Trends in self-reported traumatic brain injury among Canadians, 2005-2014: a repeated cross-sectional analysis

Deepa P. Rao, PhD ; Steven McFaull, MSc; Wendy Thompson, MSc; Gayatri C. Jayaraman, PhD

Author Affiliation:

Surveillance and Epidemiology Division, Centre for Chronic Disease Prevention, Public Health Agency of Canada, Ottawa, Ontario, Canada

Correspondence:

Deepa P. Rao, Public Health Agency of Canada, 785 Carling Avenue, Office 912B3, Ottawa, ON, K1A 0K9; Tel: 613-867-8303; Fax: 613-941-2057; Email: deepa.rao@canada.ca

Confidential

For Peer Review Only

Abstract

Background: Concussion and other traumatic brain injuries (TBI) are a form of unintentional injury that has been associated with both short and long term health effects, including possible disability. This study seeks to provide time trends in the incidence of all types of injury (ATI) and TBIs among Canadians, and to describe TBI characteristics.

Methods: Data from annual cycles of the Canadian Community Health Survey, years 2005 to 2014, were used to examine ATIs and TBIs among Canadians ages 12 years and older. TBI incidence is estimated among those individuals who reported an ATI. Descriptive methods were used to describe key characteristics (sex, age, season, activity, and venue) and 5- and 10- year trends, while generalized linear models permitted an estimation of annual percent change in TBI incidence.

Results: The incidence of ATIs, and of TBIs are increasing with an annual percent change of 1.4% (95%CI 0.9-1.9) and 9.6% (95%CI: 8.2-11.0) respectively. Sport venues (39.9%, 95%CI: 32.7-47.1) and activities (49.7%, 95%CI: 42.4-57.0) were commonly associated with TBIs, and falls were the most frequent mechanism of injury (53.9%, 95%CI: 46.7-61.0) leading to a TBI.

Interpretation: This study highlights the increasing trends in ATIs and TBIs in Canada, and underscores the need for ongoing population level surveillance to mitigate risk.

Confidential

For Peer Review Only

Introduction

Unintentional injuries are the fifth leading cause of death in Canada and the leading cause of death among those 1-44 years of age, accounting for 4.4% of deaths in 2011[1], and costing Canadians approximately $26.8 billion in 2010[2]. These injuries include traumatic brain injury (TBI) [3], which is induced by biomechanical forces caused either by a direct blow to the head, face, neck or elsewhere on the body with an impulsive force transmitted to the head resulting in a rapid onset of short-lived impairment of neurological function[4]. Since TBIs can span a wide range of severities, the term concussion is often used to refer to a mild TBI, although this latter point varies based on professional society or organization. Immediate signs and symptoms of a TBI include fogginess, memory disturbances, and vomiting, but the symptoms may not show up for hours or days after a trauma. A range of acute and/or chronic neurobehavioural symptoms (somatic, cognitive, or emotional/behavioural) may even be seen in the weeks and months following injury[5].

There have been few studies looking into population level estimates of TBI among Canadians. This paper reports on key characteristics, and 5- and 10- year trends in the annual cumulative incidence, of TBI in the general Canadian population. For our purposes, we aim to report on the full spectrum of TBIs, and do not distinguish them based on severity.

Methods

Source of data

Data from the Canadian Community Health Survey (CCHS) was used for the present study. The CCHS is a cross-sectional population health survey that includes Canadians aged 12 years and older not including those living in nursing homes or long-term care facilities or on reserves, full-time members of the Canadian Armed Forces, or civilian residents of military bases. Details about survey methodology are described elsewhere[6]. The CCHS collects self-reported data

For Peer Review Only

regarding a range of measures related to health status, health care utilization, and health determinants. Annual cycles of the CCHS, years 2005 to 2014, were used to examine the cumulative incidence of TBI among Canadians. Only data from cycles of the CCHS that included the same injury module as common content (i.e. asked to all respondents) were included for this analysis. Therefore, years 2005, 2009, 2010, 2013 and 2014 were used, and permitted a national level assessment of TBIs across those time periods.

Definitions

Respondents were asked to identify whether they experienced an injury (all types of injury or ATI) in the previous 12 months. Those who had an ATI were then asked to identify the type of their most serious injury from a list of possible options, including a "concussion or other traumatic brain injury". By definition, all cases of TBI reported in this study refer to non-fatal cases. Responses were then used to examine characteristics associated with the injury, including the environment in which the injury occurred (the place of injury, the month, and the activity one was involved in) and the mechanism of injury.

Responses for the mechanism of injury were fall, contact with a person (recorded as "bumped, pushed, or bitten"), contact with an object (recorded as "struck or crushed by object(s)"), transportation, contact with sharp object, smoke, contact with hot object, extreme weather, overexertion, physical assault, or other. The place of injury was grouped as follows: home (home or residential institution), school (school or other institution), athletic areas(sport areas in school or elsewhere), street (street, highway or sidewalk), or other (commercial, industrial, or construction area, farm, countryside, or other-not specified). Activities were defined as sports, leisure (hobbies, going up or down stairs, personal care, walking), work (working at a job or business), home (chores or unpaid work), or other (other-not specified). Given the impact of seasonality on injuries[7], a derived variable for the four seasons was created based on responses regarding the month of injury (winter: Dec., Jan., Feb.; spring: Mar., Apr., May ; summer: Jun., Jul., Aug.; fall: Sep., Oct., Nov.). Variable details are included in Appendix A.

For Peer Review Only

Statistical analyses

Analyses were completed using SAS Enterprise Guide version 5.1 (Cary, NC). All estimates of TBI reflect annual cumulative incidence among individuals who have reported an injury in the previous year. Mean and incidence estimates were weighted to reflect the Canadian household population and 95% confidence intervals were calculated using bootstrap re-sampling methods. Generalized linear models were used to estimate annual percent change (APC). Estimates are presented for all ages 12 years and above, as well as disaggregated for youth (ages 12 to 17 years) and adults (ages 18 years and above). Some results are presented with an E* to indicate that they have high sampling variability (coefficient of variation between 16.6% and 33.3%) and should be interpreted with caution where indicated. All cycles of the CCHS with national level estimates for TBI were used to describe overall time trends, while 5- and 10- year trends were examined using data from CCHS 2005, 2009, and 2014, and TBI characteristics were examined using a pooled CCHS 2013 and 2014 file (2013-14).

Results

Trends in all types of injuries

ATI rates have been growing over the past decade, with the proportion of Canadians reporting an ATI increasing by 1.4%, 95%CI: 0.9-1.9 annually. Increases were observed among both youth and adults (APC: 0.8%, 95%CI: 0.4-1.2 and 1.7%, 95%CI: 1.3-2.1 respectively). There have been significant differences in APCs based on age group, with significant decreases among those ages 12 to 17 years (APC: -2.6%, 95%CI: -3.4- -1.8) and significant increases among those 60 years and over (APC: 4.4%, 95%CI: 3.1-5.7 among ages 60 years and older). While females report significantly fewer ATIs than males for all age groups, except for among youth where differences do not exist in recent years (Table 1), the APC among females has been rising significantly compared to males of all ages (0.4%, 95%CI: 0.0-0.8 among males and 2.5%, 95%CI: 1.9-3.0 among females, Figure 2). The mean number of ATIs an individual has experienced in the previous year has also increased significantly from an average of 1.5 ATIs in

Confidential

2005 to 1.6 in 2014 , suggesting that the likelihood an individual may experience multiple ATIs over the course of a year has increased (Table 1).

Trends in TBI

The incidence of TBIs has more than doubled over the past decade where, in 2014, the proportion of Canadians with an ATI who reported having a TBI was 3.2% (Figure 1, Table 1). The APC in the incidence of TBI has been increasing (APC: all ages: 9.6%, 95%CI: 8.2-11.0; youth: 10.3%, 95%CI: 2.5-18.1; adults: 9.7%, 95%CI: 9.4-10.0, Figure 2), and among specific age ranges, significant increases are only observed among individuals aged 18 to 34 years (APC: 2.1%, 95%CI: 1.7-2.5). No significant differences in TBI incidence were observed when TBI was examined by sex (Table 1). However, the APC in incidence is higher among females than males, though not significantly so (Figure 2). The mean number ofATIs among those with a TBI and those without do not differ significantly, suggesting that the likelihood of experiencing multiple ATIs does not significantly differ between those who reported a TBI and those who did not (Table 1).

Figure 1. Trends in the incidence of traumatic brain injuries among Canadians.

Table 1. Incidence and patterns of all types of injury and traumatic brain injuries among Canadians.

Figure 2. Annual percent change in the incidence of all types of injury and traumatic brain injury among Canadians.

Characteristics of TBI

Most TBIs were reported to have occurred in a sports or athletic area in a school or other venue (39.9%, 95%CI: 32.7-47.1 among all ages, 66.4%, 95%CI: 56.4-76.4 among youth, and 30.4%, 95%CI: 21.8-39.0 among adults in 2013-14). This tendency is more evident among youth than for adults, with adults experiencing TBIs in other venues, such as the home (24.9%, 95%CI: 18.1-

Confidential

31.7 in 2013-14, data not shown). The most prevalent activity associated with TBI mirrored the most prevalent venue of injury (sports: 49.7%, 95%CI: 42.4-57.0 among all ages). Among youth, estimates show that most TBIs occurred during a sport-based activity, while among adults, the type of activity was more diverse (sports: 86.3%, 95%CI: 79.9-92.7 among youth, 36.6%, 95%CI: 27.9-45.4 among adults) (Table 2). The most reported mechanism of the TBI was injury due to a fall (all ages: 53.9%, 95%CI: 46.7-61.0; youth: 57.7%, 95%CI: 47.4-67.9; adults: 52.5%, 95%CI: 43.4-61.6), with contact with a person or object accounting for the 2nd and 3rd most reported cause, respectively (contact with person: all ages: 18.0%, 95%CI: 10.9-25.0 E*; youth: 25.9%, 95%CI: 16.5-35.3 E* adults: 15.1%, 95%CI: 6.0-24.3 E* in 2013-14; contact with object: all ages: 11.8%, 95%CI: 7.1-16.4 E*; youth: 9.5%, 95% CI: 3.8-15.1 E*; adults: 12.6%, 95%CI: 6.7-18.5 E*, data not shown) .

Table 2. Traumatic brain injuries by activity and age group.

Since activities vary based on the time of year[7], the seasonality of TBIs was examined. No significant differences were noticed on the basis of season for all ages (data not shown). However, when examining TBI injuries among youth, the incidence was significantly higher in the fall season (Figure 3).

Figure 3. Incidence of traumatic brain injuries based on season.

Interpretation

Our findings demonstrate a significant increase in the incidence of non-fatal ATIs and TBIs over the past decade. In a population of over 30 million, this suggests that 0.5% of those ages 12 years and older, or roughly 155,000 Canadians, experienced a TBI in 2014. Individuals ages 18

Confidential

to 34 years account for more than a third of those affected, and although the incidence of TBIs decreased among individuals above 60 years of age, ATIs increased significantly in that age group. Differences in ATI incidence over time were significant on the basis of sex, but not for TBI incidence. Nevertheless, the increasing trend over time in the incidence of TBI among females relative to males is still of note. Relative to those without a TBI, there were no differences in the number of injuries an individual with a TBI experienced. However, while the mean number of ATIs increased significantly over time among those reporting a TBI, they decrease significantly among those not reporting a TBI. Although it was not possible to examine the type of subsequent ATI among those reporting multiple ATIs, the trend towards reporting repeat injuries among those who report a TBI is noteworthy. TBIs were most commonly associated with sports-related activities, particularly among youth, as well as occupation among adults. Sport and athletic venues were identified as the most common venues for TBIs. The observation that fall and winter were the time of year most associated with TBIs might suggest associations with season specific activities. Falls were the mechanism of injury most associated with TBIs across all age groups, with contact with another person or object were identified as the second and third most common mechanisms.

The observed increased incidence of ATIs[8] and TBIs[9] is consistent with international observations. That TBI trends are increasing significantly among 18 to 34 year olds, and ATIs for those over 60 years, should both inform public health efforts geared towards injury prevention. The former may reflect the greater risk taking behaviour of adolescents in sport [10]. However, it is contrary to the understanding that a young brain concusses more easily than an adult one[11,12] since one would expect higher numbers among those 12 to 17 years old. That ATI incidence is increasing among those over the age of 60 is also important because, in addition to injuries in older age being a catalyst for transition into long term care, non-fatal injuries can commence a cascade of effects that impact health[13]. TBI studies suggest that a previous history of TBI increases the probability of a second TBI relative to those who have not experienced one[14]. Therefore, it is possible that some of the repeat ATIs we found may be another TBI (thereby

For Peer Review Only

potentially a second impact syndrome, if close in time), or another non-fatal ATI among those experiencing the effects of PPCS[14].

It has been suggested that females may be more susceptible to TBIs[11,15,16]. Our finding of higher APCs in ATIs and TBIs among females, combined with recent estimates from the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP)[17] showing an increasing trend in head injuries, are concerning. Given the known challenges in keeping young girls active[18], these findings suggest that females are a population that may require special attention for injury prevention efforts.

Examining activities associated with TBI, sport-related activities[5,19], including winter sports[20], and motor vehicles accidents have been previously found to be associated with TBIs[21]. In a study of high school athletes, contact with another person was the risk factor responsible for most concussions [9,15], i.e. the demographic for which we found it to be the second most common mechanism of injury, with the finding that both full-contact and partial contact sports pose a risk[15-17]. This is also reflected in recent findings regarding head injuries among children and youth[17].

Limitations

Our findings represent population-level Canadian estimates for non-fatal ATIs and TBIs using self-reported data. The lack of national data from 2006-2008, 2011, and 2012 is a limitation since they would permit further reliability to our assessment of trends. Since surveys cannot capture fatal cases, and since the data source only captured TBIs that were identified as the most serious injury in the previous year, the estimates presented herein are likely an underestimate. However, since most TBIs are not fatal (about 3% of TBI cases, based on data from the U.S. [9]) these exclusions should not reduce the external validity of our findings. Internal validity may be affected by respondent bias and the diminished validity of retrospective self-reported ATI recall[22]. Since TBIs span a wide range of severity, our use of a single label serves as a limitation. In line with this consideration, it is possible that individuals

For Peer Review Only

with mild cases may not have identified their TBI within the year post-injury, as required for data capture in the survey, thereby resulting in an underestimation of cases. Nevertheless, the generalizability of the present findings to the Canadian population is valuable, as are the level of detail. Finally, while the estimates presented in the current analysis may reflect true increases, it is possible that improved awareness of TBIs through national public health campaigns[3,23] may have improved identification and treatment practices, and thereby better data collection sensitivity in national surveys.

Conclusion and Future Directions

This study demonstrates increasing national trends in ATI and TBI incidence among Canadians, and underscores the value of ongoing national surveillance. Our observation that sport activities and venues were most associated with TBI should inform targeted prevention efforts. Furthermore, the fact that falls and contact with other people were the most common mechanism of TBI should assist with actions to limit such injury, especially given the suggested risk of full- and partial- contact sports. The impacts of TBIs extend well beyond the immediate injury, and call for lengthy and multi-disciplinary rehabilitation as well as loss of productivity[24]. A recent assessment of the health and economic burden of TBIs in Ontario estimates lifetime costs ranging between $279 million to $1.22 billion[24]. Future studies should work to combine self-reported data with hospital records so as to better describe TBI injuries and their sequelae, should distinguish TBI by their level of severity since the implications can be quite distinct, and should include ages below 12 years old since young children are also at risk. Findings discussed in this study should help to inform health promotion and prevention efforts to mitigate future TBI events.

Confidential

For Peer Review Only

References

1. Statistics Canada. The 10 leading causes of death. 2011; Available at: http://www.statcan.gc.ca/pub/82-625-x/2014001/article/11896-eng.htm. Accessed 20/08, 2016.

2. Parachute. The Cost of Injury in Canada. Toronto ON, 2015

3. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Report to Congress on mild traumatic brain injury in the United States: steps to prevent a serious public health problem. Atlanta GA, 2003.

4. McCrory P, Meeuwisse W, Aubry M, Cantu B, Dvorak J, Echemendia RJ, Engebretsen L, Johnston K, Kutcher JS, Raftery M, Sills A, Kathryn Schneider, PT, PhD, Charles H. Tator, MD, PHD, Benson BW, Davis GA, Ellenbogen RG, Guskiewicz KM, Herring SA, Iverson G, Jordan BD, Kissick J, McCrea M, McIntosh AS, Maddocks DL, Makdissi M, Purcell L, Putukian M, Turner M, Schneider K, Tator CH. Consensus statement on concussion in sport--the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Clin J Sport Med.* 2013; 23: 89-117.

5. Kirkwood MW, Yeates KO, Wilson PE. Pediatric sport-related concussion: a review of the clinical management of an oft-neglected population. *Pediatrics.* 2006; 117: 1359-1371.

6. Beland Y. Canadian community health survey--methodological overview. *Health Rep.* 2002; 13: 9-14.

7. Jespersen E, Holst R, Franz C, Rexen CT, Wedderkopp N. Seasonal variation in musculoskeletal extremity injuries in school children aged 6-12 followed prospectively over 2.5 years: a cohort study. *BMJ Open.* 2014; 4: e004165-2013-004165.

8. Coronado VG, McGuire LC, Sarmiento K, Bell J, Lionbarger MR, Jones CD, Geller AI, Khoury N, Xu L. Trends in Traumatic Brain Injury in the U.S. and the public health response: 1995-2009. *J Safety Res.* 2012; 43: 299-307.

9. Faul M, Xu L, Wald MM, Coronado VG. Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths 2002–2006. Atlanta GA, 2010.

10. Kontos AP. Perceived risk, risk taking, estimation of ability and injury among adolescent sport participants. *J Pediatr Psychol.* 2004; 29: 447-455.

11. Tator CH. Concussions and their consequences: current diagnosis, management and prevention. *CMAJ.* 2013; 185: 975-979.

Confidential

12. Baillargeon A, Lassonde M, Leclerc S, Ellemberg D. Neuropsychological and neurophysiological assessment of sport concussion in children, adolescents and adults. *Brain Inj.* 2012; 26: 211-220.

13. Public Health Agency of Canada. Seniors' falls in Canada: Second Report.

14. Guskiewicz KM, McCrea M, Marshall SW, Cantu RC, Randolph C, Barr W, Onate JA, Kelly JP. Cumulative effects associated with recurrent concussion in collegiate football players: the NCAA Concussion Study. *JAMA.* 2003; 290: 2549-2555.

15. Gessel LM, Fields SK, Collins CL, Dick RW, Comstock RD. Concussions among United States high school and collegiate athletes. *J Athl Train.* 2007; 42: 495-503.

16. Lincoln AE, Caswell SV, Almquist JL, Dunn RE, Norris JB, Hinton RY. Trends in concussion incidence in high school sports: a prospective 11-year study. *Am J Sports Med.* 2011; 39: 958-963.

17. McFaull S, Subaskaran J, Thompson W. Emergency department surveillance of injuries and head injuries associated with baseball, football, soccer and ice hockey, children and youth, ages 5 to 18 years, 2004 to 2014. *Health Promot Chronic Dis Prev Can.* 2016; 36: 13-14.

18. Cavill N, Biddle S, Sallis JF. Health Enhancing Physical Activity for Young People: Statement of the United Kingdom Expert Consensus Conference. *Pediatric Exercise Science.* 2001; 13: 12-25.

19. Public Health Agency of Canada. Head Injuries in Children and Youth – The Invisible Epidemic. Available at: http://infobase.phac-aspc.gc.ca/datalab/head-injuries-blog-en.html. Accessed 04/08, 2016.

20. Chaze B, McDonald P. Head injuries in winter sports: downhill skiing, snowboarding, sledding, snowmobiling, ice skating and ice hockey. *Neurol Clin.* 2008; 26: 325-32; xii-xiii.

21. Ontario Injury Prevention Practitioners Network. Summary: Concussion and Motor Vehicle Collisions - Exploring roadside options for first responders . November 2015.

22. Gabbe BJ, Finch CF, Bennell KL, Wajswelner H. How valid is a self reported 12 month sports injury history? *Br J Sports Med.* 2003; 37: 545-547.

23. Public Health Agency of Canada**.** Funding to Support Active and Safe Participation in Sports and Recreation. Available at: http://www.phac-aspc.gc.ca/inj-bles/2012_0829-fs-fi-eng.php. Accessed April, 2016.

24. Fu TS, Jing R, McFaull SR, Cusimano MD. Health & Economic Burden of Traumatic Brain Injury in the Emergency Department. *Can J Neurol Sci.* 2016; 43: 238-247.

Confidential

Table 1. Incidence and patterns of all types of injury and traumatic brain injuries among Canadians

		2005		2009		2014		APC	
		Percent	95%CI	Percent	95%CI	Percent	95%CI	Percent	95%CI
All types of injury (Total Population)									
ATI									
All ages		13.8	13.5-14.1	14.9	14.4-15.4	15.7	15.2-16.2	1.4	0.9-1.9
Youth		25.4	24.3-26.4	26.7	25.0-28.4	27.4	25.4-29.3	0.8	0.4-1.2
Adults		12.6	12.3-12.9	13.7	13.2-14.2	14.7	14.1-15.2	1.7	1.3-2.1
Number of ATIs									
All ages		1.5	1.45-1.53	1.6	1.55-1.67	1.6	1.58-1.70	1.0	0.2-1.9
Youth		1.9	1.75-1.96	2.0	1.78-2.16	2.1	1.89-2.29	1.3	1.1-1.6
Adults		1.4	1.37-1.46	1.5	1.48-1.60	1.6	1.50-1.63	1.1	0.2-2.0
Incidence of ATIs by age group									
12-17 years		17.2	16.5-17.9	16.0	15.0-17.0	13.6	12.7-14.6	-2.6	-3.4- -1.8
18-34 years		32.0	31.1-33.0	32.4	30.8-33.9	31.1	29.5-32.7	-0.3	-1.0- 0.3
35-59 years		38.3	37.2-39.3	37.6	36.0-39.2	37.0	35.4-38.7	-0.4	-0.5- -0.3
60+ years		12.5	11.9-13.1	14.0	13.0-15.0	18.2	17.0-19.4	4.4	3.1 - 5.7
ATI incidence by sex									
All ages	Males	16.4	15.9-16.8	17.0	16.2-17.7	17.1	16.2-17.9	0.4	0.0-0.9
	Females	11.4	11.0-11.7	12.9	12.3-13.4	14.3	13.7-15.0	2.5	1.9-3.0
Youth	Males	29.7	28.1-31.3	29.1	26.5-31.8	29.0	26.3-31.8	-0.3	-0.5-0.0
	Females	20.7	19.2-22.1	24.1	21.8-26.5	25.6	22.8-28.3	2.2	0.8-3.6
Adults	Males	14.9	14.4-15.4	15.7	14.9-16.5	16.0	15.2-16.9	0.8	0.3-1.3
	Females	10.5	10.1-10.8	11.8	11.2-12.4	13.4	12.8-14.1	2.7	2.5-2.9
Traumatic brain injury (Among individuals who reported an ATI within the previous year)									
TBI incidence									
All ages		1.4	1.2-1.7	1.9	1.4-2.4	3.2	2.6-3.9	9.6	8.2-11.0
Youth		2.7	2.0-3.4	2.7	1.7-3.8	5.7	4.1-7.3	10.3	2.5-18.1
Adults		1.2	0.9-1.4	1.8	1.2-2.4	2.9	2.2-3.5	9.7	9.4-10.0
Number of ATIs (mean)									
All ages	TBI	1.5	1.4-1.3	1.6	1.6-1.7	1.6	1.6-1.7	0.7	-0.2-1.5
	No TBI	2.0	1.7-2.3	1.7	1.3-2.1	1.7	1.3-2.1	-1.8	-4.1-0.5
Youth	TBI	1.8	1.7-2.0	2.0	1.8-2.2	2.1	1.9-2.3	1.6	0.7-2.5
	No TBI	2.2	1.6-2.8	2.5	1.0-3.9	1.9	1.6-2.2	-1.6	-6.5- 3.3
Adults	TBI	1.4	1.4-1.5	1.5	1.5-1.6	1.6	1.5-1.6	1.5	1.2-1.7
	No TBI	1.9	1.5-2.3	1.5	1.2-1.8	1.7	1.2-2.2	-1.2	-6.0-3.5
Incidence of TBI by age group									
12-17 years		31.9	25.1-38.8	22.7 [E]	13.7-31.7	23.9	16.8-31.0	-3.5	-9.0- 2.0
18-34 years		35.1	27.7-42.5	37.5	25.6-49.3	42.3	31.6-53.0	2.1	1.7-2.5
35-59 years		24.7	17.6-31.8	32.5 [E]	19.7-45.2	27.2	19.4-35.0	0.7	-5.0-6.5
60+ years		8.2 [E]	4.7-11.8	7.3 [E]	3.1-11.5	6.6 [E]	3.5-9.7	-2.4	-2.9- -1.9
TBI incidence by sex									
All ages	Males	1.4	1.0-1.7	2.1	1.4-2.8	2.8	2.1-3.5	7.2	4.9-9.4
	Females	1.5	1.2-1.9	1.7	1.0-2.3	3.7	2.7-4.7	12.0	5.6-18.4
Youth	Males	2.7	1.8-3.5	3.4	2.0-4.8	5.7	3.4-7.9	8.9	6.5-11.3
	Females	2.6	1.5-3.8	1.9	0.4-3.5	5.8	3.3-8.2	13.3	-2.6-23.3
Adults	Males	1.1	0.7-1.4	1.9	1.1-2.7	2.4	1.6-3.1	7.5	2.9-12.1
	Females	1.3	1.0-1.7	1.6	0.9-2.4	3.4	2.3-4.6	12.3	7.2-17.4

Canadian Community Health Survey, years 2005, 2007, 2009, 2010, 2013 and 2014 .
Ages 12 years and over.
Youth reflects ages 12 to 17 years, adults reflects ages 18 years and above.
Estimates for traumatic brain injury are reported among all Canadians who reported an injury (all types) in the previous year.
APC: Annual percent change, ATI: all types of injury, TBI: traumatic brain injury.
E: Interpret with caution due to high sampling variability (coefficient of variation between 16.6% and 33.3%)

Table 2. Traumatic Brain Injuries by activity and age group

	All Ages	Youth	Adults
	% (95%CI)	% (95%CI)	% (95%CI)
Sports	49.7 (42.4-57.0)	86.3 (79.9-92.7)	36.6 (27.9-45.4)
Leisure	20.1 (14.9-25.4)	8.3 (2.7-13.8)[E]	24.4 (17.6-31.1)
Work	9.0 (5.3-12.7)[E]	[F]	12.2 (7.1-17.4)[E]
Home	6.1 (3.2-9.0)[E]	[F]	7.8 (3.8-11.8)[E]
Motor vehicle	7.9 (3.3-12.5)[E]	[F]	10.0 (3.9-16.1)[E]

Canadian Community Health Survey, 2013-14
Ages 12 years and over.
Youth reflects ages 12 to 17 years, adults reflects ages 18 years and above.
Estimates for traumatic brain injury are reported among all Canadians who reported an injury (all types) in the previous year.
E: Interpret with caution due to high sampling variability (coefficient of variation between 16.6% and 33.3%)
F: Unable to report (coefficient of variation above 33.3%)

For Peer Review Only

APPENDIX A: Survey Instrument

Relevant questions used from the Canadian Community Health Survey[1] - Injury Module

Variable Name	INJ_01
Question	In the past 12 months, that is, from (date one year ago) to yesterday, were you injured?
Responses	
YES	1
NO	2
DON'T KNOW	7
REFUSAL	8

Variable Name	INJ_02
Question	How many times were you injured?
Responses	
NUMBER OF TIMES	1 - 30
NOT APPLICABLE	96
DON'T KNOW	97
NOT STATED	98

Variable Name	INJ_03
Question	Thinking about the most serious injury, in which month did it happen?
Responses	
JANUARY	1
FEBRUARY	2
MARCH	3
APRIL	4
MAY	5
JUNE	6
JULY	7
AUGUST	8
SEPTEMBER	9
OCTOBER	10
NOVEMBER	11
DECEMBER	12
NOT APPLICABLE	96
DON'T KNOW	97
REFUSAL	98
NOT STATED	99

Variable Name	INJ_05
Question	What type of injury did you have? For example, a broken bone or burn.
Responses	
MULTIPLE INJURIES (EXC. MINOR INJ.)	1
BROKEN OR FRACTURED BONES	2
BURN, SCALD, CHEMICAL BURN	3
DISLOCATION	4
SPRAIN OR STRAIN (INCL. TORN LIG.)	5
CUT, PUNCTURE, ANIMAL BITE	6
SCRAPE(S), BRUISE(S), BLISTER(S)	7
CONCUSSION OR OTHER BRAIN INJURY	8
POISONING(EXC. FOOD POIS, POISON IVY)	9
INJURY TO INTERNAL ORGANS	10
OTHER	11
NOT APPLICABLE	96
DON'T KNOW	97
REFUSAL	98
NOT STATED	99

Confidential

Variable Name	INJ_08
Question	Where were you when you were injured? For example, someone's house, an office building, construction site.
Responses	
IN A HOME OR ITS SURROUNDING AREA	1
RESIDENTIAL INSTITUTION	2
SCHOOL, COLLEGE, UNIVERSITY	3
SPORTS OR ATHLECTICS AREA OF SCHOOL	4
OTHER SPORTS OR ATHLETICS AREAS	5
OTHER INSTITUTION	6
STREET, HIGHWAY, SIDEWALK	7
COMMERCIAL AREA	8
INDUSTRIAL OR CONSTRUCTION AREA	9
FARM	10
COUNTRYSIDE, FOREST, LAKE, OCEAN, …	11
OTHER	12
NOT APPLICABLE	96
DON'T KNOW	97
REFUSAL	98
NOT STATED	99

Variable Name	INJ_09
Question	What were you doing when you were injured?
Responses	
SPORTS OR PHYSICAL EXERCISE	
LEISURE OR HOBBY	
WORKING AT A JOB OR BUSINESS	
HOUSEHOLD CHORES, OTHER UNPAID WORK	
SLEEPING, EATING, PERSONAL CARE	
GOING UP AND DOWN STAIRS	
DRIVER OR PASSENGER IN/ON ROAD MOTOR VE.	
DRIVER OR PASSENGER IN/ON OFF-R. MOTOR V	
WALKING	
OTHER	
NOT APPLICABLE	
DON'T KNOW	
REFUSAL	
NOT STATED	

Variable Name	INJ_10
Question	Was the injury the result of a fall?
Responses	
YES	1
NO	2
NOT APPLICABLE	6
DON'T KNOW	7
REFUSAL	8
NOT STATED	

Variable Name	INJDCAU
Question Name	Cause of injury - (Derived variable)
Responses	
FALL	1
TRANSPORTATION ACCIDENT	2
BUMPED, PUSHED, BITTEN	3
STRUCK OR CRUSHED BY OBJECT(S)	4
CONTACT W/SHARP OBJECT, TOOL OR MACHINE	5

Confidential

SMOKE, FIRE, FLAMES	6
CONTACT W/HOT OBJECT, LIQUID OR GAS	7
EXTREME WEATHER OR NATURAL DISASTER	8
OVEREXERTION OR STRENUOUS MOVEMENT	9
PHYSICAL ASSAULT	10
OTHER	11
NOT APPLICABLE	98
NOT STATED	99

References:

1. Statistics Canada. Canadian Community Health Survey, Annual Component – 2014.

Confidential

STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist

A checklist of items that should be included in reports of observational studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Section and Item	Item No.	Recommendation	Reported on Page No.
Title and Abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/Rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study Design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	
		Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	
		Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	3-4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed	
		Case-control study—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-5

Confidential

Section and Item	Item No.	Recommendation	Reported on Page No.
Data Sources/ Measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	3-4
Bias	9	Describe any efforts to address potential sources of bias	10
Study Size	10	Explain how the study size was arrived at	
Quantitative Variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical Methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive Data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome Data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	5-7

Confidential

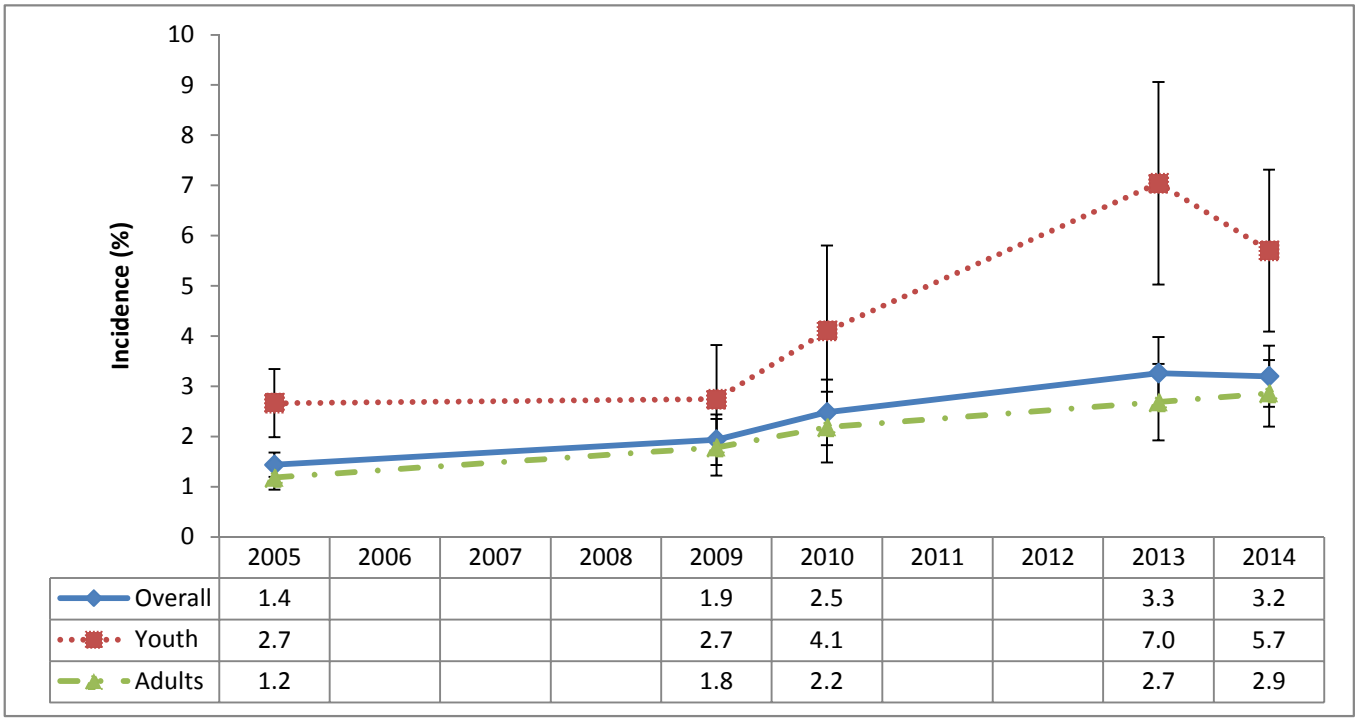
Section and Item	Item No.	Recommendation	Reported on Page No.
Main Results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5-7
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other Analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key Results	18	Summarise key results with reference to study objectives	7-9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	9-10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
Generalisability	21	Discuss the generalisability (external validity) of the study results	9-10
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.

Confidential

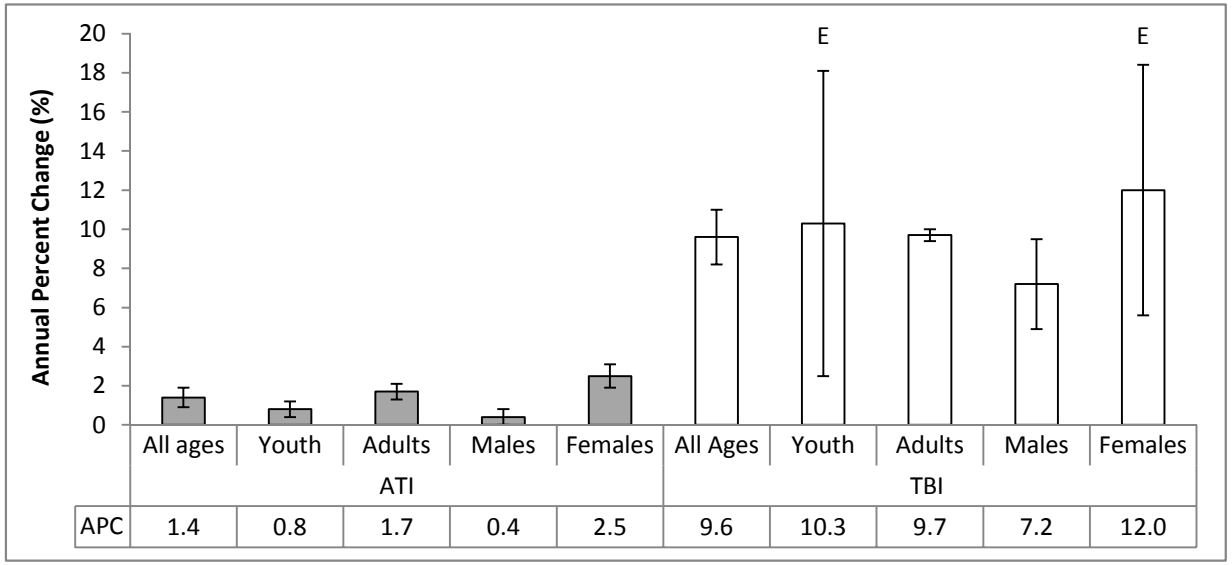
Figure 1. Trends in the incidence of traumatic brain injuries among Canadians.



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Overall	1.4				1.9	2.5			3.3	3.2
Youth	2.7				2.7	4.1			7.0	5.7
Adults	1.2				1.8	2.2			2.7	2.9

Canadian Community Health Survey, years 2005, 2007, 2009, 2010, 2013 and 2014 .
Ages 12 years and over.
Youth reflects ages 12 to 17 years, adults reflects ages 18 years and above.
Estimates for traumatic brain injury are reported among all Canadians who reported an injury (all types) in the previous year.

Figure 2: Annual percent change in the incidence of all types of injury and traumatic brain injury among Canadians.



Canadian Community Health Survey, years 2005, 2007, 2009, 2010, 2013 and 2014 .

Ages 12 years and over.

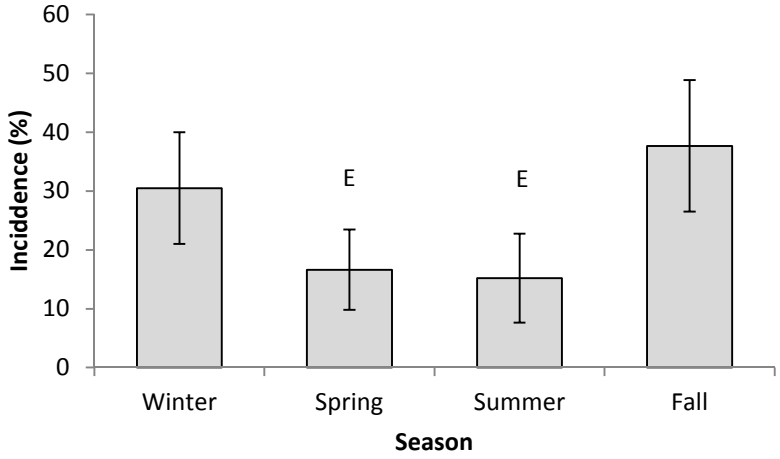
Youth reflects ages 12 to 17 years, adults reflects ages 18 years and above.

Estimates for traumatic brain injury are reported among all Canadians who reported an injury (all types) in the previous year.

E: Interpret with caution due to high sampling variability (coefficient of variation between 16.6% and 33.3%)

ATI: all types of injury, TBI: traumatic brain injury.

Figure 3. Incidence of Traumatic Brain Injuries based on season among youth



Source: Statistics Canada, Canadian Community Health Survey, 2013-14
E: Interpret with caution due to high sampling variability (coefficient of variation between 16.6% and 33.3%)
Youth refers to ages 12 to 17 years old.