Title: Traumatic brain injury and incarceration in men and women: 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 traumatic brain injury (TBI) and incarceration risk in men and women.

Methods: We identified a cohort of 1.418 million young adults (aged 18-28) on July 1, 1997, living in Ontario, Canada, from administrative health records; they were followed to December 31, 2011. TBI history was obtained from emergency and hospital records and incarceration history was obtained from Canadian federal correctional 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 18 297 599 person-years of follow-up. The incidence of incarceration was higher in persons with prior TBI compared to those without a prior TBI. In fully adjusted models, men and women who had sustained a TBI were approximately 2.5 times more likely to be incarcerated than men and women who had not sustained a TBI, respectively.

Interpretation: TBI was associated with an increased risk of incarceration in 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.

Key words: Traumatic brain injury; prison; gender

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Introduction

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 people in 2010/11, an increase of over 20% since 2004/05(5). TBI 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, like aggression and impulsivity, could increase propensity for criminal justice involvement(9-12). Meta-analyses indicate that the lifetime prevalence of TBI is high in persons 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 have examined the association between TBI and criminal justice involvement focusing on criminality and violent crime(18-21). All suggest an association between TBI and criminal justice involvement although results were not always statistically significant(18-21). There has been no research examining the association between traumatic brain injury and risk of incarceration for serious or chronic offences and none in Canada.

Our study builds on the literature regarding TBI and criminal justice involvement with a particular focus on serious and chronic offending. In Canada, the federal justice system supervises persons sentenced by the courts to two years or more. Such sentences would be characteristic for persons committing a serious offence or who are chronically in contact with the criminal justice system(22). Our overall objective was to determine if prior TBI was associated with an increased risk of incarceration in men and women.

Methods

Setting and design

We conducted a cohort study of young adults aged 18-28 in Ontario, Canada, between July 1, 1997 and March 31, 2011 using linked administrative data. This study was approved by the institutional review board at Sunnybrook Health Sciences Centre, Toronto, Canada and received additional approvals at St. Michael's Hospital and the University of Toronto.

Participants

Individuals aged 18 to 28 years on July 1, 1997 (i.e. the index date) were included if they were eligible for health care in Ontario between January 1, 1993 and July 1, 1997.i.e.,listed in the Registered Persons Database, a population-based registry for health 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 health care eligibility. 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 the 5 years prior and women without health care utilization in the 3 years prior were no longer in the province and their date of ineligibility was 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 datasets to correctional records. Health datasets included the Registered Persons Database, the Ontario Health Insurance Plan database, the Canadian

Institutes for Health Information Discharge Abstracts Database, and the National Ambulatory Care Reporting System. The correctional dataset was the Offender Management System, a computerized record system that tracks information from admission until sentence completion, maintained by the Correctional Service Canada, the government agency responsible for supervising persons with federal sentences(28). All persons who enter a federal correctional facility will be recorded in the Offender Management System, and these data have 100% population coverage. Datasets were linked using unique encoded identifiers and analyzed at the Institute for Clinical Evaluative Sciences and 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 OMS. We retained the first federal sentence occurring between January 1, 1998 and March 31, 2011. We excluded persons with suspended records(i.e., pardoned).

The exposure of interest was TBI. Persons with a recorded diagnosis of TBI in the Discharge Abstracts Database or the National Ambulatory Care Reporting System between July 1, 1997 and September 30, 2010 were classified as sustaining a TBI. The Discharge Abstracts Database contained hospital discharges and the National Ambulatory Care Reporting System contained emergency room visits. Although these are national databases, we only had access to Ontario data. TBI was based on ICD-9 and ICD-10 diagnoses codes: ICD-9 codes in the range of 800-

801, 803-804, 850-854.1 or 959.01(30) or ICD-10 codes in the range of S02.0, S02.1, S02.3, S02.7, S02.8, S02.9, S06, S07.1, T90.2, T90.5 were considered TBI related visits(30, 31).

TBI since index was treated as a binary time-varying covariate. We lagged the exposure variable by six-months to account for time between committing the related crime and entering the prison system. In 2008, this median time was approximately 3 months(32); by lagging the exposure variable to six months, we reduce the possibility that TBI was sustained after the crime was committed for the majority 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 January 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 four types of mental health diagnoses: psychotic disorders (ICD-9: 295-298)(40); non-psychotic disorders (ICD-9: 300-302; 306; 309; 311)(40); substance abuse disorders (ICD-9: 291-292; 303-304)(40, 41); or social problems (ICD-9: 897-902; 904-906; 909)(40). If an individual had at least one of these diagnostic codes in the applicable databases between January 1, 1995 and June 30, 1997 they were considered positive for that mental health diagnoses.

We used three neighbourhood-level measures of marginalization used widely 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). Individuals stopped contributing to the Cox model on their date of first federal incarceration; death; loss of health care eligibility; or March 31, 2011. Because persons were censored at the time of first federal incarceration and we lagged the exposure variable by six months, we reduce the possibility of protopathic bias.

We report crude and multivariable adjusted Hazard Ratios (HR) and 95% confidence intervals (95% CI) 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 in two ways: 1) complete case analyses; 2) modeling 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 missingness biased our statistical inference(47-49).

Sensitivity analysis

We performed seven sensitivity analyses. 1) Excluding individuals reporting TBI between 1993 and 1997 in efforts to obtain an "incident" cohort; 2) Excluding individuals whose correctional records were linked to health records probabilistically(29); 3) Lagging the TBI exposure variable by one year; 4) Not lagging the TBI exposure variable; 5) Broadening the definition of TBI to include primary care visits; 6) Estimating risk of incarceration for persons discharged from the emergency room for TBI and those who were hospitalized for TBI; 7) Treating TBI as a 3-level exposure variable:0 TBI, 1 TBI or 2 or more TBI.

Results

The cohort included 748,393 men and 731,013 women. Table 1 presents baseline characteristics of respondents by TBI over follow-up. There were 77,519 persons (5.2%) who sustained at least one TBI. After excluding those with missing data, 716,585 men and 701,480 women remained. Together, they contributed 18,297,599 person-years of follow-up (mean=12.7 years; median =13.7 years).

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 federally incarcerated 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 in 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 (3.5 per 100,000 person-years, 95% CI:32.1-34.5). In unadjusted models, men who had sustained a TBI

had a three-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 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 approximately four 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=0.73).

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

Interpretation:

We conducted a population-based cohort study to explore the association between TBI and risk of incarceration for serious and chronic offending. Our findings indicate that sustaining a TBI was associated with an increased risk of incarceration for such offences. The relative association was similar in men and women and was upheld in a variety of sensitivity analyses, although estimates were less precise and not always significant in women.

These findings contribute to emerging research suggesting TBI is an important risk factor for criminal justice involvement(18-20) and builds on this evidence: it is the largest of its kind with 16% more criminal justice events than reported previously(19). Further, this is the only study to explore how TBI is associated with serious and chronic offending with a focus exclusively on persons sentenced to federal custody(28). A more novel contribution of our research is the sex-based analyses. Only one study has examined how TBI affects incarceration risk in men and women separately(19). Although the confidence limits for women were wide, reflecting the small number of women who were incarcerated in our study, they are consistent with prior research: the relative increase in incarceration risk was similar in men and women who sustained a TBI(10). Finally, although prior research suggests multiple head injuries are *common* in correctional populations, we are one of the first to explore if there is a dose-response relationship with TBI and *risk* of incarceration(50).

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 Swedish study, with a similar effect size, studied only violent crime(18). It may be that the types of crimes committed, or the length of sentences received, differ in persons with and without a prior TBI, and that these differences drive the stronger associations. Differences could also be related to other aspects of the research methodology. As an example, we are the first to explicitly model TBI as a time-varying exposure allowing us to capture TBI at the time of incarceration, as opposed to 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 towards the null. Finally, 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

TBI was measured using diagnosis codes from emergency room 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 were unable to assign scores to 35% of the TBI-population 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 experience incarceration than men and women who were discharged from the ER with a TBI, suggesting the risk of incarceration could be greater for those with more severe TBI. We also acknowledge potential measurement error in our control variables which could introduce residual confounding (e.g., mental health was captured using diagnosis codes and not all individuals with mental illness seek medical attention)(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 account for this could have biased effect estimates, we do 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 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 experience incarceration. 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 vs. falls) affect incarceration risk differently.

Conclusions

We found that TBI was associated with an increased risk of incarceration for serious and chronic offending in both men and women. Our findings are based on a large, population-based cohort of young adults who were followed for an average of approximately 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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Table 1. Sociodemographic characteristics and medical history of study cohort at study baseline, by traumatic brain injury status, Ontario, Canada (1997-2011) (N=1 479 406)

Characteristics	At least 1 TBI[a] (N=77 519) n, %	No TBI (N=1 401 887) n, %
Incarcerated Over follow-up		
No	77,117 (99.5)	1,398,556 (99.8)
Yes	402 (0.5)	3,331 (0.2)
Age (mean, sd)	22.8 (3.2)	23.1 (3.2)
18-21 years	32,235 (41.6)	489,801 (34.9)
22-24 years	19,779 (25.5)	372,714 (26.6)
25-28 years	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[b]		
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	2,984 (3.8)	58,357 (4.2)
Ethnic concentration[b]		
Q1 (least concentrated)	11,669 (15.1)	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 concentrated)	19,313 (24.9)	384,859 (27.5)
Missing	2,984 (3.8)	58,357 (4.2)
Residential Instability[b]		
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	2,984 (3.8)	58,357 (4.2)
Previous TBI[c,d]		
No	68,639 (88.5)	1,326,647 (94.6)
Yes	8,880 (11.5)	75,240 (5.4)
Psychotic Mood Disorder[c,,e,f]		
No	76,368 (98.5)	1,390,308 (99.2)
Yes	1,151 (1.5)	11,579 (0.8)
Non-psychotic Mood Disorder[c,e,g]		
No	57,909 (74.7)	1,119,044 (79.8)
Yes	19,610 (25.3)	282,843 (20.2)
Substance use disorder[c,e,h]		
No	74,869 (96.6)	1,381,839 (98.6)
Yes	2,650 (3.4)	20,048 (1.4)
Social Problems[c,e,i]		
No	74,721 (96.4)	1,365,949 (97.4)
Yes	2,798 (3.6)	35,938 (2.6)

Q1: quintile 1; TBI: Traumatic brain injury
[a] At least 1 TBI between April 1 1997- December 2011
[b] As per the Ontario Marginalization Index, by quintile
[c] Medical records from physician visits, including primary care providers
[d] History of TBI between April 1, 1993- June 30, 1997
[e] History of diagnosis between January 1, 1995-June 30, 1997
[f] Defined as hospital visit for ICD-9 diagnostic codes in the range of 295-298
[g] Defined as hospital visit for ICD-9 diagnostic codes in the range of 300-302; 306; 309; 3011
[h] Defined as hospital visit for ICD-9 diagnostic codes in the range of 291-292; 303-304

[1] Defined as hospital visit for ICD-9 diagnostic codes in the range 897-906; 909

Table 2. Incidence Rate (IR), Unadjusted and Adjusted Hazard Ratio (HR)for incarceration in Men, by Traumatic Brain Injury, Sociodemographic Characteristics, and Medical History, Ontario, Canada, 1997-2011 (N= 716 585)

Characteristics	Number 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[a]								
No	2965	8 891 856	33.5	32.1,34.5	**1.00**	**1.00**	**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								
18-21 years	1297	3 262 825	39.8	37.6, 42.0	**1.00**	1.00	1.00	1.00
22-24 years	873	2 449 332	35.6	33.3, 38.1	**0.90**	**0.82, 0.98**	**0.87**	**0.80, 0.95**
25-28 years	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	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[b]								
Q1 (least deprived)	439	2 204 177	19.9	18.1, 21.9	1.00	1.00	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[b]								
Q1 (least concentrated)	416	1 344 374	29.8	27.1, 32.8	1.00	1.00	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 concentrated)	1149	2 580 852	42.8	40.4, 45.3	**1.44**	**1.29, 1.61**	1.06	0.94, 1.20
Residential Instability[b]								
Q1 (least unstable)	485	2 189 635	22.3	20.2, 24.2	1.00	1.00	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 [c,d]								
No	2801	8 570 118	32.7	31.5, 33.9	1.00	1.00	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 [c,e,f]								
No	3233	9 159 856	35.3	34.1, 36.5	1.00	1.00	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
Non-psychotic Mood Disorder [c,e,g]								
No	2255	7 957 300	28.3	27.2,29.5	1.00	1.00	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 [c.e.h]								
No	2988	9 081 002	32.9	31.7, 34.1	1.00	1.00	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 [c,e,i]								
No	3169	9 099 282	34.8	33.6, 36.1	1.00	1.00	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**

CI: Confidence interval; HR: Hazard Ratio; IR: Incidence Rate; Q1: quintile 1; TBI: traumatic brain injury

[a] At least 1 TBI between June 30, 1997 and March 31, 2011
[b] As per the Ontario Marginalization Index, by quintile
[c] Based on medical records from physician visits, including primary care providers
[d] History of TBI between April 1, 1993- June 30, 1997
[e] History of diagnosis between January 1, 1995-June 30, 1997
[f] Defined as hospital visit for ICD-9 diagnostic codes in the range of 295-298
[g] Defined as hospital visit for ICD-9 diagnostic codes in the range of 300-302; 306; 309; 301
[h] Defined as hospital visit for ICD-9 diagnostic codes in the range of 291-292; 303-304
[i] Defined as hospital visit for ICD-9 diagnostic codes in the range 897-906; 909

Table 3. Incidence Rate (IR), Unadjusted and Adjusted Hazard Ratio (HR)for incarceration in Women, by Traumatic Brain Injury, Sociodemographic Characteristics, and Medical History, Ontario, Canada, 1997-2011 (N=701 480)

Characteristics	Number 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	**210**	**9 058 616**	**2.3**	**2.0, 2.6**				
TBI[a]								
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								
18-21 years	77	3 141 869	2.4	2.0, 3.1	1.00	1.00	1.00	1.00
22-24 years	47	2 369 277	1.9	1.5, 2.6	0.81	0.56, 1.16	0.77	0.54, 1.11
25-28 years	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	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[b]								
Q1 (least deprived)	29	2 181 375	1.3	0.9, 1.9	1.00	1.00	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[b]								
Q1 (least concentrated)	13	1 242 374	1.0	0.6, 1.8	1.00	1.00	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 632316	3.3	2.7, 4.1	**3.20**	**1.78, 5.72**	2.71	**1.44, 5.09**
Residential Instability[b]								
Q1 (least unstable)	28	2 051 860	1.4	0.9, 2.0	1.00	1.00	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 [c,d]								
No	185	8 690 013	2.1	1.8, 2.4	1.00	1.00	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 [c,e,f]								
No	198	8 983 104	2.2	1.9, 2.5	1.00	1.00	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**
Non-psychotic Mood Disorder [c,e,g]								
No	111	6 592 676	1.7	1.4, 2.0	1.00	1.00	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 [c.e.h]								
No	182	9 212 901	2.0	1.7, 2.3	1.00	1.00	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 [c,e,i]								
No	186	8 717 397	2.1	1.8, 2.5	1.00	1.00	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**

CI: Confidence interval; HR: Hazard Ratio; IR: Incidence Rate; Q1: quintile 1; TBI: traumatic brain injury

[a] At least 1 TBI between June 30, 1997 and March 31, 2011
[b] As per the Ontario Marginalization Index, by quintile
[c] Based on medical records from physician visits, including primary care providers
[d] History of TBI between April 1, 1993- June 30, 1997
[e] History of diagnosis between January 1, 1995-June 30, 1997
[f] Defined as hospital visit for ICD-9 diagnostic codes in the range of 295-298
[g] Defined as hospital visit for ICD-9 diagnostic codes in the range of 300-302; 306; 309; 301
[h] Defined as hospital visit for ICD-9 diagnostic codes in the range of 291-292; 303-304
[i] Defined as hospital visit for ICD-9 diagnostic codes in the range 897-906; 909

Table 4. Sensitivity Analyses: Hazard Ratio (HR) and 95% Confidence Interval (CI) of Traumatic Brain Injury and Incarceration in Men and Women, Ontario, Canada (1997-2011)

	Male				Female			
Sensitivity analysis	Unadjusted models		Adjusted models		Unadjusted models		Adjusted models	
	HR[a]	95% CI[b]	HR[a]	95% CI[b]	HR[a]	95% CI[b]	HR[a]	95% CI[b]
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 individuals with TBI prior to 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**
ER 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 Counts:								
0 TBI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1 TBI	**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+ TBI	**9.13**	**5.92, 14.05**	**4.50**	**2.92, 6.95**	[a]	[a]	[a]	[a]

CI: Confidence Interval; HR: Hazard Ratio; TBI: Traumatic brain injury

a Estimate not provided: no women experienced more than 1 TBI and went on to be incarcerated

Title: Traumatic brain injury and incarceration in men and women: a population-based cohort study

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Contributor's statement: AM, RM, LAK, LAS, AC, ABN and FIM conceived the study and were integral with the acquisition of data. KEM, RM, FIM analyzed the data. KEM, RM, LAK, GW, LAS, FIM were involved in the interpretation of data. KEM wrote the first draft of the manuscript and received critical input from all co-authors. All authors approved the final version of this manuscript and agree to act as guarantors of the work.

Conflict of interest: AM, LAK, GW, LAS are employees of the Correctional Service of Canada.

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STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Title: Traumatic brain injury and incarceration in men and women: a **population-based cohort study**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **Yes, completed**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Page 1, Lines 11-23**
Objectives	3	State specific objectives, including any prespecified hypotheses **Page 1: Lines 23-24**
Methods		
Study design	4	Present key elements of study design early in the paper **Page 2, Lines 28-29**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Page 2, Lines 28-43**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **Page 2-3: Lines 33-43**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Page 3-4: Lines 57-93**
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 **Page 3-4: Lines 57-93**
Bias	9	Describe any efforts to address potential sources of bias **Page 2, Lines 38-43** **Page 3, Lines 52-54** **Page 4: Lines 72-76** **Page 5: Lines 103-104**
Study size	10	Explain how the study size was arrived at

		Page 2: Lines 33-35
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Page 4: Line 72**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, explain how loss to follow-up was addressed
		(*e*) Describe any sensitivity analyses **Page 5-6: Lines 95-123**
Result		
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 **Page 6, Lines 126-130**
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) Summarise follow-up time (eg, average and total amount) **Page 6, Lines 126-130** **Table 1**
Outcome data	15*	Report numbers of outcome events or summary measures over time **Page 6, Lines 132-134; Table 2** **Page 7: Lines 141-143, Table 3**
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
		(*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 **Page 6-7: Lines 132-145** **Tables 2,3**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **Page 7-8, Lines 147-153**

		Table 4
Discussion		
Key results	18	Summarise key results with reference to study objectives **Page 7, Lines 156-160**
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 **Page 9-10, Lines 190-215**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **Page 8-9, Lines 162-189**
Generalisability	21	Discuss the generalisability (external validity) of the study results **Page 9/10, Lines 206-209**
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 **Cover page**

*Give information separately for exposed and unexposed groups.

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 http://www.strobe-statement.org.