the province of Quebec, the fold increase for females between 2008 and 2014 was 1.43, while in CHIRPP it was 1.52 (all CHIRPP injuries) and 1.63 (population within 5 km). In males, the fold increase was less than in females: 1.29 for the province of Quebec, 1.33 using all CHIRPP injuries, and 1.52 using population within 5 km. As to the decrease in mTBI rates between 2014 and 2016, the fold decrease was the same for males and females, for the province as well as for CHIRPP.

Rates by age group and sex showed large variations between CHIRPP and the provincial rates. When using all CHIRPP data as denominator, the best fit was found in males aged 0 to 4 years, while the worst fit was in females aged 5 to 8 years. As to the population within 5 km, the best fit between CHIRPP and the provincial rates was found in males aged 5 to 8 years, and the worst in children (males and females) aged 13 to 17 years.

Because the recent increase in mTBI rates has been reported in other studies, we compared CHIRPP mTBI rates with findings from these other studies (Table 1). As with each of the other studies, CHIRPP reported positive increases for the different periods, but also concurred with these studies on how the increases varied with age. The two studies with similar designs to ours produced strikingly similar results. Chen et al.,[25] who only considered ED visits in the United States, observed that between 2006 and 2013, for the ages 0 to 17 years, the fold increase in mTBI rates was 1.3; in CHIRPP it was 1.3 (when using all injuries as the denominator). Fridman et al.,[13] who only considered the index concussion (as CHIRPP does—only the first visit for an injury is tabulated) reported that in the age group 5 to 18 years, there was a 3.7-fold increase for concussions between 2004 and 2013. For CHIRPP, when only considering concussions,

FIGURE 4
Quebec provincial mTBI rates versus CHIRPP rates in two Montréal hospitals, in males aged 0 to 4 years, 2003–2016

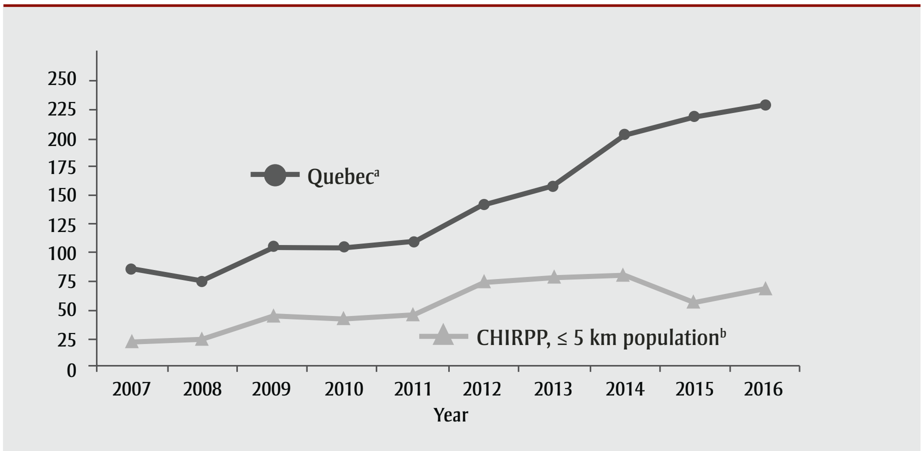


Abbreviations: CHIRPP, Canadian Hospitals Injury Reporting and Prevention Program; mTBI, mild traumatic brain injury.

[a] Quebec provincial mTBI rates per 10 000 males aged 0 to 4 years.

[b] Number of mTBI per 1000 CHIRPP injuries in males aged 0 to 4 years at The Montreal Children's Hospital and Centre hospitalier universitaire mère-enfant Sainte-Justine.

FIGURE 5
Quebec provincial mTBI rates versus CHIRPP rates in two Montréal hospitals, in children aged 13 to 17 years, 2007–2016



Abbreviations: CHIRPP, Canadian Hospitals Injury Reporting and Prevention Program; mTBI, mild traumatic brain injury.

[a] Quebec provincial mTBI rates per 10 000 children aged 0 to 4 years.

[b] Number of mTBI in children aged 13 to 17 living within 5 km of either The Montreal Children's Hospital or Centre hospitalier universitaire mère-enfant Sainte-Justine per 10 000 children aged 13 to 17 years living within 5 km of either hospital.

TABLE 1
Summary of findings regarding the increase in rates of mTBI in the pediatric population, CHIRPP rates compared with rates in various locations, 2003 to 2017

				CHIRPP rates in the same time period	
	Age	Period	Fold increase	CHIRPP all[a] Fold increase	CHIRPP ≤ 5km[b] Fold increase
Ambulatory visits, United States[23]	6–21	2007–13	4.0	1.7	1.3
Private insurer, United States[15]	0–17	2004–13	1.7	1.4	—
ED visits, United States[25]	0–17	2006–13	1.3	1.3	—
ED visits, United States[12]	12–18	2005–15	1.4	2.0	—
NEISS[20]	0–10	2007–11	1.6	1.2	1.1
Private insurer, United States[18]	0–4	2007–14	no variation	no variation	no variation
	5–9		2.3	1.5	1.5
	10–14		2.9	2.1	2.2
	15–19		2.2	2.4	3.0
ED visits, United-States[11]	0–4	2006–12	1.2	no variation	—
	5–9		1.4	1.1	—
	10–14		1.7	2.1	—
	15–19		2.0	2.4	—
Private insurer, United States[26]	0–9	2010–15	1.2	1.1	1.0
	10–19		1.7	1.6	1.4
All visits, Ontario[14]	5–18	2003–13	1.8	1.5	—
Ontario, only index concussions (all visits)[13]	5–18	2004–13	3.7	3.7	—
	5–18	2007–13	3.7	3.5	5.6

Abbreviations: CHIRPP, Canadian Hospitals Injury Reporting and Prevention Program; ED, emergency department; NEISS, National Electronic Injury Surveillance System.

Note: — Unavailable for the given period.

[a] Calculated using all CHIRPP injuries as denominator.

[b] Calculated using population living within 5 km of either of two provincially designated pediatric trauma centres in Montréal (The Montreal Children's Hospital at McGill University Health Centre, and Centre hospitalier universitaire mère-enfant Sainte-Justine).

the fold increase was also 3.7 (using all CHIRPP injuries as the denominator).

One advantage of CHIRPP is that it only considers the first visit for an injury and discards any follow-up consultations, thus providing true rates of injuries, rather than reporting on utilization of medical services. Conclusions drawn from administrative data that include all visits by the same patient for the same injury, introduce a significant bias for anyone wanting to comment on the increased rates of mTBI. While data from the Quebec study[16] confirmed that the number of visits per patient for mTBI remained the same between 2003 and 2016, another from Ontario[13] concluded that follow-up visits, within three months of the first visit for a concussion, tripled between 2003 and 2013 in patients aged 5 to 18 years. Interestingly, if we adjust the rates of the Quebec study[16] down 1.75, the average number of mTBI visits per patient per year (to represent the number of mTBI rather than the number of consultations for an mTBI, as patients consult more than once for the same mTBI) and compare them to CHIRPP's mTBI rates for children living within 5 km of either of the two trauma hospitals, we find that the average rates of mTBI between 2007 and 2016 were quite similar: 106.3 per 10 000 (95% CI: 96.5–116.1) in CHIRPP and 98.2 per 10 000 (95% CI: 91.5–104.8) for Quebec.

As for CHIRPP data, the main limitation when using it as a tool to study yearly fluctuations pertains to patients who consult the ED and leave without being seen (LWBS). The proportions of LWBS vary from one year to the next, from 4.5% to 9.4%, which means that some years, more patients are not recorded in CHIRPP. This, we believe, only impacts the mTBI CHIRPP rates when using the population living within 5 km of either hospital as the denominator; rates calculated using CHIRPP's total injuries would not be affected, we believe, since the proportion of mTBI in those who LWBS remains the same from one year to the next.

Conclusion

Our study suggests that CHIRPP's representativeness of a population may be greater than suggested in earlier studies,[3-9] and our results support the usefulness of CHIRPP as a surveillance tool and its capacity to identify fluctuations in injuries within the population.

The data were limited to the two CHIRPP centres in Montréal, and we cannot say if other CHIRPP centres in Canada would produce similar results. Further research could answer these questions more definitively, but so far, there is encouraging evidence that CHIRPP rates are representative of the population.

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Conflicts of interest

The authors declare they have no conflicts of interest.

Authors' contributions and statement

Four authors contributed to this manuscript: Glenn Keays, Debbie Friedman, Isabelle Gagnon and Marianne Beaudin. GK drafted the manuscript, and all authors contributed to its revision. GK analyzed the data and DF, IG and MB contributed to the development and revisions. GK takes responsibility for the paper as a whole.

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

Age at first alcohol use predicts current alcohol use, binge drinking and mixing of alcohol with energy drinks among Ontario Grade 12 students in the COMPASS study

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Abstract

Introduction: This study investigates the influence of age at first use of alcohol on current alcohol use and associated behaviours in a large sample of Canadian youth.

Methods: This descriptive-analytical study was conducted among Ontario Grade 12 students enrolled in the COMPASS Host Study between 2012 and 2017. We used generalized estimating equations (GEE) modelling to determine associations between age at first alcohol use and likelihood of current versus non-current alcohol use, binge drinking and mixing of alcohol with energy drinks among respondents.

Results: Students reporting an age at first alcohol use between ages 13 and 14 years were more likely to report current alcohol use versus non-current use (OR = 2.80, 95% CI: 2.26–3.45) and current binge drinking versus non-current binge drinking (OR = 3.22, 95% CI: 2.45–4.25) compared to students reporting first alcohol use at age 18 years or older. Students who started drinking at 8 years of age or younger were more likely to report current versus non-current alcohol use (OR = 3.54, 95% CI: 2.83–4.43), binge drinking (OR = 3.99, 95% CI: 2.97–5.37), and mixing of alcohol with energy drinks (OR = 2.26, 95% CI: 1.23–4.14), compared to students who started drinking at 18 years or older.

Conclusion: Starting to drink alcohol in the early teen years predicted current alcohol use, current binge drinking and mixing of alcohol with energy drinks when students were in Grade 12. Findings indicate a need for development of novel alcohol prevention efforts.

Keywords: *youth, alcohol, initiation, first drink, binge drinking, public health*

Highlights

- Prevalence of current alcohol use among Grade 12 students ranged between 45% and 53% across the six-year study period.
- Students who started drinking between the ages of 13 and 14 years were nearly 3 times more likely to drink alcohol and over 3 times more likely to binge drink in Grade 12 compared to those who started drinking at age 18 years or older.
- Students who started drinking at age 8 years or younger were nearly 3.5 times more likely to drink alcohol and 4 times more likely to binge drink in Grade 12 compared to those who started drinking at 18 years of age or older.

Introduction

Alcohol use in adolescents negatively affects their mental and physical development;[1] peer and parental alcohol use are key influences on such behaviour.[2] For these reasons, the minimum legal drinking age has been set at 18 years for Alberta, Quebec and Manitoba, and at 19 years for all other Canadian provinces and territories. Psychosocial factors including pubertal changes, emotional vulnerability and sensation-seeking behaviour have been shown to promote alcohol use in adolescents who are transitioning to high school.[2,3] Using data from the Mental Health Supplement of the Ontario Health Survey, DeWit and colleagues[4] demonstrated associations between early age at first use of alcohol and development of lifetime alcohol abuse and dependence at 10 years since first use of alcohol. Survival analyses showed that respondents who had their first drink of alcohol between ages 13 and 14 were five times more likely to develop alcohol abuse than those who started to drink at 19 years or older.[4] Respondents who reported first drinking between ages 11 and 12 were over nine times more likely to develop alcohol dependence than those who started to drink at 19 years or older.[4]

Binge drinking, or the consumption of five or more alcoholic drinks on one occasion,[5] has been associated with lower academic performance and other risk behaviours including smoking and the use of illicit drugs.[6] Data from the Canadian Community

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Health Survey showed that, of youth aged between 12 and 17 years, 4.2% (n = 94 300) reported engaging in heavy drinking in 2017, and 3.4% (n = 77 100) reported engaging in heavy drinking in 2018.[7] Data from the Youth Risk Behaviour Survey further suggested that while binge drinking rates were similar among girls and boys, rates rose with increasing age and grade level.[6] Binge drinking during adolescence has also been predictive of binge drinking into early adulthood. Data from the National Longitudinal Survey of Youth indicated that binge drinking between 17 and 20 years of age increased the relative risk of binge drinking between 30 and 31 years of age by over twofold for males and over threefold for females.[8] Mixing of alcohol with energy drinks has also been associated with increased alcohol intake per drinking occasion,[9] and is deemed a strong indicator of risk-taking behaviour among youth.[10] Additional studies have shown associations between early adolescent alcohol use and alcohol-related injuries,[11] as well as increased likelihood of alcohol dependence later in life.[12]

Other indicators of health status also compound early initiation of alcohol use in youth. Findings from the first cycle of the COMPASS Host Study showed that students who smoked were 61% more likely to use alcohol and had a twofold increased likelihood of binge drinking, while students who used marijuana had a tenfold increased likelihood of using alcohol and a twelvefold increased likelihood of binge drinking.[13] Students who were physically active according to Health Canada guidelines were also 29% more likely to use alcohol and 35% more likely to engage in binge drinking, suggesting a strong influence of schools' sporting culture on alcohol use behaviours among youth.[13] There was no difference in likelihood of current alcohol use or current binge drinking between males and females.[13] From a resilience perspective, resources that protect against youth binge drinking can be grouped into factors that include the strength of personal relationships[14] and school structure.[15]

The goal of the current study was to gain knowledge about youth who use alcohol, specifically on predictors of their alcohol use and related behaviours within the current policy environment. To our knowledge, this paper is the first to investigate whether age at first alcohol use predicts current alcohol use, binge drinking or mixing of alcohol with energy drinks among a large sample of Canadian youth.

Methods

Study description

The COMPASS Host Study is a prospective cohort study (2012 to 2021) designed to collect data from a convenience sample of Canadian secondary schools and the students between Grades 9 and 12 who attend these schools. Annual student-level assessments are made on rates of alcohol use, marijuana and tobacco use, obesity, school connectedness, bullying, academic achievement and mental health via the COMPASS Student Questionnaire, described elsewhere.[16] Comprehensive details on the COMPASS Host Study, including sampling, data collection and linkage process, are available online (www.compass.uwaterloo.ca). Ethics approval for this study was obtained from the University of Waterloo's Office of Research Ethics (ORE # 17264) and respective school boards.

Sample

In our investigation, we used data from Ontario Grade 12 students in year 1 (2012) through year 6 (2017) of the COMPASS Host Study. The inclusion criteria comprised all English-speaking school boards that had secondary schools with Grades 9 through 12 and a student population of at least 100 students or greater per grade level; had schools that operated in a standard school/classroom setting; and permitted the use of active-information passive-consent parental permission protocols.[16] We approached all school boards meeting the inclusion criteria.

There were 5699 participating Grade 12 students (from 43 schools) in year 1; 9370 (from 79 schools) in year 2; 8322 (from 78 schools) in year 3; 8046 (from 72 schools) in year 4; 7146 (from 68 schools) in year 5; and 6505 (from 61 schools) in year 6. Study participation rates in each year ranged from 78% to 82%, with the primary reasons for non-response being absenteeism or scheduled spare at the time of survey. Students with missing data on any of the study variables were removed, resulting in a final sample of 4813 Grade 12 students in year 1; 7749 in year 2; 6736 in year 3; 6470 in year 4; 5685 in year 5; and 5389 in year 6.

Measures

Demographics, alcohol use behaviours and risk factors were queried via the COMPASS Student Questionnaire. To assess sex, students were asked, "Are you female or male?" To assess ethnicity, students were asked, "How would you describe yourself?" Responses were grouped as: *White* for "White"; and *non-White* for "Black" or "Asian" or "Off-Reserve Aboriginal" or "Latin American/Hispanic" or "Mixed/Other." To assess levels of school connectedness, we used a six-item derived measure. These items assessed students' agreement with the following statements, as previously reported:[15] "I feel close to people at my school"; "I feel I am part of my school"; "I am happy to be at my school"; "I feel the teachers at my school treat me fairly"; "I feel safe in my school"; and "Getting good grades is important to me." Scores range between 6 and 24, with higher scores indicating higher levels of school connectedness. Cronbach's α for this measure was 0.83.

To assess age at first alcohol use, students were asked, "How old were you when you first had a drink of alcohol that was more than a sip?" Responses were grouped as: age 8 years or younger; 9–10 years; 11–12 years; 13–14 years; 15–16 years; 17 years; and 18 years or older. To assess alcohol use, students were asked, "In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?" Responses were grouped in three categories: *Current* for "Once a month" or "2 or 3 times a month" or "Once a week" or "2 to 3 times a week" or "4 to 6 times a week" or "Every day"; *Non-current* for "I did not drink alcohol in the last 12 months" or "I have only had a sip of alcohol" or "Less than once a month"; and *Never* for "I have never drunk alcohol." To assess binge drinking behaviour, students were asked, "In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?" Responses were grouped as: *Current* for "Once a month" or "2 to 3 times a month" or "Once a week" or "2 to 5 times a week" or "Daily or almost daily"; *Non-current* for "I did not have 5 or more drinks on one occasion in the last 12 months" or "Less than once a month"; and *Never* for "I have never done this." To assess mixing of alcohol with energy drinks, students were asked, "In the last 12 months, have you had alcohol mixed or pre-mixed with an energy drink (such as Red Bull, Rock Star, Monster or another brand)?” Responses were grouped as: *Current* for “Yes”; *Non-current* for “I did not do this in the last 12 months”; and *Never* for “I have never done this.”

To assess smoking status, students were asked, “On how many of the last 30 days did you smoke one or more cigarettes?” Responses ranged from “None” to “30 days (every day)” and were grouped in two categories: *Current smoker* for responses ranging from 1 to 30 days; and *Non-smoker* for a response of 0 days. To assess marijuana use, students were asked, “In the last 12 months, how often did you use marijuana or cannabis?” Responses were grouped in three categories: *Current* for “Once a month” or “2 or 3 times a month” or “Once a week” or “2 to 3 times a week” or “4 to 6 times a week” or “Every day”; *Non-current* for “I have used marijuana but not in the last 12 months” or “Less than once a month”; and *Never* for “I have never used marijuana.” To assess levels of physical activity, students were queried on how many minutes of hard and moderate physical activity they did on each of the last seven days. Following the Canadian Society for Exercise Physiology 24-hour movement guidelines, students who completed at least 60 minutes of moderate and/or hard physical activity on each day in the past seven days were classified as *Meeting physical activity guidelines*, while students who completed less than 60 minutes of activity in the past seven days were classified as *Not meeting physical activity guidelines*.

Statistical analyses

We used descriptive statistics to show the distribution of the study variables. Marginal logistic regression using generalized estimating equations (GEE) models were then used to examine whether age at first alcohol use influences current versus non-current alcohol use, binge drinking and mixing of alcohol with energy drinks in the last 12 months among students who drink. Full models were fitted for each outcome. All models controlled for sex (male/female), ethnicity (White or non-White), school connectedness, year of data collection, smoking status, marijuana use and physical activity level, and accounted for within-school clustering.

We fitted GEE models using the SAS PROC GEE procedure with a binomial distribution and a logit function. All models used an exchangeable working correlation structure based on the results of initial analyses. We used empirical standard error estimates to calculate confidence intervals and test statistics. Analyses were conducted using the statistical software package SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Demographics

As shown in Table 1, the most frequently reported age at first alcohol use was between ages 15 and 16 years; proportions ranged between 31.0% and 34.0% across years. An average of 24.5% of Grade 12 students reported an age at first alcohol use between 13 and 14 years of age, while an average of 4.5% reported an age at first use of 8 years of age or younger across years. Among Grade 12 students, prevalence of current alcohol use ranged between 45.0% and 53.0% across years (Figure 1). Prevalence of current alcohol use increased modestly in 2013 ($p = .003$), and steadily declined between 2013 and 2017 ($p < .001$). As shown in Table 2 and Figure 2, prevalence of current binge drinking ranged between 29.0% and 38.0% across years, with steady declines from 2013 to 2017 ($p < .05$). Prevalence of mixing alcohol with energy drinks was highest in 2012 at 26.0%, and steadily declined across years to 17.0% in 2017 ($p < .001$), as shown in Table 2 and Figure 3. Students reported school connectedness scores between 18.0 ± 3.5 and 18.3 ± 3.5 across years (Table 1).

Alcohol use

Compared to students reporting an age at first alcohol use of 18 years or older, students reporting an age at first alcohol use between 13 years and 14 years (odds ratio [OR] 2.80, 95% CI: 2.26–3.45), 11 years and 12 years (OR 2.86, 95% CI: 2.29–3.56), and 8 years or less (OR 3.54, 95% CI: 2.83–4.43) had an increased likelihood of current versus non-current alcohol use (Table 3). For every 1-unit increase in school connectedness, there was an associated 5% increase in likelihood of current alcohol use versus non-current alcohol use (OR 1.05, 95% CI: 1.04–1.06). Boys were more likely to report current versus non-current alcohol use over girls (OR 1.20, 95% CI: 1.12–1.28).

Binge drinking

As shown in Table 3, compared to students with an age at first alcohol use of 18 years or older, students reporting an age at first alcohol use of 16 years or younger were more likely to report current binge drinking over non-current binge drinking (ages 15 to 16 years, OR = 1.97, 95% CI: 1.51–2.55; ages 13 to 14 years, OR = 3.22, 95% CI: 2.45–4.25; ages 11 to 12 years, OR = 2.96, 95% CI: 2.27–3.87; ages 9 to 10 years, OR = 3.36, 95% CI: 2.49–4.54; ages 8 years or younger, OR = 3.99, 95% CI: 2.97–5.37). Boys were more likely to report current binge drinking over non-current binge drinking compared to girls (OR = 1.32, 95% CI: 1.24–1.40). For every 1-unit increase in school connectedness, there was a 3% increase in likelihood of current over non-current binge drinking (OR = 1.03, 95% CI: 1.02–1.04). Students were less likely to report current versus non-current binge drinking between 2015 and 2017, compared to the baseline year of 2012 (2015, OR = 0.82, 95% CI: 0.71–0.94; 2016, OR = 0.81, 95% CI: 0.71–0.93; 2017, OR = 0.68, 95% CI: 0.60-0.78).

Mixing alcohol with energy drinks

Compared to students reporting an age at first alcohol use of 18 years or older, students reporting an age at first alcohol use of 8 years or younger had a twofold increase in the likelihood of current versus non-current mixing of alcohol with energy drinks (OR = 2.26, 95% CI: 1.23–4.14); see Table 3. Boys were more likely to report current versus non-current mixing of alcohol with energy drinks over girls (OR = 1.25, 95% CI: 1.13–1.39). Non-White students were more likely to report current versus non-current mixing of alcohol with energy drinks compared to White students (OR = 1.15, 95% CI: 1.02–1.29). School connectedness did not influence likelihood of current versus non-current mixing of alcohol with energy drinks. Students were less likely to report current versus non-current mixing of alcohol with energy drinks between 2013 and 2017, compared to the baseline year of 2012 (2013, OR = 0.74, 95% CI: 0.63–0.87; 2014, OR = 0.74, 95% CI: 0.63–0.87; 2015, OR = 0.72, 95% CI: 0.61–0.85; 2016, OR = 0.68, 95% CI: 0.58–0.80; 2017, OR = 0.80, 95% CI: 0.66–0.96); see Table 3.

TABLE 1
Demographics of Ontario Grade 12 student respondents in the COMPASS Host Study between 2012 and 2017

		2012		2013		2014		2015		2016		2017	
		N = 4813		N = 7749		N = 6736		N = 6470		N = 5685		N = 5389	
		n	%	n	%	n	%	n	%	n	%	n	%
Sex	**Girls**	2430	50	3916	51	3477	52	3251	50	2938	52	2727	51
	Boys	2383	50	3833	49	3259	48	3219	50	2747	48	2662	49
Ethnicity	**White**	3844	80	6237	80	5392	80	5021	78	4437	78	4085	76
	Non-White[a]	969	20	1512	20	1344	20	1449	22	1248	22	1304	24
Age at first use of alcohol	**≤ 8 years**	217	5	329	4	324	5	300	5	238	4	222	4
	9–10 years	107	2	235	3	152	2	173	3	140	2	121	2
	11–12 years	307	6	451	6	371	6	357	6	335	6	249	5
	13–14 years	1252	26	1978	26	1664	25	1535	24	1319	23	1251	23
	15–16 years	1545	32	2639	34	2217	33	2059	32	1747	31	1754	33
	17 years	218	5	367	5	329	5	327	5	290	5	269	5
	≥ 18 years	47	1	55	1	48	1	67	1	61	1	59	1
	Only a sip/never	1120	23	1695	22	1631	24	1652	26	1555	27	1464	27
Alcohol use in past 12 months	**Current**	2455	51	4102	53	3323	49	3155	49	2669	47	2449	45
	Non-current	1803	37	2676	35	2422	36	2247	35	2019	36	2007	37
	Never	555	12	971	13	991	15	1068	17	997	18	933	17
Binge drinking in past 12 months	**Current**	1783	37	2940	38	2359	35	2189	34	1830	32	1584	29
	Non-current	1488	31	2372	31	2087	31	2005	31	1715	30	1720	32
	Never	1542	32	2437	31	2290	34	2276	35	2140	38	2085	39
Mixing alcohol with energy drinks in past 12 months	**Current**	1270	26	1817	23	1437	21	1290	20	971	17	907	17
	Non-current	446	9	814	11	634	9	556	9	451	8	358	7
	Never	3097	64	5118	66	4665	69	4624	71	4263	75	4130	77
Smoking status	**Current**	695	14	1188	15	1002	15	1059	16	885	16	759	14
	Non-smoker	4118	86	6561	85	5734	85	5411	84	4800	84	4630	86
Marijuana use	**Current**	1084	23	1772	23	1557	23	1488	23	1308	23	1307	24
	Non-current	1162	24	1850	24	1541	23	1480	23	1256	22	1262	23
	Never	2567	53	4127	53	3638	54	3502	54	3121	55	2820	52
Meeting physical activity guidelines	**Yes**	2142	45	3458	45	3039	45	2992	46	2601	46	2193	41
	No	2671	55	4291	55	3697	55	3478	54	3084	54	3196	59
School connectedness[b]	**Mean (SD)**	18.3 (3.2)		18.2 (3.3)		18.2 (3.5)		18.3 (3.5)		18.0 (3.5)		18.0 (3.6)	

[a] Refers to Black, Asian, Off-Reserve Aboriginal, Latin American/Hispanic, and Other/Mixed.
[b] Scores range from 6 to 24, with higher scores indicating higher levels of school connectedness.

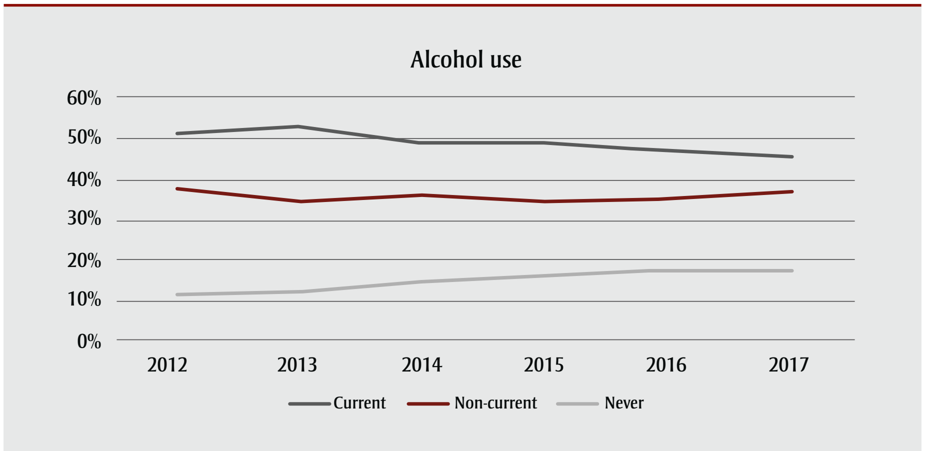
Other indicators of risk

Students who reported current smoking had an increased likelihood of current versus non-current alcohol use (OR = 2.15, 95% CI: 1.93–2.39), current versus non-current binge drinking (OR = 2.37, 95% CI: 2.15–2.60), and current versus non-current mixing of alcohol with energy drinks (OR = 1.57, 95% CI: 1.41–1.76), compared to non-smoking students. Current marijuana users had an increased likelihood of current versus non-current alcohol use (OR = 3.83, 95% CI: 3.49–4.21), current versus non-current binge drinking (OR = 4.12, 95% CI: 3.80–4.48), and current versus non-current mixing of alcohol with energy drinks (OR = 1.54, 95% CI: 1.37–1.73), compared to students who never used marijuana. Physically active students had an increased likelihood of current versus non-current alcohol use (OR = 1.31, 95% CI: 1.24–1.39), and current versus non-current binge drinking (OR = 1.38, 95% CI: 1.30–1.46), compared to relatively inactive students.

Discussion

Our study shows associations between age at first alcohol use and current alcohol use and related behaviours among a large sample of Ontario Grade 12 students. Students who reported first drinking alcohol between ages 13 and 14 years were nearly 3 times more likely to engage in drinking alcohol, and over 3 times more likely to binge drink, compared to those who reported first drinking at age 18 or older. Students who reported first drinking

FIGURE 1
Prevalence of alcohol use among Ontario Grade 12 students in the COMPASS Host Study, 2012–2017



alcohol at age 8 years or younger were 3.5 times more likely to engage in drinking alcohol, nearly 4 times more likely to binge drink, and over 2 times more likely to engage in mixing alcohol with energy drinks than those who reported first drinking at age 18 or older. As evidenced elsewhere,[4] the younger students were at the time of their first use of alcohol, the more likely they were to display current alcohol use and maladaptive patterns of use upon transition to adulthood. While Miller and colleagues[6] showed similar rates of binge drinking among boys and girls in high school, results from the present study showed that boys in Grade 12 were more likely to engage in binge drinking and mixing of alcohol with energy drinks than girls. As indicated in previous work,[13] students who smoked, used marijuana and were physically active were more likely to use alcohol, display binge drinking, and engage in mixing alcohol with energy drinks. Moreover, increasing levels of school connectedness among these Grade 12 students were found to increase likelihood of drinking alcohol and binge drinking, indicating the potential influence of peer drinking networks within the school environment.[2] Our study also showed that physically active Grade 12 students and Grade 12 students with higher levels of school connectedness were more likely to use alcohol and binge drink. While resilience frameworks have shown associations between measures of school connectedness and alcohol use behaviours among youth,[6,17,18] we hypothesize that such associations may show a nonlinear, U-shaped relationship. Consistently high school connectedness may be indicative of other factors, such as involvement in school sports,[19] which has been linked to increased likelihood of alcohol use.[13,15]

Prevalence of current alcohol consumption was relatively high among the sample of Grade 12 students, with rates above 45% across years. Prevalence of current binge drinking among these students was also relatively high, with rates fluctuating between 29% and 38% across years. Modest declines in rates of binge drinking from 2012 through 2017 may be attributed to relative increases in students who reported never binge drinking, as the proportion of students reporting non-current binge drinking remained stable. While not evaluative, declines in binge drinking rates have paralleled emphasis on municipal alcohol policies by Public Health Ontario,[20] along with a focus on alcohol-related injuries by the Alcohol Locally Driven Collaborative Project (LDCP) Team.[21]

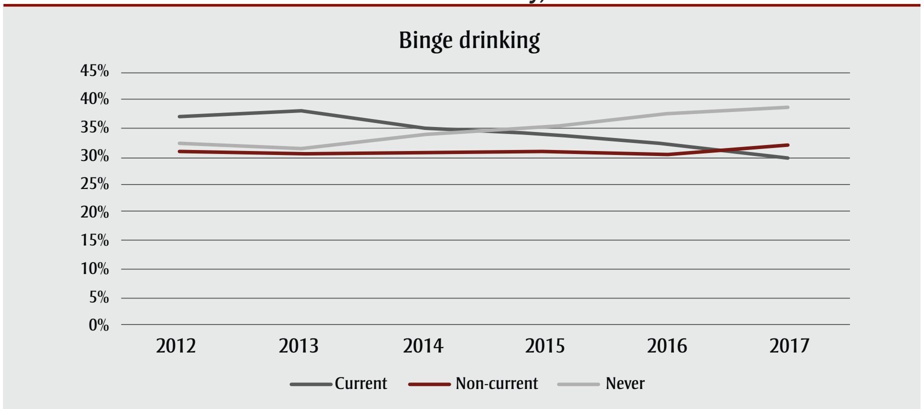
Mixing of alcohol with energy drinks has been considered a marker for risk-taking behaviour,[10] with a meta-analysis showing that consumers who combined alcohol with energy drinks over alcohol alone tended to consume more alcohol per drinking occasion.[9] Health Canada regulations for food and natural products manufacturers stipulates labelling of energy drinks with text including "not recommended for children" and "do not mix with alcohol." The deadline for compliance with this labelling regulation was

TABLE 2
Prevalence of alcohol use, binge drinking, and mixing of alcohol with energy drinks in the past 12 months among Ontario Grade 12 students in the COMPASS Host Study, 2012–2017

		2012 (%)	2013 (%)	*p*-value[a]	2014 (%)	*p*-value[a]	2015 (%)	*p*-value[a]	2016 (%)	*p*-value[a]	2017 (%)	*p*-value[a]
Alcohol use in past 12 months	**Current**	51	53		49		49		47		45	
	Non-current	37	35	.003	36	< .001	35	< .001	36	< .001	37	< .001
	Never	12	13		15		17		18		17	
Binge drinking in past 12 months	**Current**	37	38		35		34		32		29	
	Non-current	31	31	.592	31	.040	31	< .001	30	< .001	32	< .001
	Never	32	31		34		35		38		39	
Mixing alcohol with energy drinks in past 12 months	**Current**	26	23		21		20		17		17	
	Non-current	9	11	< .001	9	< .001	9	< .001	8	< .001	7	< .001
	Never	64	66		69		71		75		77	

[a] *p*-value is for test of difference versus baseline 2012 year.

FIGURE 2
Prevalence of binge drinking among Ontario Grade 12 students in the COMPASS Host Study, 2012–2017

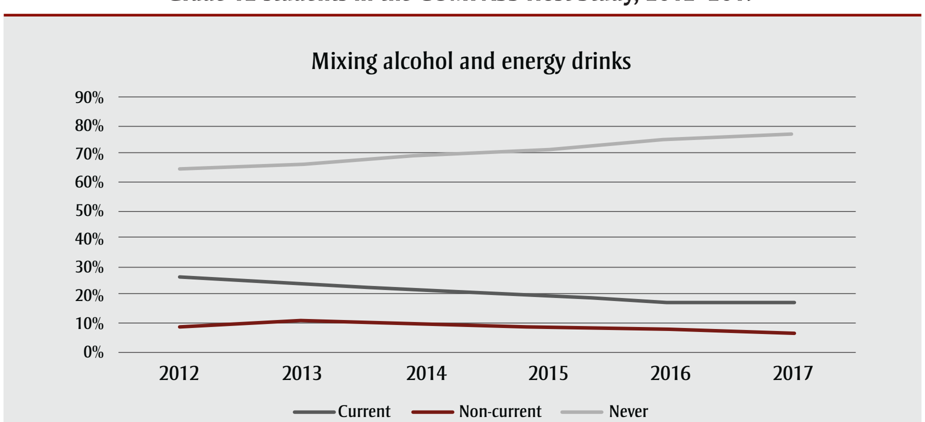


December 2013. Prevalence of mixing alcohol with energy drinks among Grade 12 students was below 30% in 2012 and steadily declined thereafter. Natural experiments would show whether the decline could have resulted from this policy; regardless, a near 10% decrease in prevalence across six years shows promise for future cross-sectoral strategies for prevention and cessation programming.[22]

Strengths and limitations

Our study utilized a large sample of Grade 12 students from a convenience sample of schools in the province of Ontario. COMPASS is a prospective cohort study (2012 to 2021) collecting data from a convenience sample of secondary schools and the students between Grades 9 and 12 who attend these schools. COMPASS utilizes purposive sampling for recruitment of participating schools from different geographical regions.[16] While this approach may impact external validity, data are comparable with other large-scale surveys on alcohol use and binge drinking prevalence among Canadian youth—namely, the Canadian Community Health Survey (2009/2010) and the Canadian Alcohol and Drug Monitoring Survey[23] and the Canadian Student Tobacco, Alcohol and Drugs Survey.[24] Data from the COMPASS Host Study's student questionnaire are self-reported, and though bias may have been introduced through self-report, this method provides an emic representation of students' health behaviours. The data collection procedures further limit social desirability bias by using an active-information, passive-consent permission approach, which has been found to maintain confidentiality and minimize underreporting.[25] While the repeat cross-sectional design of our study also accounts for changes in the sample over time, interpretation of findings may only be relevant to a substantive proportion of Grade 12 students.

FIGURE 3
Prevalence of mixing of alcohol with energy drinks among Ontario Grade 12 students in the COMPASS Host Study, 2012–2017



Conclusion

There is a high prevalence of alcohol use among Grade 12 students in Ontario, with relative stability across a six-year time period. Binge drinking rates peaked and modestly declined across years, while mixing of alcohol with energy drinks generally decreased across years. An age at first alcohol use of 14 years or younger predicted current alcohol use among Grade 12 students. An age at first alcohol use of 16 years or younger predicted current binge drinking, while an age at first use of 12 years or younger predicted mixing of alcohol with energy drinks among Grade 12 students. Findings indicate a need for novel approaches for alcohol prevention and cessation programming for youth.

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Conflicts of interest

The authors have no conflicts of interest to report.

Authors' contributions and statement

SH conceptualized the study and wrote the manuscript. KB conducted the data analyses. SL designed the survey and collected the study data. All authors contributed to the interpretation of the findings and development of manuscript drafts, and approved the final version of the 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.

TABLE 3
GEE binomial logistic regression models examining the influence of age at first use of alcohol on current versus non-current alcohol use, binge drinking, and mixing of alcohol with energy drinks in the past 12 months among Ontario Grade 12 students in the COMPASS Host Study who drink, 2012–2017

		Current vs. non-current[a] alcohol use (n = 27 725)			Current vs. non-current[a] binge drinking (n = 24 072)			Current vs. non-current[a] mixing of alcohol with energy drinks (n = 10 506)		
		OR	95% CI		OR	95% CI		OR	95% CI	
			Lower	Upper		Lower	Upper		Lower	Upper
Sex	Girls									
	Boys	1.20	1.12	1.28	1.32	1.24	1.40	1.25	1.13	1.39
Ethnicity	White									
	Non-White	0.81	0.75	0.88	0.94	0.84	1.05	1.15	1.02	1.29
Year of collection	2012									
	2013	1.04	0.91	1.17	0.99	0.87	1.14	0.74	0.63	0.87
	2014	0.89	0.80	0.99	0.87	0.77	0.99	0.74	0.63	0.87
	2015	0.90	0.80	1.00	0.82	0.71	0.94	0.72	0.61	0.85
	2016	0.89	0.79	0.99	0.81	0.71	0.93	0.68	0.58	0.80
	2017	0.80	0.69	0.93	0.68	0.60	0.78	0.80	0.66	0.96
Age at first use of alcohol	≥ 18 years									
	≤ 8 years	3.54	2.83	4.43	3.99	2.97	5.37	2.26	1.23	4.14
	9–10 years	2.81	2.15	3.67	3.36	2.49	4.54	1.39	0.75	2.59
	11–12 years	2.86	2.29	3.56	2.96	2.27	3.87	1.73	0.97	3.10
	13–14 years	2.80	2.26	3.45	3.22	2.45	4.25	1.51	0.85	2.68
	15–16 years	1.69	1.39	2.06	1.97	1.51	2.55	1.43	0.80	2.53
	17 years	0.73	0.60	0.90	0.93	0.69	1.27	1.48	0.81	2.69
Smoking status	Non-smoker									
	Current	2.15	1.93	2.39	2.37	2.15	2.60	1.57	1.41	1.76
Marijuana use	Never									
	Non-current	1.90	1.76	2.05	2.01	1.89	2.14	1.13	1.01	1.27
	Current	3.83	3.49	4.21	4.12	3.80	4.48	1.54	1.37	1.73
Meeting physical activity guidelines	No									
	Yes	1.31	1.24	1.39	1.38	1.30	1.46	1.06	0.96	1.16
School connectedness[b]		1.05	1.04	1.06	1.03	1.02	1.04	0.99	0.98	1.00

Abbreviations: GEE, generalized estimating equation; OR, odds ratio.
Note: Reference categories are "Girls," "White," "2012," "≥ 18 years of age," "Non-smoker," "Never" and "No."
[a] Never users were excluded.
[b] Scores range from 6 to 24, with higher scores indicating higher levels of school connectedness.

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At-a-glance

Twenty years of diabetes surveillance using the Canadian Chronic Disease Surveillance System

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Tweet this article

Abstract

In 1999, the Government of Canada, along with the provinces and territories, established the National Diabetes Surveillance System (NDSS) to track rates of diabetes in Canada. The NDSS used a novel method to systematically collect and report national diabetes data using linked administrative health databases. The NDSS has since evolved to become the Canadian Chronic Disease Surveillance System (CCDSS) and provides information on over 20 chronic conditions. This At-a-glance report provides the most up-to-date CCDSS information on diabetes rates in Canada. Currently, 8.8% of Canadians (9.4% male, 8.1% female, aged one year and older) live with diabetes, and approximately 549 new cases are diagnosed each day. Since 2000, the age-standardized prevalence rate has increased by an average of 3.3% per year. The age-standardized incidence rate has remained relatively stable, and all-cause mortality rates among those with diabetes have decreased by an average of 2.1% per year. This suggests that people are living longer with a diabetes diagnosis.

Highlights

- The Canadian Chronic Disease Surveillance System has provided important information on diabetes rates in Canada since 2000.
- Currently, 8.8% of Canadians (9.4% male, 8.1% female, aged one year and older) live with diabetes.
- The age-standardized prevalence rate of diabetes has increased over time, whereas the age-standardized incidence rate has remained stable.
- The all-cause mortality rate among those with diabetes has decreased, suggesting people are living longer with a diabetes diagnosis.

Introduction

Diabetes mellitus is a metabolic disorder characterized by impaired insulin secretion or action, resulting in hyperglycemia. Diabetes can result in a range of long-term complications such as cardiovascular disease, retinopathy, nephropathy, neuropathy, amputations and decreased life expectancy.[1] The majority of diabetes cases can be classified into one of two categories: type 1 diabetes or type 2 diabetes. In the general population, it is estimated that approximately 90% of all diabetes diagnoses are type 2 diabetes, 9% are type 1 diabetes and 1% are other types of diabetes (e.g. gestational diabetes, other specific types related to gene or drug interactions).[1] Type 1 diabetes is an autoimmune disease and cannot be prevented.[1] Type 2 diabetes occurs due to a wide range of social, environmental and genetic factors.[1,2] Risk factors for type 2 diabetes include obesity, unhealthy diet (e.g. high in ultra-processed foods), physical inactivity, lower socioeconomic status, increased age and ethnicity (e.g. increased risk among Black Canadians, South Asian Canadians, and Indigenous peoples).[2,3] Data from the Canadian Health Measures Survey suggest approximately 7.3% of Canadians (aged 12 years and older) are living with diabetes. However, this is based on self-report data and may be an underestimation.[4]

To respond to the challenge of diabetes in Canada, the Government of Canada, along with provinces and territories, established the National Diabetes Surveillance System (NDSS) in 1999.[5,6] Specifically, the NDSS was established to enable ongoing surveillance of diabetes and its complications; to create a national standardized database through the integration of new and existing databases; to disseminate national comparative information to inform effective prevention and treatment strategies for diabetes; and to provide a basis for evaluating economic or cost-related issues regarding the care, management and treatment of diabetes in Canada.[5] Since it was launched, the NDSS has evolved to become the Canadian Chronic Disease Surveillance System (CCDSS), now under the responsibility of the Public Health Agency of Canada (PHAC), and is able to provide information on 20 chronic conditions.[5] The CCDSS has been used previously to report on trends over time for chronic disease in Canada, including incidence, mortality and multimorbidity.[7-10] The CCDSS first reported on diabetes in 2000; thus, 2019 marks 20 years of diabetes surveillance using the CCDSS. This work provides information on trends in diabetes prevalence, incidence and all-cause mortality in Canada since the inception of the CCDSS.

Methods

The Canadian Chronic Disease Surveillance System

Through the CCDSS, provincial and territorial health insurance registry records are

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linked using a unique personal identifier to the corresponding physician billing claims, hospital discharge abstract records and prescription drug records to provide information on incidence, prevalence and mortality.[11-13] Data on identified disease cases are extracted by each province and territory using a standard analytical approach, based on case definitions for each CCDSS disease or condition. Individual-level data are aggregated at the provincial or territorial level before submission to PHAC to protect patient privacy. Data are collected and updated on a regular basis and provide information by age group, sex, province/territory and trends over time. The CCDSS provides data for all Canadians who are eligible for provincial or territorial health insurance—approximately 97% of the population.

Diabetes case definition

Canadians aged 1 year and older are identified as having diagnosed diabetes if they have at least one hospitalization record, or at least two physician claims in a two-year period with an ICD (International Statistical Classification of Diseases and Related Health Problems) code for diabetes. The current case definition is unable to distinguish between type 1 and type 2 diabetes and reports on both types combined. Prevalence is lifetime prevalence and incidence is the first time the patient meets the criteria for diabetes. Valid ICD codes are: ICD-9-CM: 250, and ICD-10-CA: E10, E11, E12, E13, E14. To account for diabetes during pregnancy, records containing codes for diabetes are removed for women aged 10 to 54 years for 120 days preceding and 190 after hospital records containing any pregnancy or obstetrical code. Some provinces and territories have additional exclusions: data from Nova Scotia for individuals aged 1 to 19 are excluded; data from Yukon are excluded before 2010/11; data from Nunavut are excluded before 2005/06; data from Saskatchewan are not available for 2016/17. Additional details on the diabetes case study can be found on the CCDSS online data tool (https://health-infobase.canada.ca/ccdss/data-tool/)[3] and elsewhere.[5]

Statistical analysis

CCDSS data presented here are current as of March 2019 and include Canadians aged 1 year and older with diagnosed type 1 and type 2 diabetes combined, excluding gestational diabetes. Data are presented for each fiscal year (i.e. April 1 to March 31). Crude rates were based on randomly rounded counts to an adjacent multiple of 10. Age-standardized rates are based on nonrounded counts and standardized to the 2011 final postcensal Canadian population released in 2013 using life-course age groups. Mortality rate ratio was calculated by dividing the all-cause mortality rate among individuals with diabetes by the all-cause mortality rate among individuals without diabetes. A rate ratio greater than one indicates that individuals with the disease experience a higher mortality burden compared to individuals without the disease, regardless of the cause of death. Assuming the baseline age-standardized mortality rates between those with and without the disease are similar, the difference in their all-cause mortality represented by the rate ratio can be attributed to deaths directly or indirectly related to the disease. Additional details can be found online in the CCDSS summary of methods (https://health-infobase.canada.ca/ccdss/data-tool/Methods).

We used Joinpoint software to run piecewise regression models to calculate change in age-standardized rates over time and identify any statistically significant changes in trends from 2000/01 to 2016/17 (Joinpoint software version 4.2.0.2, National Cancer Institute, Bethesda, MD, USA). This allowed us to identify time periods where the annual percent change differed significantly. The maximum number of joinpoints was set at four. The minimum number of observations from a joinpoint to the start or end of the data and the minimum number of observations between joinpoints were set at four. Age-standardized rates account for differences in age structure of the population over time. We used SAS version 9.3 (SAS Institute Inc., Cary, NC, USA) for all other statistical analysis. Significance was set at $p < .05$.

Results and discussion

Rates of diabetes are shown in Table 1. In 2016/17, approximately 8.8% of Canadians (9.4% male, 8.1% female, aged ≥ 1 year) were living with diabetes. Diabetes prevalence was higher in adults than in children and youth (10.9% vs. 0.3%). This means that in 2016/17, approximately 3.2 million Canadians were living with diabetes (Figure 1-A); or approximately 1 in 11 adults (aged ≥ 20 years) and 1 in 333 children and youth (aged 1–19 years). Since 2000/01, age-standardized prevalence rates have increased by an average of 3.3% per year ($p < .001$; Figure 1-A). The greatest increase averaged 5.3% between 2000/01 and 2006/07 ($p < .001$). From 2006/07 to 2010/11, the age-standardized prevalence rate increased an average of 3.3% per year ($p < .001$); from 2010/11 to 2016/17, the age-standardized prevalence rate increased an average of 1.2% per year ($p < .001$).

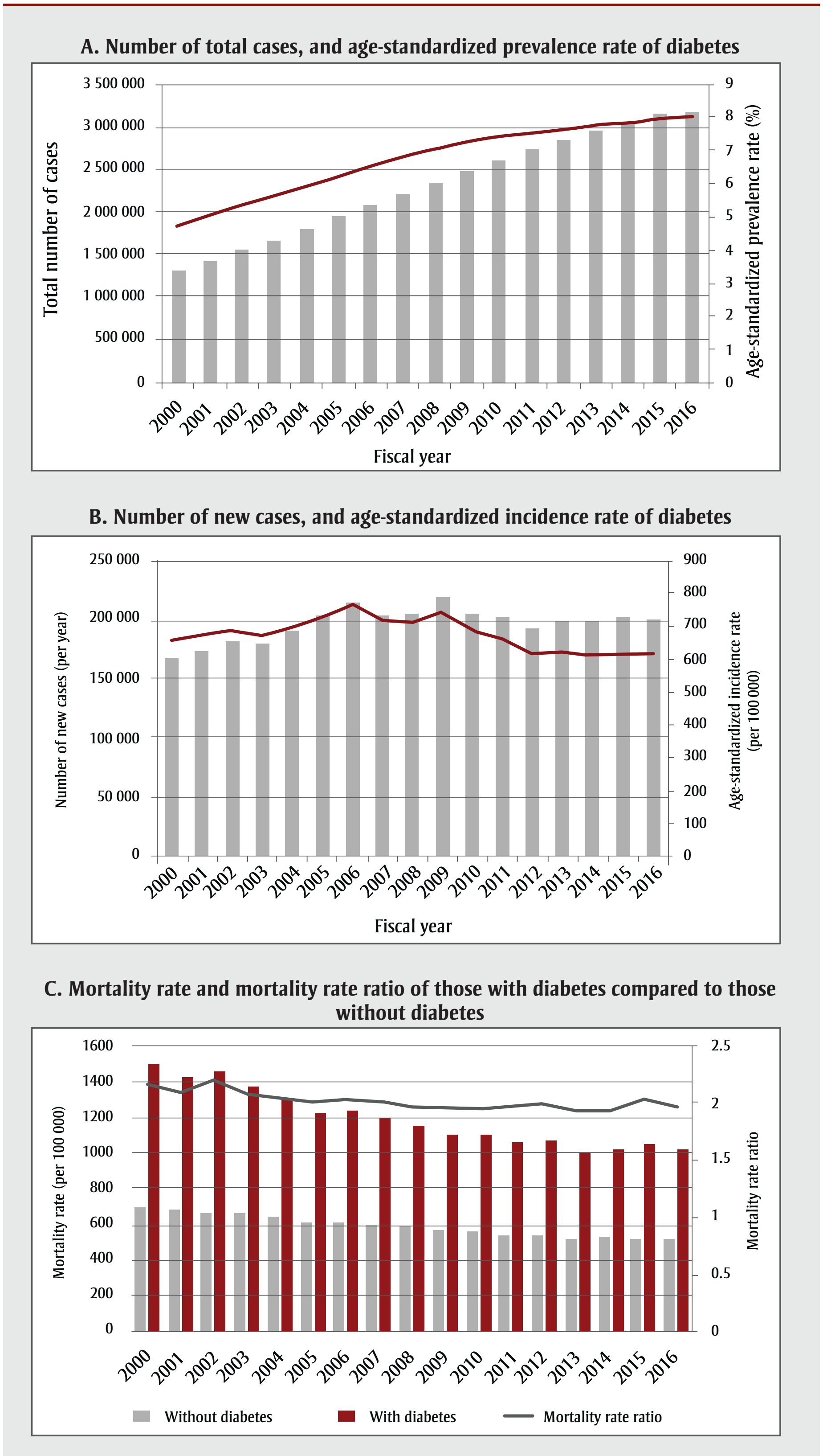
In 2016/17, the rate of newly diagnosed diabetes cases was 603.5 per 100 000 Canadians (aged ≥ 1 year). This is approximately 200 400 new cases per year, or

TABLE 1
Diabetes rates in Canada, Canadian Chronic Disease Surveillance System, 2016/17

Indicator	Total	Male	Female
Prevalence (n,%)			
Total population (aged ≥ 1 year)	3 170 969 (8.8)	1 686 700 (9.4)	1 484 260 (8.1)
Children (aged 1–19 years)	24 330 (0.3)	12 700 (0.3)	11 630 (0.3)
Adults (aged ≥ 20 years)	3 146 630 (10.9)	1 674 010 (11.8)	1 472 630 (10.0)
Incidence (n, rate per 100 000)			
Total population (aged ≥ 1 year)	200 400 (603.5)	109 230 (667.9)	91 160 (540.9)
Children (aged 1–19 years)	3 070 (42.1)	1 530 (40.9)	1 540 (43.3)
Adults (aged ≥ 20 years)	197 330 (761.5)	107 700 (853.7)	89 630 (674.0)
Mortality rate ratio (total population, aged ≥ 1 year; 95% CI)	1.96 (1.91, 2.02)	1.80 (1.74, 1.85)	2.11 (2.00, 2.23)

Abbreviation: CI, confidence interval.
Notes: Data are current as of March 2019 and include diagnosed type 1 and type 2 diabetes combined, but exclude gestational diabetes. Data from Nova Scotia for individuals aged 1–19 years are excluded; data from Yukon are excluded before 2010/11; data from Nunavut were excluded before 2005/06; data from Saskatchewan are not available for 2016/17.

FIGURE 1
Trends in diabetes rates from 2000/01 to 2016/17



Data source: Canadian Chronic Disease Surveillance System (CCDSS).
Notes: Data are current as of March 2019 and include diagnosed type 1 and type 2 diabetes combined, but exclude gestational diabetes. Data from Nova Scotia for individuals aged 1–19 are excluded; data from Yukon are excluded before 2010/11; data from Nunavut were excluded before 2005/06; data from Saskatchewan are not available for 2016/17.

549 new cases per day (Figure 1-B). From 2000/01 to 2006/07, the age-standardized incidence rate increased by an average of 2.2% per year ($p < .001$); from 2006/07 to 2016/17, the age-standardized incidence decreased by an average of 2.2% per year ($p < .001$). This means that throughout the surveillance period, age-standardized incidence rates have remained relatively stable (average annual percent change: −0.5, $p = .10$). In 2016/17, the all-cause mortality rate for those with diabetes was 1020.6 per 100 000, compared to 519.5 per 100 000 for those without diabetes (Figure 1-C). From 2000/01 to 2016/17, there was a decrease in the all-cause mortality rate (average annual percent change: −2.1, $p < .001$). This was especially pronounced from 2000/01 to 2013/14, when the all-cause mortality rate decreased by 2.9% ($p < .001$). From 2013/14 to 2016/17 there was no change (annual percent change: 1.7%, $p = .30$). Compared to those without diabetes, the mortality rate ratio for those with diabetes is approximately 1.96 (95% CI: 1.91, 2.02) times higher.

Strengths and limitations

Compared to other surveillance systems or surveys, the CCDSS provides several advantages. Namely, the CCDSS is able to collect incidence data (more sensitive to changes in the epidemiology of the disease than prevalence); examine trends over time; produce comparable data across provinces and territories (see https://health-infobase.canada.ca/ccdss/data-tool and search "diabetes" and "geographic comparisons"); and include population-level data based on medically diagnosed diseases or conditions. The main limitation of this work is that the current case definition is not able to differentiate between type 1 and type 2 diabetes. The CCDSS is also limited to diagnosed diabetes among health service users. This may underestimate prevalence due to subclinical or undiagnosed diabetes. This work did not examine the influence of other contextual factors that may impact changes in rates over time (e.g. why there were differences in the annual percent change). Future work should continue to refine the case definition for diabetes, including the possibility of including prescription drug databases.[14] It would also be beneficial to examine contextual factors that may influence rates of diabetes in Canada. Future work could also examine multimorbidity status, as well as calculate costs associated with various diseases.

Conclusion

The CCDSS and its unique architecture provide rich data on chronic diseases and conditions in Canada. Over the past 20 years, PHAC, in partnership with all provinces and territories, has been able to report on diabetes rates in Canada. This report provides the most up-to-date information on diabetes prevalence, incidence and mortality in Canada. In 2016/17, 8.8% of Canadians were living with diabetes. That includes approximately 1 in 11 adults, and 1 in 333 children and youth. Approximately 549 new cases are diagnosed every day. The age-standardized prevalence rate of diabetes has increased over time, whereas the age-standardized incidence rate has remained relatively stable. This may be due, in part, to the fact that people are living longer with the disease, as can be seen in the decline in mortality rate over time. However, mortality risk is much higher among those with diabetes than those without the disease, and diabetes remains one of the major chronic diseases in Canada.

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Conflicts of interest

The authors declare no conflicts of interest.

Authors' contributions and statement

AGL conceived of the manuscript and wrote the first draft. AGL and YJG completed the statistical analysis. All authors critically reviewed and provided comments on all aspects of the paper. All authors approved the final version of this work.

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

Cancer trends in Canada, 1984 to 2015

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Abstract

Examining incidence trends of all cancers combined in order to understand cancer trends can be misleading, as patterns can vary across individual cancer types. This paper highlights findings on trends over time from *Canadian Cancer Statistics 2019*, as measured by the annual percent change (APC) of age-standardized incidence rates. Among the results were a recent increase in thyroid cancer in males (APC: 6.4%, 1997–2015), as well as decreases in prostate cancer (APC: −9.1%, 2011–2015) and cervical cancer (APC: −3.3%, 2010–2015).

Keywords: *neoplasms, data analysis, trend, cancer*

Highlights

- The incidence of some cancers is changing rapidly in Canada.
- Recent trends show increasing rates of thyroid cancer in males, drawing attention to the potential impact of overdiagnosis.
- Prostate cancer incidence is decreasing rapidly, likely reflecting recent changes in screening guidelines.

Introduction

Chronic disease trends are often seen as stable or changing at low rates in populations. For example, the incidence rate of diabetes in Canada went from 6.7 per 1000 population in 2003/04 to 6.3 per 1000 in 2013/14.[1] Up to 2011, before the incidence rates of prostate cancer started to decline rapidly, this claim of relative stability could also be made for all cancers, if they were presented as an overall group. *Canadian Cancer Statistics 2019* (CCS 2019) reports that from 1984 to 2015, cancer incidence rates in Canada increased 0.1% per year on average.[2] However, this collective picture is misleading, as trends can differ greatly depending on the cancer type and the time period.[2]

Monitoring incidence of individual cancers over time can help identify emerging trends, highlight where progress has been made, and suggest where more work and resources are needed. The purpose of this report is to feature findings from the CCS 2019 report relating to time trends in the incidence of cancers in Canada, with a particular focus on patterns of change for individual cancer types.

TABLE 1
Annual percentage change (APC) in age-standardized incidence rates by cancer site and sex, Canada (excluding Quebec), 1984 to 2015

Cancer type	Males				Females			
	Year		APC	*p*-value	Year		APC	*p*-value
	From	To			From	To		
Oral	1984	2004	−2.5	< .001	1984	2003	−1.0	< .001
	2004	2011	2.1	.003	2003	2015	0.7	.028
	2011	2015	−0.1	.94				
Esophagus	1984	2006	0.3	.020	1984	2015	−0.4	< .001
	2006	2010	4.3	.068				
	2010	2015	−2.4	.015				
Stomach	1984	2002	−2.5	< .001	1984	1999	−3.0	< .001
	2002	2015	−1.1	< .001	1999	2015	−0.8	< .001
Colorectal	1984	1996	−0.7	< .001	1984	1996	−1.5	< .001
	1996	2000	0.9	.33	1996	2000	1.2	.23
	2000	2011	−0.5	.001	2000	2011	−0.5	< .001
	2011	2015	−2.2	< .001	2011	2015	−1.9	.002
Liver	1984	2011	3.8	< .001	1984	2015	2.7	< .001
	2011	2015	0.2	.88				
Pancreas	1984	2000	−1.5	< .001	1984	2015	0.1	.58
	2000	2015	0.8	.009				
Larynx	1984	2015	−2.6	< .001	1984	1991	0.7	.64
					1991	2015	−3.0	< .001

Continued on the following page

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TABLE 1 (continued)
Annual percentage change (APC) in age-standardized incidence rates by cancer site and sex, Canada (excluding Quebec), 1984 to 2015

Cancer type	Males				Females			
	Year		APC	*p*-value	Year		APC	*p*-value
	From	To			From	To		
Lung and bronchus	1984	1990	−0.6	.087	1984	1993	2.9	< .001
	1990	2003	−2.2	< .001	1993	2011	0.9	< .001
	2003	2011	−0.9	.002				
	2011	2015	−3.3	< .001	2011	2015	−1.3	.043
Melanoma	1984	2015	2.2	< .001	1984	1994	0.1	.79
					1994	2015	2.0	< .001
Breast	1984	2015	0.5	.015	1984	1991	2.1	< .001
					1991	2015	−0.2	.010
Cervix	N/A				1984	2006	−2.1	< .001
					2006	2010	1.5	.41
					2010	2015	−3.3	< .001
Uterus	N/A				1984	1990	−1.5	.063
					1990	2006	0.5	.013
					2006	2011	3.7	.002
					2011	2015	0.1	.92
Ovary	N/A				1984	1994	−1.7	< .001
					1994	2015	−0.4	.001
Prostate	1984	1993	6.3	< .001	N/A			
	1993	1997	−3.0	.38				
	1997	2001	4.1	.23				
	2001	2011	−1.6	.006				
	2011	2015	−9.1	< .001				
Testis	1984	2015	1.3	< .001	N/A			
Bladder	1984	2009	−1.0	< .001	1984	2009	−0.9	< .001
	2010	2015	−1.5	.052	2010	2015	−1.3	.18
Kidney and renal pelvis	1984	1989	4.0	.005	1984	2015	1.0	< .001
	1989	2003	0.1	.64				
	2003	2011	2.8	< .001				
	2011	2015	−0.3	.76				
Brain/CNS	1984	2009	−0.2	.081	1984	2011	−0.3	.002
	2009	2015	−1.9	.012	2011	2015	−3.2	.059
Thyroid	1984	1997	2.8	.002	1984	1998	3.8	< .001
	1997	2015	6.4	< .001	1998	2002	11.9	< .001
					2002	2011	6.5	< .001
					2011	2015	0.1	.94
Hodgkin lymphoma	1984	2015	−0.4	< .001	1984	2015	0.0	.74
Non-Hodgkin lymphoma	1984	2015	1.3	< .001	1984	1993	2.2	< .001
					1993	2015	0.9	< .001
Multiple myeloma	1984	2007	0.3	.077	1984	2015	0.6	< .001
	2007	2015	2.6	< .001				
Leukemia	1984	1994	−0.9	.067	1984	2003	−0.2	.18
	1994	2015	0.7	< .001	2003	2007	3.7	.071
					2007	2015	−0.6	.14

Data source: Canadian Cancer Statistics Advisory Committee. Canadian cancer statistics 2019. Toronto (ON): Canadian Cancer Society; 2019.
Abbreviations: APC, annual percent change; CNS, central nervous system; N/A, not applicable.

Methods

Results are drawn from the incidence chapter of the CCS 2019 report,[2] covering the period from 1984 to 2015. Quebec was not included because data were available up to 2010 only. The Canadian Cancer Registry (CCR)[3] was the source of data for 1992 to 2015, and the National Cancer Incidence Reporting System (NCIRS) was utilized prior to 1992.

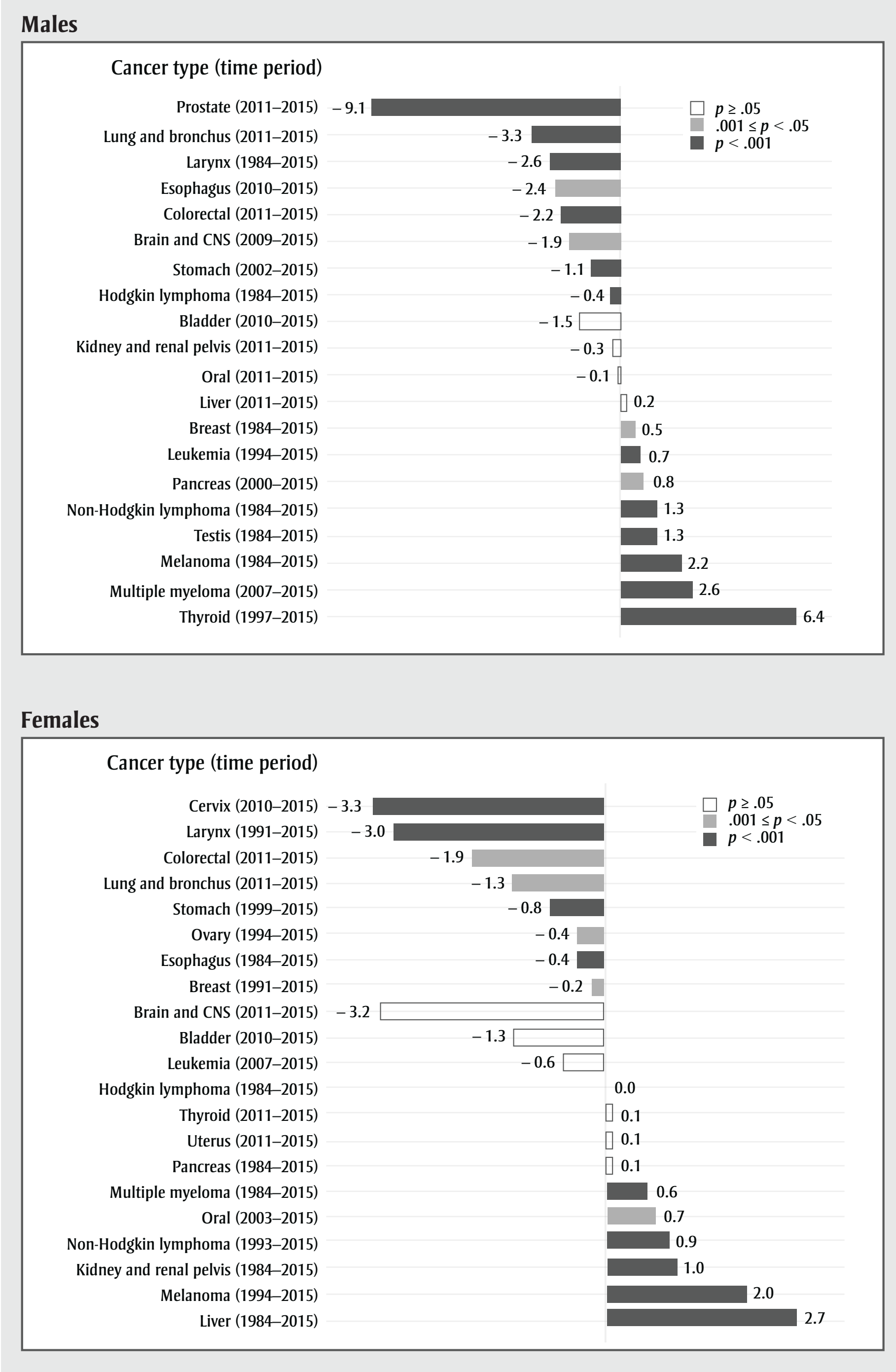
All analyses were performed by the Public Health Agency of Canada. Age-standardized incidence rates (ASIRs) were calculated through direct standardization using the age structure of the 2011 Canadian population by five-year age group. Joinpoint[4] analysis software (version 4.6.0.0) was used to calculate the annual percent change (APC) using the annual ASIRs for each cancer type from 1984 to 2015, and to determine years in which the APC changed significantly. The minimum time span to report a trend was set at five years. Thus, the most recent trend period possible was 2011 to 2015. Otherwise, default Joinpoint parameters were used. In total, 23 types of cancer were investigated.

Results and discussion

Table 1 shows all trends identified by Joinpoint between 1984 and 2015; Figure 1 pulls out the most recent trend. For both sexes in Figure 1, cancers were divided into those that have decreased or increased significantly (p-value $<$ .05 or p-value $<$ .001) in the most recent trend and those that have been stable (p-value $\geq$ .05). The following text highlights a few of the results.

Thyroid cancer has stabilized in females after many years of increase; however, it is still increasing rapidly in males. The increase may be due to overdiagnosis resulting from increased use of diagnostic technologies such as ultrasound;[5] however, recent studies also show an increase in late-stage papillary tumours, suggesting that the overall increase may not be entirely due to overdiagnosis.[6] The increase in **multiple myeloma** in males and females could be related to the increased prevalence of obesity.[7] It may also be due to improved detection and case ascertainment, as the rate of myeloma is relatively stable in countries with high ascertainment.[8-12] **Melanoma** rates are still increasing in males and females. Exposure to ultraviolet radiation through sunlight,

FIGURE 1
Most recent[a] annual percent change (APC) in age-standardized incidence rates, by cancer site and sex, Canada (excluding Quebec)



Data source: Canadian Cancer Statistics Advisory Committee. Canadian cancer statistics 2019. Toronto (ON): Canadian Cancer Society; 2019.

Abbreviation: CNS, central nervous system.

[a] The APCs were calculated from 1984 to 2015. If one or more significant change in the trend of rates was detected, the APC reflects the trend from the most recent significant change to 2015. If no significant change was detected, the APC reflects the trend over the entire period.

tanning beds and sun lamps are well-established risk factors for melanoma.[13] Increase in ultraviolet light exposure without corresponding increases in sun safety behaviours likely explains these increasing rates.[14]

Laryngeal cancer is strongly associated with smoking,[15] and the decreasing trend observed in both males and females likely reflects the decreasing trend in smoking rates in Canada.[16,17] The same observations probably explain the recent trend in **lung cancer** ASIR in males and females. The recent decline in **colorectal cancer** ASIR is likely due in part to increased screening that identifies treatable precancerous polyps. Since 2007, the majority of provinces and territories have implemented organized colorectal cancer screening programs.[18] While not evident in this report, increasing rates have been reported in the younger population, likely due in part to the prevalence of obesity.[19] **Esophageal cancer** ASIR is decreasing in both males and females. Risk factors for this cancer include obesity, alcohol consumption and tobacco consumption.[20] Whereas obesity[7] and sales of alcoholic drinks[21] have been increasing in Canada, past decreases in tobacco consumption[22] may account for the decreasing rates. In males, liver cancer ASIR has stabilized, though it is still increasing in females. Increases in the most common type of **liver cancer**, hepatocellular carcinoma (HCC), are generally driven by chronic hepatitis B and C infection, as well as increasing rates of excessive alcohol consumption and diabetes.[23] However, HCC is more prevalent in low-income countries, and the increase in Canada may be partially explained by rising immigration from regions where HCC is common, including parts of Asia and Africa.[24]

Female breast cancer ASIR has decreased slowly since 1991. This pattern is likely due to mammography screening and long-term changes in risk factors.[25] **Cervical cancer** is decreasing, largely due to routine screening with Pap tests. Every province in Canada (except Quebec) has an organized cervical cancer screening program. Current guidelines recommend screening every two to three years starting at age 21 or 25 until age 65 or 70.[26] In the coming years, human papillomavirus vaccination is expected to result in further reductions in cervical cancer incidence.[27] The ASIR of **prostate cancer** over time has mirrored the utilization of prostate-specific antigen testing (PSA) in Canada.[28] In 2014, the Canadian Task Force on Preventive Health Care advised against PSA screening in men of all ages due to a lack of evidence for benefits and the risk of overdiagnosis and harms of unnecessary treatment.[29] Prostate cancer ASIRs are currently decreasing rapidly.

In 2014, Cancer Care Ontario implemented a new cancer reporting system that brought several enhancements to the identification of cancer cases, including the registration of *in situ* **bladder cancers**, which were not previously reported.[30] The implementation was retrospectively applied to the data from 2010 onward. This change created an apparent increase in incident cases of bladder cancer for the year 2010 and after. Although the decreasing trend for bladder cancer from 2010 to 2015 is comparable to that of 1984 to 2009, this time period is not long enough to be significant. We forced a joinpoint in 2010 to account for the data collection artefact.

Brain and central nervous system (CNS) cancers decreased 3.9% annually in females between 2011 and 2015, although the decrease was not statistically significant ($p = .059$). The lack of significance is most likely due to the shortness of the trend and the variability in the annual rates. The significant decrease of 1.9% per year in males started in 2009.

Conclusion

Results show that cancer trends in Canada are dynamic and type-specific. The most recent trends show increasing rates of thyroid cancer in males, drawing attention to the potential impact of overdiagnosis on cancer incidence. Conversely, rates of other cancers have recently decreased, most notably prostate and cervical cancers. The decreases for prostate and cervical cancers underscore the potential impact of improving screening guidelines based on the best evidence. Specifically, reductions in overscreening (e.g. prostate cancer) and the implementation of routine screening (e.g. cervical cancer) can both lead to decreased incidence.

Conflicts of interest

The authors have no conflicts of interest to declare.

Authors' contributions and statement

All authors contributed to the design, conceptualization and revision of the work. Drafting, analysis and interpretation of the data were done by the Public Health Agency of Canada.

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