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Research

Association between traumatic brain injury and incarceration: a population-based cohort study

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Abstract

Background: There is recent evidence to suggest that sustaining a traumatic brain injury (TBI) increases risk of criminal justice system involvement, including incarceration. The objective of this study was to explore the association between TBI and risk of incarceration among men and women in Ontario.

Methods: We identified a cohort of 1.418 million young adults (aged 18–28 yr) on July 1, 1997, living in Ontario, Canada, from administrative health records; they were followed to Dec. 31, 2011. History of TBI was obtained from emergency and hospital records, and incarceration history was obtained from the Correctional Service of Canada records. We estimated the hazard of incarceration using Cox proportional hazard models, adjusting for relevant sociodemographic characteristics and medical history.

Results: There were 3531 incarcerations over 18 297 508 person-years of follow-up. The incidence of incarceration was higher among participants with prior TBI compared with those without a prior TBI. In fully adjusted models, men and women who had sustained a TBI were about 2.5 times more likely to be incarcerated than men and women who had not sustained a TBI.

Interpretation: Traumatic brain injury was associated with an increased risk of incarceration among men and women in Ontario. Our research highlights the importance of designing primary, secondary and tertiary prevention strategies to mitigate risk of TBI and incarceration in the population.

Traumatic brain injury (TBI) is an important public health concern: the estimated global lifetime prevalence is 3.49%.[1–4] In Ontario, Canada, there were 1.7 new cases of TBI per 1000 population in 2010/11, an increase of moe than 20% since 2004/05.[5] Traumatic brain injury may result in long-term disability and is a major cause of death and disability.[6,7] The impacts of TBI are broad and diverse and may include behavioural changes and cognitive impairment.[7,8]

Potential behavioural consequences of TBI, such as aggression and impulsivity, could increase propensity for involvement with criminal justice.[9–12] Some meta-analyses have shown that the lifetime prevalence of TBI is high among those in correctional facilities and may be substantially higher than the general population.[13–15] This finding has also been reported in Canada.[16,17] Four longitudinal studies examined the association between TBI and criminal justice involvement and focused on criminality and violent crime.[18–21] All suggested an association between TBI and criminal justice involvement, although results were not always significant.[18–21]

Our study builds on the literature regarding TBI and criminal justice involvement, with a particular focus on serious and chronic offending. Our overall objective was to determine if prior TBI was associated with an increased risk of incarceration among men and women.

Methods

Setting and design

We conducted a cohort study of young adults in Ontario between July 1, 1997, and Mar. 31, 2011, using linked administrative data. In Canada, the federal justice system supervises

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people sentenced by the courts to 2 years or more of incarceration. Such sentences would be characteristic for persons committing a serious offence or who are chronically in contact with the criminal justice system.[22]

Participants

Potential participants aged 18–28 years on July 1, 1997 (i.e., the index date), were included if they were eligible for health care in Ontario between Jan. 1, 1993, and July 1, 1997 (i.e., listed in the Registered Persons Database, a population-based registry for health care maintained by the Ontario Ministry of Health and Long-Term Care).[23] This age group was selected because of their high risk of TBI and criminal justice involvement.[5,24,25] Participants remained in the cohort until they were federally incarcerated, died or lost their eligibility for health care. Ontario's administrative health data do not consistently capture those who emigrate from the province and would be ineligible for health care: we assumed men without health care utilization in 5 years and women without health care utilization in 3 years were no longer in the province, and their date of ineligibility was the date of last contact plus 3 or 5 years. Longer time since last contact was allowed for young men as they are less likely to seek health care.[26,27]

Data sources and linkage

This study linked administrative health data sets to correctional records. Health data sets included the Registered Persons Database, the Ontario Health Insurance Plan database, the Canadian Institute for Health Information Discharge Abstracts Database and National Ambulatory Care Reporting System. Correctional records were obtained from the Offender Management System, a computerized record system that tracks information from admission until sentence completion that is maintained by the Correctional Service of Canada, the government agency responsible for supervising persons with federal sentences.[28] All people who enter a federal correctional facility will be recorded in the Offender Management System, and these data have 100% population coverage. Data sets were linked using unique encoded identifiers and analyzed at the Institute for Clinical Evaluative Sciences, Toronto; this linkage is described elsewhere.[29]

Variable definitions

The outcome was federal incarceration, defined as admission date to a federal facility, obtained from the Offender Management System. The accuracy of admission date has not been systematically studied in the Offender Management System. We retained the first federal sentence occurring between Jan. 1, 1998, and Mar. 31, 2011. We excluded anyone with suspended records (i.e., pardoned).

Traumatic brain injury was the exposure of interest. People with a recorded diagnosis of TBI in the Discharge Abstracts Database or the National Ambulatory Care Reporting System between July 1, 1997, and Sept. 30, 2010, were classified as sustaining a TBI. The Discharge Abstracts Database contained hospital discharges and the National Ambulatory Care Reporting System contained emergency department visits. Although these are national databases, we only had access to Ontario data. Classification of TBI was based on International Classification of Diseases, 9th revision [Clinical Modification] (ICD-9) codes and International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10) diagnosis codes. We considered ICD-9 codes 800–801, 803–804, 850–854.1 or 959.01,[30] or ICD-10 codes S02.0, S02.1, S02.3, S02.7, S02.8, S02.9, S06, S07.1, T90.2 or T90.5 as TBI-related visits.[30,31]

Traumatic brain injury since index was treated as a binary time-varying covariate. We lagged the exposure variable by 6 months to account for time between committing the related crime and entering the prison system. In 2008, this median time was about 3 months;[32] by lagging the exposure variable to 6 months, we reduced the possibility that TBI was sustained after the crime was committed for most of the cohort.

Individual-level covariates were age, sex, rurality, prior history of TBI and history of a mental health diagnosis at baseline. Covariates were selected a priori based on their associations with TBI and/or incarceration[5,25,33–39] and their availability in administrative data. Age, sex and rurality (residential postal code) were extracted from the Registered Persons Database. History of TBI between Jan. 1, 1993, and July 1, 1997, was obtained from the Discharge Abstracts Database or the Ontario Health Insurance Plan database, the latter containing all physician billings. We did not ascertain lifetime history of TBI because of data quality concerns in Ontario's administrative data before 1993. We considered 4 types of mental health diagnoses: psychotic disorders (ICD-9 codes 295–298),[40] nonpsychotic disorders (ICD-9 codes 300–302, 306, 309 and 311),[40] substance abuse disorders (ICD-9 codes 291–292 and 303–304)[40,41] or social problems (ICD-9 codes 897–902, 904–906 and 909).[40] If a participant had at least 1 of these diagnostic codes in the applicable databases between Jan. 1, 1995, and June 30, 1997, we considered them to have had a mental health diagnosis.

We used 3 neighbourhood-level measures from the Ontario Marginalization Index that are widely used in Ontario: ethnic concentration, material deprivation and residential instability.[42–44]

Statistical analyses

We performed descriptive analyses, by TBI, over follow-up. We also calculated the crude incidence of federal incarceration for men and women.

To examine the association between TBI and federal incarceration, we used an extended Cox proportional hazards model with time-varying covariates.[45] Data were organized as a counting process structure with a July 1, 1997, origin.[46] Participants stopped contributing to the Cox model on their date of first federal incarceration, death, loss of health care eligibility or Mar. 31, 2011. Because persons were censored at the time of first federal incarceration and we lagged the exposure variable by 6 months, we reduced the possibility of protopathic bias.

We report crude and multivariable adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) for men and women. Multivariable models were adjusted for age, neighbourhood

marginalization, prior history of TBI and mental health diagnosis history. We also ran a pooled model to test for an interaction by sex. The proportionality assumption was not violated.[45]

We handled missing data as follows: complete case analyses and modelling missing as a separate category. The results were similar, and we report the findings from the complete-case analyses. Because the proportion of missing data was so small (< 5%), it is unlikely that our statistical inference was biased by missingness.[47–49]

Sensitivity analysis

We performed 7 sensitivity analyses: we excluded participants who reported TBI between 1993 and 1997 to obtain an "incident" cohort; we excluded participants whose correctional records were linked to health records probabilistically;[29] we lagged the TBI exposure variable by 1 year; we did not lag the TBI exposure variable; we broadened the definition of TBI to include primary care visits; we estimated risk of incarceration for participants who were discharged from the emergency department for TBI and those who were admitted to hospital for TBI; and we treated TBI as a 3-level exposure variable: 0 TBI, 1 TBI, or 2 or more TBI.

Ethics approval

This study was approved by the Research Ethics Board at Sunnybrook Health Sciences Centre, Toronto, and received additional approvals from St. Michael's Hospital, Toronto, and the University of Toronto.

Results

We included 748 393 men and 731 013 women in the study cohort. Table 1 presents baseline characteristics of participants by TBI over follow-up. There were 77 519 participants (5.2%) who sustained at least 1 TBI. After excluding those with missing data, 716 585 men and 701 480 women remained. Together, they contributed 18 297 508 person-years of follow-up (mean [SD] = 12.7 (3.19) yr, median [interquartile range] = 13.7 [13.74–13.74] yr).

Table 2 presents the rate of federal incarceration for men overall and by characteristics of interest, as well as unadjusted and adjusted HRs. There were 3321 men who were incarcerated federally over follow-up, yielding an incidence rate of 35.9 per 100 000 person-years (95% CI 34.7–37.2). The incidence of incarceration was higher among men who had sustained a TBI (102.6 per 100 000 person-years, 95% CI 91.9–113.2) compared with men who had not sustained a TBI (33.5 per 100 000 person-years, 95% CI 32.1–34.5). In unadjusted models, men who had sustained a TBI had a 3-times greater hazard of incarceration than men who had not sustained a TBI. The association attenuated in fully adjusted models (HR 2.47, 95% CI 2.21–2.77).

Table 3 presents data for women. There were 210 women who were federally incarcerated over 9 058 616 person-years of follow-up, yielding an incidence rate of 2.3 per 100 000 person-years (95% CI 2.0–2.6). In crude models, TBI increased the hazard of incarceration about 4-fold. In fully adjusted models, the hazard of incarceration was 2.76 times higher in women with, as opposed to without, a TBI (95% CI 1.65–4.60).

We did not find evidence of an interaction between TBI, sex and risk of incarceration ($p = 0.7$).

Table 4 presents estimates from our sensitivity analyses. Among men, TBI was a risk factor for incarceration regardless of the exposure or cohort definition. Among women, the magnitude of association between TBI and risk of incarceration was strong but not significant in 3 analyses. We also found a suggestion of a dose–response relationship between number of TBIs and risk of incarceration among men.

Interpretation

We conducted a population-based cohort study to explore the association between TBI and risk of incarceration for serious

Table 1 (part 1 of 2): Participant characteristics at baseline, by traumatic brain injury status (n = 1 479 406)

Characteristic	No. (%) of participants with at least 1 TBI§§,¶¶ n = 77 519	No. (%) of participants without TBI n = 1 401 887
Incarcerated over follow-up		
No	77 117 (99.5)	1 398 556 (99.8)
Yes	402 (0.5)	3331 (0.2)
Age, yr; mean ± SD	22.8 ± 3.2	23.1 ± 3.2
Age group, yr		
18–21	32 235 (41.6)	489 801 (34.9)
22–24	19 779 (25.5)	372 714 (26.6)
25–28	25 505 (32.9)	539 372 (38.5)
Sex		
Female	28 410 (36.6)	702 603 (50.1)
Male	49 109 (63.4)	699 284 (49.9)
Rural residence		
No	65 596 (84.6)	1 207 066 (86.1)
Yes	11 657 (15.0)	171 652 (12.2)
Missing	266 (0.3)	23 169 (1.7)
Material deprivation*		
Q1 (least deprived)	15 248 (19.7)	328 137 (23.4)
Q2	16 063 (20.7)	307 752 (22.0)
Q3	15 825 (20.4)	277 083 (19.8)
Q4	14 342 (18.5)	235 336 (16.8)
Q5 (most deprived)	13 057 (16.8)	195 222 (13.9)
Missing	2984 (3.8)	58 357 (4.2)
Ethnic concentration*		
Q1 (least)	11 669 (15.0)	188 437 (13.4)
Q2	15 008 (19.4)	251 657 (18.0)
Q3	13 577 (17.5)	239 193 (17.1)
Q4	14 968 (19.3)	279 384 (19.9)
Q5 (most)	19 313 (24.9)	384 859 (27.5)
Missing	2984 (3.8)	58 357 (4.2)

Table 1 (part 2 of 2): Participant characteristics at baseline, by traumatic brain injury status (*n* = 1 479 406)

Characteristic	No. (%) of participants with at least 1 TBI§§,¶¶ *n* = 77 519	No. (%) of participants without TBI *n* = 1 401 887
Residential instability*		
Q1 (least unstable)	15 491 (20.0)	312 087 (22.3)
Q2	15 296 (19.7)	285 173 (20.3)
Q3	14 741 (19.0)	255 428 (18.2)
Q4	17 437 (22.5)	288 167 (20.6)
Q5 (most unstable)	11 570 (14.9)	202 675 (14.5)
Missing	2984 (3.8)	58 357 (4.2)
Previous TBI†,‡		
No	68 639 (88.5)	1 326 647 (94.6)
Yes	8880 (11.5)	75 240 (5.4)
Psychotic mood disorder†,§,¶		
No	76 368 (98.5)	1 390 308 (99.2)
Yes	1151 (1.5)	11 579 (0.8)
Nonpsychotic mood disorder†,§,**		
No	57 909 (74.7)	1 119 044 (79.8)
Yes	19 610 (25.3)	282 843 (20.2)
Substance use disorder†,§,††		
No	74 869 (96.6)	1 381 839 (98.6)
Yes	2650 (3.4)	20 048 (1.4)
Social problems†,§,††,‡‡		
No	74 721 (96.4)	1 365 949 (97.4)
Yes	2798 (3.6)	35 938 (2.6)

Note: ICD-9 = International Classification of Diseases, 9th Revision, [Clinical Modification], Q = quintile, SD = standard deviation, TBI = traumatic brain injury.
*As per the Ontario Marginalization Index[42] by quintile.
†Medical records from physician visits, including primary care providers.
‡History of TBI between Apr. 1, 1993, and June 30, 1997.
§History of diagnosis between Jan. 1, 1995, and June 30, 1997.
¶Defined as hospital visit for ICD-9 diagnostic codes 295–298.
**Defined as hospital visit for ICD-9 diagnostic codes 300–302, 306, 309 and 3011.
††Defined as hospital visit for ICD-9 diagnostic codes 291–292 and 303–304.
‡‡Defined as hospital visit for ICD-9 diagnostic codes 897–906 and 909.
§§At least 1 TBI between Apr. 1, 1997, and December 2011.
¶¶Unless specified otherwise.

and chronic offending. Our findings show that sustaining a TBI was associated with an increased risk of incarceration for such offences. The relative association was similar among men and women, and was upheld in a variety of sensitivity analyses, although estimates were less precise and not always significant among women.

These findings contribute to emerging research suggesting that TBI is an important risk factor for criminal justice involvement[18–20] and builds on this evidence.[19]

A more novel contribution of our research is the sex-based analyses. Schofield and colleagues examined how TBI affects incarceration risk among men and women separately.[19] They found that men and women with a history of TBI were about 1.5 times more likely to have a corrective services record than those without a history of TBI. Although the confidence limits for women were wide, reflecting the small number of women who were incarcerated in our study, they are consistent with Schofield and colleagues' research:[19] the relative increase in incarceration risk was similar among men and women who sustained a TBI.[19] Prior research has found that multiple head injuries are prevalent in correctional populations: in the United Kingdom, 32% of young men reported more than 1 TBI with a loss of consciousness.[50] Our study reports the hypothesis that multiple head injuries may increase risk of incarceration.

We report effect sizes consistent with Sweden[18] and almost twice as large as those in Australia,[20] Finland[21] and New Zealand.[19] Such inconsistences may arise from different outcome definitions. Studies reporting smaller effect sizes used a more general outcome of criminality,[19–21] whereas the study in Sweden, with a similar effect size, only examined violent crime.[18] It may be that the types of crimes committed, or the length of sentences received, differ in people with and without a prior TBI, and these differences may drive the stronger associations.

Differences could also be caused by other aspects of research methodology. For example, we modelled TBI as a time-varying exposure that allowed us to capture TBI at the time of incarceration, instead of assuming TBI was stable over follow-up. If TBI is positively associated with criminal justice involvement, as it appears to be, such misclassification would have biased effect estimates in previous studies toward the null. In addition, studies were conducted in countries with diverse criminal justice and health care systems: differences in effect sizes could be related to broader societal factors. Most importantly, taken together, the body of research supports the hypothesis that TBI is associated with an increased risk of criminal justice involvement.[18–21]

Limitations

Traumatic brain injury was measured using diagnosis codes from emergency department and hospital visits, and we may have missed persons with mild TBI who were not treated in these settings: a New Zealand study suggested that 95% of all TBIs are mild.[24] In a sensitivity analysis, we relaxed the definition of TBI to include physician visits and the association remained. We intended to explore severity of TBI by assigning ICD diagnoses based severity scores, but we were unable to assign scores to 35% of the population with TBI because these ICD codes were head injury, unspecified. However, our sensitivity analyses found that men and women admitted to hospital with a TBI were more likely to be incarcerated than men and women who were discharged from the emergency department with a TBI, which suggests the risk of incarceration could be greater for those with more severe TBI. We also acknowledge potential measurement error in our control variables that could introduce residual confounding (e.g., mental health was captured using diagnosis codes, and medical attention is not sought by all people with mental illness).[51] We did not have information on severity of impulsivity and substance use in the administrative data, both of which have been associated with TBI and criminal justice involvement.[33,52] Although failing to

Table 2: Incidence rate (IR), and unadjusted and adjusted hazard ratios (HRs) for incarceration among men in Ontario from 1997 to 2011, by traumatic brain injury, sociodemographic characteristics and medical history (*n* = 716 585)

Characteristics	No. of incarcerations	Person-years	Incidence rate per 100 000 person-years	Unadjusted model	Adjusted model
			IR (95% CI)	HR (95% CI)	HR (95% CI)
Overall	**3321**	**9 238 892**	**35.9 (34.7–37.2)**		
TBI*					
No	2965	8 891 856	33.5 (32.1–34.5)	**1.00**	**1.00**
Yes	356	347 126	102.6 (91.9–113.2)	**3.26 (2.91–3.64)**	**2.47 (2.21–2.77)**
Age, yr					
18–21	1297	3 262 825	39.8 (37.6–42.0)	1.00	(1.00)
22–24	873	2 449 332	35.6 (33.3–38.1)	**0.90 (0.82–0.98)**	**0.87 (0.80–0.95)**
25–28	1151	3 526 825	32.6 (30.8–34.6)	**0.82 (0.76–0.89)**	**0.77 (0.71–0.83)**
Rural residence					
No	2966	8 115 993	36.5 (35.2–37.9)	1.00	1.00
Yes	355	1 123 388	31.6 (28.1–35.1)	**0.87 (0.77–0.97)**	1.03 (0.91–1.17)
Material deprivation†					
Q1 (least deprived)	439	2 204 177	19.9 (18.1–21.9)	1.00	1.00
Q2	569	2 129 505	26.7 (24.6–29.0)	**1.34 (1.19–1.52)**	**1.29 (1.14–1.47)**
Q3	639	1 933 271	33.0 (30.6–35.7)	**1.66 (1.47–1.88)**	**1.48 (1.30–1.68)**
Q4	704	1 627 296	43.3 (40.2–46.6)	**2.17 (1.93–2.45)**	**1.76 (1.55–2.00)**
Q5 (most deprived)	970	1 344 731	72.1 (67.7–76.8)	**3.62 (3.24–4.06)**	**2.54 (2.23–2.89)**
Ethnic concentration†					
Q1 (least)	416	1 344 374	29.8 (27.1–32.8)	1.00	1.00
Q2	563	1 773 547	30.5 (28.1–33.2)	1.03 (0.90–1.16)	1.03 (0.91–1.17)
Q3	531	1 656 420	30.8 (28.3–33.6)	1.04 (0.91–1.18)	1.00 (0.87–1.14)
Q4	662	1 883 787	33.8 (33.1–36.5)	**1.14 (1.00–1.28)**	1.04 (0.91–1.18)
Q5 (most)	1149	2 580 852	42.8 (40.4–45.3)	**1.44 (1.29–1.61)**	1.06 (0.94–1.20)
Residential instability†					
Q1 (least unstable)	485	2 189 635	22.3 (20.2–24.2)	1.00	1.00
Q2	492	2 012 090	24.4 (22.4–26.7)	1.10 (0.97–1.25)	1.01 (0.89–1.15)
Q3	611	1 783 041	34.3 (31.6–37.1)	**1.55 (1.37–1.75)**	**1.20 (1.06–1.37)**
Q4	919	1 952 207	47.1 (44.1–50.2)	**2.12 (1.90–2.37)**	**1.38 (1.22–1.56)**
Q5 (most unstable)	814	1 301 008	62.5 (58.4–67.0)	**2.82 (2.52–3.16)**	**1.74 (1.53–1.97)**
Previous TBI‡,§					
No	2801	8 570 118	32.7 (31.5–33.9)	1.00	1.00
Yes	520	668 864	77.7 71.3–84.7	**2.38 (2.17–2.61)**	**1.88 (1.71–2.07)**
Psychotic mood disorder‡,¶,**					
No	3233	9 159 856	35.3 (34.1–36.5)	1.00	1.00
Yes	88	79 126	111.2 (90.2–137.1)	**3.15 (2.55–3.89)**	1.02 (0.82–1.27)
Nonpsychotic mood disorder‡,¶,††					
No	2255	7 957 300	28.3 (27.2–29.5)	1.00	1.00
Yes	1066	1 281 682	83.2 (78.3–88.3)	**2.93 (2.72–3.16)**	**2.25 (2.09–2.44)**
Substance use disorder‡,¶,‡‡					
No	2988	9 081 002	32.9 (31.7–34.1)	1.00	1.00
Yes	333	157 980	210.8 (189.3–234.7)	6.40 (5.72–7.17)	3.67 (3.25–4.13)
Social problems‡,¶,§§					
No	3169	9 099 282	34.8 (33.6–36.1)	1.00	1.00
Yes	152	139 700	108.9 (92.8–127.6)	3.12 (2.66–3.68)	1.71 (1.45–2.02)

Note: CI = confidence interval, HR = hazard ratio, ICD-9 = International Classification of Diseases, 9th Revision, [Clinical Modification], IR = incidence rate, Q = quintile, TBI = traumatic brain injury. Values in boldface type represent confidence limits that do not cross 1.
*At least 1 TBI between June 30, 1997, and Mar. 31, 2011.
†As per the Ontario Marginalization Index,[42] by quintile.
‡Based on medical records from physician visits, including primary care providers.
§History of TBI between Apr. 1, 1993, and June 30, 1997.
¶History of diagnosis between Jan. 1, 1995, and June 30, 1997.
**Defined as hospital visit for ICD-9 diagnostic codes 295–298.
††Defined as hospital visit for ICD-9 diagnostic codes 300–302, 306, 309 and 301.
‡‡Defined as hospital visit for ICD-9 diagnostic codes 291–292 and 303–304.
§§Defined as hospital visit for ICD-9 diagnostic codes 897–906 and 909.

Table 3: Incidence rate (IR), and unadjusted and adjusted hazard ratios (HRs) for incarceration among women in Ontario from 1997 to 2011, by traumatic brain injury, sociodemographic characteristics and medical history (*n* = 701 480)

Characteristics	No. of incarcerations	Total person-years	IR (per 100 000 person-years)	Unadjusted model	Adjusted model
			IR (95% CI)	HR (95% CI)	HR (95% CI)
Overall	**210**	**9 058 616**	**2.3 (2.0–2.6)**		
TBI*					
No	193	8 875 705	2.2 (1.9–2.5)	1.00 (1.00)	1.00 (1.00)
Yes	17	182 912	9.3 (4.9–13.7)	**4.15 (2.15–6.86)**	**2.76 (1.65–4.60)**
Age, yr					
18–21	77	3 141 869	2.4 (2.0–3.1)	1.00	1.00
22–24	47	2 369 277	1.9 (1.5–2.6)	0.81 (0.56–1.16)	0.77 (0.54–1.11)
25–28	86	3 547 472	2.4 (2.0–3.0)	0.99 (0.73–1.34)	0.90 (0.66–1.23)
Rural residence					
No	190	8 151 021	2.3 (2.0–2.7)	1.00	1.00
Yes	23	1 139 914	2.0 (1.3–3.0)	0.82 (0.52–1.30)	1.37 (0.81–2.31)
Material deprivation†					
Q1 (least deprived)	29	2 181 375	1.3 (0.9–1.9)	1.00	1.00
Q2	26	2 048 689	1.3 (0.9–1.9)	0.95 (0.56–1.62)	0.92 (0.54–1.56)
Q3	47	1 861 048	2.5 (1.9–3.4)	**1.90 (1.19–3.02)**	1.61 (0.99–2.61)
Q4	41	1 614 514	2.5 (1.9–3.7)	**1.91 (1.19–3.07)**	1.37 (0.82–2.30)
Q5 (most deprived)	67	1 352 988	5.0 (3.9–6.3)	**3.72 (2.41–5.75)**	**2.17 (1.31–3.57)**
Ethnic concentration†					
Q1 (least concentrated)	13	1 242 374	1.0 (0.6–1.8)	1.00	1.00
Q2	32	1 669 734	1.9 (1.3–2.7)	1.83 (0.96–3.49)	1.89 (0.99–3.61)
Q3	32	1 598 383	2.0 (1.4–2.8)	1.91 (1.00–3.65)	1.98 **(1.02–3.83)**
Q4	45	1 915 808	2.3 (1.8–3.1)	**2.24 (1.21–4.16)**	2.24 **(1.17–4.30)**
Q5 (most concentrated)	88	2 632 316	3.3 (2.7–4.1)	**3.20 (1.78–5.72)**	2.71 **(1.44–5.09)**
Residential instability†					
Q1 (least unstable)	28	2 051 860	1.4 (0.9–2.0)	1.00	1.00
Q2	24	1 881 424	1.3 (0.8–1.9)	0.93 (0.54–1.61)	0.91 (0.52–1.58)
Q3	39	1 718 755	2.3 (1.6–3.1)	**1.66 (1.02–2.70)**	**1.34** (0.80–2.25)
Q4	56	1 992 259	2.8 (2.2–3.6)	**2.06 (1.31–3.24)**	**1.30** (0.79–2.16)
Q5 (most unstable)	63	1 414 316	4.4 (3.5–5.7)	**3.27 (2.09–5.10)**	**1.88 (1.14–3.09)**
Previous TBI‡,§					
No	185	8 690 013	2.1 (1.8–2.4)	1.00	1.00
Yes	25	368 602	6.8 (4.6–10.0)	**3.18 (2.10–4.84)**	**2.25 (1.47–3.45)**
Psychotic mood disorder‡,¶,**					
No	198	8 983 104	2.2 (1.9–2.5)	1.00	1.00
Yes	12	75 512	15.9 (9.0–28.0)	**7.21 (4.03–12.91)**	2.54 **(1.37–4.70)**
Nonpsychotic mood disorder‡,¶,††					
No	111	6 592 676	1.7 (1.4–2.0)	1.00	1.00
Yes	99	2 465 939	4.0 (3.3–4.9)	**2.38 (1.82–3.12)**	**1.60 (1.20–2.14)**
Substance use disorder‡,¶,‡‡					
No	182	9 212 901	2.0 (1.7–2.3)	1.00	1.00
Yes	32	114 994	27.8 (19.7–39.3)	**14.69 (10.08–21.40)**	**8.65 (5.78–12.95)**
Social problems‡,¶,§§					
No	186	8 717 397	2.1 (1.8–2.5)	1.00	1.00
Yes	24	341 219	7.0 (4.7–10.5)	**3.30 (2.15–5.04)**	**1.98 (1.28–3.08)**

Note: CI = confidence interval, HR = hazard ratio, ICD-9 = International Classification of Diseases, 9th Revision, [Clinical Modification], IR = incidence rate, Q = quintile, TBI = traumatic brain injury. Values in boldface type represent confidence limits that do not cross 1.
*At least 1 TBI between June 30, 1997, and Mar. 31, 2011.
†As per the Ontario Marginalization Index,[42] by quintile.
‡Based on medical records from physician visits, including primary care providers.
§History of TBI between Apr. 1, 1993, and June 30, 1997.
¶History of diagnosis between Jan. 1, 1995, and June 30, 1997.
**Defined as hospital visit for ICD-9 diagnostic codes 295–298.
††Defined as hospital visit for ICD-9 diagnostic codes 300–302, 306, 309 and 301.
‡‡Defined as hospital visit for ICD-9 diagnostic codes 291–292 and 303–304.
§§Defined as hospital visit for ICD-9 diagnostic codes 897–906 and 909.

Table 4: Sensitivity analyses: unadjusted and adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) for traumatic brain injury and incarceration among men and women in Ontario from 1997 to 2011

	Men		Women	
	Unadjusted model	Adjusted model	Unadjusted model	Adjusted model
Sensitivity analysis	HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Final model	**3.26 (2.91–3.64)**	**2.47 (2.21–2.77)**	**4.15 (2.15–6.86)**	**2.76 (1.65–4.60)**
Exclude participants with TBI before baseline	**3.84 (3.23–4.57)**	**3.08 (2.59–3.67)**	**2.90 (1.18–7.13)**	2.12 (0.86–5.23)
Exclude records probabilistically linked	**4.43 (3.76–5.28)**	**3.14 (2.66–3.71)**	**3.23 (1.42–7.38)**	2.08 (0.91–4.79)
Year-lagged TBI exposure	**3.70 (3.14–4.36)**	**2.71 (2.30–3.20)**	**2.60 (1.06–6.38)**	1.66 (0.67–4.11)
No lagged TBI exposure	**4.16 (3.60–4.82)**	**3.06 (2.64–3.54)**	**4.51 (2.35–8.62)**	**2.93 (1.52–5.65)**
Include TBI-related visits to primary care providers	**3.92 (3.57–4.30)**	**3.02 (2.75–3.32)**	**4.79 (3.22–7.12)**	**3.78 (2.25–5.06)**
Diagnosis code type				
Hospital admission	**4.89 (3.55–6.73)**	**3.41 (2.47–4.71)**	**10.19 (2.53–41.09)**	**7.12 (1.76–28.86**
ED visit	**3.13 (2.78–3.52)**	**2.40 (2.13–2.70)**	**4.15 (2.51–6.86)**	**2.55 (1.48–4.38)**
TBI count				
0	1.00	1.00	1.00	1.00
1	**3.67 (3.12–4.31)**	**2.77 (2.35–3.26)**	**4.02 (1.96–8.25)**	**2.70 (1.30–5.57)**
≥ 2	**9.13 (5.92–14.05)**	**4.50 (2.92–6.95)**	–*	–*

Note: CI = confidence interval, ED = emergency department, HR = hazard ratio, TBI = traumatic brain injury. Values in boldface type represent confidence limits that do not cross 1.
*Estimate not provided. No women had more than 1 TBI and went on to be incarcerated.

account for this could have biased effect estimates, we did not expect residual confounding to be the driving explanation behind our findings given the magnitude of association observed. Thinking about generalizability, this study examined the association between TBI and chronic and serious offending. Although our findings are consistent other research, we cannot say with certainty that the association would hold for more general criminal justice involvement. We did not have information on admissions to provincial facilities. We fully recognize that the pathway to incarceration and criminal justice involvement is complex. Relationships may be bidirectional (e.g., impulsive behaviour and substance abuse can be a cause or consequence of TBI[18,19] and not all persons with a TBI will go on to be incarcerated). More research is needed to deconstruct how TBI could play a role in these pathways and if different mechanisms of injury (e.g., motor vehicle collisions v. falls) affect incarceration risk differently.

Conclusion

We found that TBI was associated with an increased risk of incarceration for serious and chronic offending among both men and women. Our findings are based on a large population-based cohort of young adults who were followed for an average of about 13 years and are consistent with research reported elsewhere. Future research should focus on primary, secondary and tertiary prevention, which may help to reduce incarceration or improve the outcomes of persons with TBI who are incarcerated.

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