Incidence and Associated Risk Factors of Traumatic Brain Injury in a Cohort of Homeless and Vulnerably Housed Adults in 3 Canadian Cities

Mohammadali Nikoo, Anne Gadermann, Matthew J. To, Michael Krausz, Stephen W. Hwang, and Anita Palepu

Version Post-Print/Accepted Manuscript


Publisher's Statement This is a non-final version of an article published in final form in Journal of Head Trauma Rehabilitation 2016 Nov. The final published version is available via https://dx.doi.org/10.1097/HTR.0000000000000262.

How to cite TSpace items

Always cite the published version, so the author(s) will receive recognition through services that track citation counts, e.g. Scopus. If you need to cite the page number of the TSpace version (original manuscript or accepted manuscript) because you cannot access the published version, then cite the TSpace version in addition to the published version using the permanent URI (handle) found on the record page.
Abstract

Objective: To examine the factors associated with incident traumatic brain injury (TBI) among homeless and vulnerably housed persons over a three-year follow-up period.

Setting & participants: Data were obtained from the Health and Housing in Transition study, which tracked the health and housing status of 1190 homeless or vulnerably housed individuals in three Canadian cities for 3 years. Design & Main Measures: Main measure was self-reported incident TBI during the follow-up period. Associated risk factors were ascertained using mixed effects logistic regression. Results: During 1st, 2nd and 3rd years of follow-up, 187 (19.4%), 166 (17.1%) and 172 (17.9%) participants reported a minimum of one incident TBI, respectively. Among 825 participants with available data for all 3-years of follow-up, 307 (37.2 %) reported at least one incident TBI during the 3-year follow-up period. Lifetime prevalence of TBI, endorsing a history of mental health diagnoses at baseline, problematic alcohol and drug use, younger age, poorer mental health and residential instability were associated with increased risk of incident TBI during follow-up period.

Conclusion: Rehabilitation programs for TBI, mental health support and addressing residential instability and problematic substance use may reduce further risk of TBI and its associated poor health and social outcomes in this population.

Keywords

traumatic brain injury, homeless, risk factor, prevalence, incidence
Introduction

Lifetime prevalence of Traumatic brain injury (TBI) is higher among the homeless population than the general population and is associated with many adverse health-related outcomes such as. These adverse outcomes include but are not limited to physical and mental health conditions, cognitive impairment, substance use, suicidality, victimization and increased mortality\(^1\)\(^-\)\(^7\) and more health care utilization and service \(^2\) \textit{incarceration}. A high percentage of persons who are homeless experience their first TBI before the first homelessness episode \(^5\)\(^-\)\(^9\) and most of them experience multiple TBIs during their life \(^5\)\(^-\)\(^9\). While previous literature including a previously published paper on this sample \(^2\) has focused more on the factors associated with lifetime prevalence of TBI among people who are homeless and its associated factors \(^1\)\(^-\)\(^7\), \(^9\), less is known about the underlying risk factors of rather than incident TBI in a prospective study\(^1\)\(^-\)\(^7\),\(^9\). In some of these studies, the interval between age of people who are homeless Understanding this issue, first sustained TBI and the assessment was more than a decade, which increases the risk of recall bias. In addition, an individual’s risk factors for sustaining a TBI several years ago may not be the same as risk factors for incident TBI. For example, the increased risk of TBI due to unsafe household environment for a child will not remain the same a decade later.\(^6\),\(^7\). Identifying risk factors for incident TBI may inform policy makers and healthcare professionals about those individuals at higher risk of acquiring new TBI; provide a better understanding of what preventive measures may be beneficial to this population; and indicate the importance of cognitive rehabilitation in this population. We, therefore, sought to determine the underlying risk factors of incident
TBI during follow-up among a cohort of homeless or vulnerably housed persons who participated in the Health and Housing in Transition (HHiT) study.

Methods

Participants and Recruitment

The data for these analyses were obtained from the HHiT study, a multi-site longitudinal study that tracked the health and housing status of a sample of homeless or vulnerably housed individuals in Canada. At baseline, 1,190 participants who were homeless or vulnerably housed and 18 years old and over were recruited in three major Canadian urban areas, i.e. Vancouver, British Columbia; Ottawa, Ontario; and Toronto, Ontario, from January to December 2009. Individuals were re-interviewed every 12 months for a 3-year time period. A homeless participant was defined as a person living in a shelter, public space and motor vehicle, abandoned building, or not having their own place. A vulnerably housed participant was defined as a person living in their own room, apartment or place, but had been homeless and/or had two or more moves over the past 12 months. The sampling procedure of the study is described in detail elsewhere. Briefly, homeless participants were recruited in shelters and meal programs. Vulnerably housed participants were randomly selected from the stock of low-cost housing in Ottawa and Toronto and single room occupancy (SRO) hotels in Vancouver. Due to challenges in gaining access to residents at these sites, our sampling plan for vulnerably housed participants was modified to also recruit from meal programs, community health centers, and drop-in centers.

Ethical Considerations
Informed consent was obtained from each participant before inclusion in the study. The participants were paid an honorarium ($20 CAD) following the interview. Research Ethics Boards at St. Michael’s Hospital (Toronto), the University of Ottawa, and the University of British Columbia (Vancouver) approved the study.

**Study Instrument and Measures**

The complete description of the survey questionnaire and its application has been previously published. Data were obtained through structured in-person interviews with trained interviewers, which lasted approximately 60-90 minutes. From baseline assessments, we ascertained socio-demographic characteristics (age, gender, self-reported ethnicity/cultural group, education), city of recruitment, lifetime prevalence of TBI and epilepsy, problematic drug and alcohol use, lifetime prevalence of mental health diagnoses, mental health status, and lifetime duration of homelessness.

Lifetime prevalence of TBI was determined using the question “Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?”. The question is part of the National Survey of Homeless Assistance Providers and Clients (NSHAPC) and has been used in several studies with homeless and vulnerably housed populations to measure self-reported TBI in the past as well as among prison inmates. These studies have demonstrated that self-reported TBI in response to this question was associated with other measures in theoretically expected directions, indicating the construct validity of this question to assess self-reported TBI. Specifically, self-reported TBI in response to this question was associated with seizures, substance use problems, poorer physical health and mental health status, worse anger and aggression scores and a trend towards poorer cognitive test results, more emergency
Self-reported TBI has also been validated against hospital medical records in a sample of prison inmates, further supporting the accuracy of self-reported TBI. Participants were asked to report any chronic health conditions (adapted from the Canadian Community Health Survey) that had lasted or were expected to last 6 months or more and had been diagnosed by a healthcare professional. Mental health status of participants was measured using Mental Component Summary (MCS) of 12-item Short Form Health Survey (SF-12). To assess lifetime prevalence of mental health diagnoses, participants were asked: “Have you ever been diagnosed with a mental health problem?” The 10-item Drug Abuse Screening Test (DAST-10) was used to screen for drug use with problematic drug use defined as a DAST-10 score ≥ 6, which indicate potentially clinically significant drug use and would merit intensive assessment. The Alcohol Use Disorders Identification Test (AUDIT), a 10-item questionnaire, was used to screen for alcohol use disorder (positive screen ≥ 8) and we defined problematic alcohol use as an AUDIT score of ≥ 20. These instruments have been validated for use in previous studies of vulnerable populations.

Follow-up
Participants had annual follow-up interviews from which we ascertained incident TBI events during the follow-up period. They provided primary and alternative contact information at the baseline survey so that they could be located for follow-up visits. Our outcome variable was whether participants had at least one incident TBI during the past year at each of three follow-up years. At each follow-up, participants were asked: “Have you had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented during the past year?” Positive response to these questions was considered
as a TBI event during the prior year. We also ascertained participants’ problematic alcohol use during past year as an AUDIT score of $\geq 20^{17,18}$, problematic drug use during past year defined as a DAST-10 score $\geq 6$ and mental health status during last 4 weeks measured by the SF-12 MCS score of $\geq 6^{20,21}$ at each follow-up interview. Lifetime prevalence of TBI at each follow-up year was defined as positive lifetime history of TBI at the baseline and/or TBI incidence during previous follow-up years. Residential stability during the past year was defined as being functionally housed and staying in the same location without interruption for more than 180 days during the past year at each follow-up interview following the methods described by Tsemberis $^{22,23}$.

Further details on the description of housing variables in this study is provided on the study website $^{23}$.

**Statistical analysis**

Descriptive statistics were used to summarize all numeric and categorical variables. Numeric variables were described as mean (standard deviation), and categorical variables were described as frequency (percentage).

We fit mixed effects logistic regression models to ascertain the factors associated with incident TBI during each year for the 3-year follow-up period. Initially, mixed effects logistic regression analyses were conducted separately to examine the unadjusted association between each fixed and time-varying predictor with incident TBI during follow-up years. Fixed predictors were only assessed at baseline and included age, gender (those who identified themselves as transgender were not included in the regression analysis because of their small number [1.4%]), ethnicity (White, Black/African-Canadian, First Nations/Indigenous, Mixed ethnicity, other [Asian and Hispanic]).
education (post-secondary or higher, completed high school or equivalent, some high school), city of recruitment, lifetime duration of homelessness, lifetime prevalence of epilepsy, lifetime prevalence of mental health diagnoses, and lifetime prevalence of TBI. 

We included baseline age and age duration of first homelessness in time intervals before inclusion and in the regression analyses. Time-varying predictors included problematic alcohol use and drug use during past year, residential stability during past year, lifetime prevalence of TBI and SF-12 mental health summary scores during past 4 weeks. We followed the methodology provided by UCLA: statistical consulting group for building the mixed effects logistic regression model. The clusters were the multiple observations collected per participant. Age, gender and other variables that met the cut-off of P ≤ 0.1 were jointly included in the multiple observations collected per participant. We set p-value ≤ 0.1 as a cut-off for the bivariate analyses. Age, gender and other variables that met the cut-off were included in a final multivariable mixed effects logistic regression model. Results of this model were summarized with adjusted odds ratios (95% Confidence interval). Statistical tests were 2-tailed and P ≤ .05 was considered statistically significant. All analyses were performed using R version R-3.3.0 for Mac.

Results

A total of 1190 participants were recruited and interviewed at baseline in this study amongst which a total of 968, 970 and 962 participants attended the 1st, 2nd and 3rd follow-up interviews, respectively. Mean age of participants at baseline was 42.2 years (SD=10.6) and 385 (32.4%) were female. Lifetime prevalence of TBI was 60.4% (n=718) at the baseline interview. Data on incident TBI during follow-up
interviews were available for 965, 969 and 961 participants for the 1st, 2nd and 3rd follow-up interviews with 187 (19.4%), 166 (17.1%) and 172 (17.9%) participants reporting a minimum of one incident TBI during the 1st, 2nd and 3rd years of follow-up, respectively.

Data regarding incident TBI during any of follow-up years were available for 1084 participants and 363 (33.5%) incident TBIs were recorded for them. Data regarding incident TBI during all 3-year follow-up were available for 825 participants and 307 (37.2%) reported at least one incident TBI during the follow-up period. Among those with incident TBI during the follow-up period, 60 (19.5%) had not reported a lifetime history of TBI at baseline and experienced their first TBI during the 3-year follow-up period. Characteristics of the study sample with available data on incident TBI at each follow-up interview are presented in Table 1.

In the bivariate mixed effects logistic regression analyses evaluating the simple association of each predictor with the risk of incident TBI during follow-up, ethnicity (P = 0.03), city (P = 0.02), lifetime prevalence of TBI (P < 0.01), history of epilepsy (P < 0.01), history of mental health diagnosis (P < 0.01), SF-12 Mental health summary score (P < 0.01), MCS, problematic alcohol use (P < 0.01), problematic drug use (P < 0.01) and residential stability during the past year (P = 0.01) met the cut-off for the final model. Results of the simple bivariate and multivariable models regarding factors associated with incident TBI during follow-up period are summarized in Table 2. The final multivariable mixed effects logistic regression analysis showed that lifetime prevalence of TBI [AOR = 3.10; 95% CI: 2.20, 4.38], mental health diagnoses at baseline [AOR = 1.38; 95% CI: 1.02, 1.88], problematic alcohol [AOR = 2.42; 95% CI: 1.68, 3.47] and drug use [AOR =
1.35; 95% CI: 1.01, 1.82] were independently associated with increased odds of incident TBI during the follow-up period, while after adjustment for gender, ethnicity, city and history of epilepsy. In contrast, older age [AOR = 0.93; 95% CI: 0.88, 0.99], better mental health summary score [AOR = 0.97; 95% CI: 0.96, 0.98] and residential stability [AOR = 0.75; 95% CI: 0.57, 0.99] were associated with decreased odds of experiencing incident TBI during the follow-up period after adjustment for gender, ethnicity, city and history of epilepsy, the above-mentioned variables.

Discussion

At each follow-up year, 17.1%-19.4% of participants reported a minimum of one incident TBI while during the whole 3-year follow-up period, a total of 37.2% of participants reported at least one incident TBI during follow-up period. Our results estimate the minimum self-reported annual rate of incident TBI among homeless or vulnerably housed individuals during the yearly follow-up period to be at least 17,120 per 100,000 which is relatively very high compared to 500 per 100,000 in the general population. Among those with incident TBI during the follow-up period of our study, 60 (19.5%) had not reported a lifetime history of TBI at baseline and experienced their first TBI during the 3-year follow-up period. This indicates that a high percentage of the recorded TBIs (approximately 1 out of 5) occurred as the first lifetime event, which implies highlights their vulnerability and the importance of preventive measures for TBI in this population. In the final multivariable model, we found the following factors independently associated with incident TBI: lifetime prevalence of TBI, endorsing a
mental health diagnoses at baseline, problematic alcohol and drug use. Older, younger age, higher/lower mental health summary score and residential stability/instability were independently associated with decreased odds of incident TBI during follow-up.

Problematic alcohol use and problematic drug use were both independently associated with higher odds of incident TBI during the 3-year follow-up period. Previous studies in the general population have also found an increased risk of incident TBI related to substance use. A literature review on substance use and TBI found that substance use was not only associated with an increased risk of TBI, but also with increased morbidity and excessive substance use after the TBI. The authors noted that risk-taking behaviour was a factor that was closely associated with substance use and might also be contributing to the higher risk of incident TBI. These findings suggest that substance use interventions targeting persons who are homeless or vulnerably housed could be an effective approach for reducing the risk of incident and recurring TBI in this population.

A history of previous TBI demonstrated the strongest independent predictor association of incident TBI during follow-up. After a history of previous TBI, it has been suggested that an initial first TBI increases the there is a two-fold increase risk for a subsequent TBI, by a factor of two and a second TBI is associated with an eightfold increased risk of yet another TBI. A study by Varamo et al followed 827 subjects with head trauma who presented to the Emergency Department. Varamo et al followed 827 subjects who presented to the Emergency Department with head trauma.
for 10 years or until death. They concluded that alcohol-related head trauma is more likely to predispose the subject to subsequent TBI than is the severity of the index trauma itself. There might be other persisting factors among persons affected by TBI, which puts them at further risk of subsequent TBI. For example, cognitive impairment and domestic violence are among the risk factors that have been shown to play significant roles in incident TBI and were not assessed variables in this study. Higher risk of incident TBI among those with a lifetime history of TBI, consistent with the existing literature, suggests that TBI is not usually a single occurrence and in contrast, it can predispose affected individuals to future multiple consecutive TBI events, which increases the adverse consequences related to TBI. Effective therapeutic interventions such as cognitive assessment and rehabilitation of individuals with a lifetime history of TBI may also be an effective preventive measure to avoid future TBI events among them. A history of mental health diagnosis was associated with increased odds of incident TBI during follow-up while better mental health summary scores reduced the odds of incident TBI during the follow-up period. Participants with TBI have been shown to achieve lower scores on the Short Form-36, a more detailed version of the SF-12 administered in this study. SF-36 score was also significantly different between varying severities of TBI in previous studies. The role of TBI in initiation of several mental health conditions is more established. We may also explain why history of mental health conditions could be associated with increased risk of future TBI. First, some mental health diagnoses such as bipolar disorder predispose participants to taking more risky behaviours. Secondly, mental health conditions are associated with increased substance use, which further puts
individuals at risk of further TBI. However, we have adjusted for substance use in our
model. Thirdly, cognitive impairment in mental health conditions such as schizophrenia
and mood disorders can amplify increased risk of TBI by mental health conditions.
Residential stability was negatively associated with incident TBI during the follow-up
period. While this
Endorsing a history of mental health diagnosis was associated with increased odds of
incident TBI during follow-up. Previous studies have demonstrated an association of TBI
with subsequent mental health diagnoses. There are a number of potential pathways
of how mental health conditions could be associated with increased risk of future TBI
including increased likelihood of high-risk behaviours as well as the high prevalence
of concomitant substance use, which may put individuals with mental health conditions
at risk of further TBI, however, we adjusted for substance use in our model. Cognitive
impairment in mental health conditions such as schizophrenia and mood disorders could also amplify increased risk of TBI. Hence, mental health support and
psychosocial interventions could be an option for reducing further risk of incident TBIs
in this population.

Better mental health component summary scores were associated with lower odds of
incident TBI. Participants with TBI have been shown to achieve lower scores on the
Short Form-36, a detailed version of the SF-12 administered in this study. SF-36 scores
were also significantly different between varying severities of TBI in previous studies. Residential stability was negatively associated with incident TBI during the follow-up
period. This is consistent with previous literature demonstrating high prevalence of TBI
among individuals who are homeless \(^1\)–\(^7\), it also implicates. It highlights that not only is unstable housing \(\textit{is-}\) associated with lifetime prevalence of TBI, it is \(\textit{also}\) associated with an ongoing increased \(\textit{risk odds}\) of incident TBI during the follow-up period after adjustment for other risk factors. This suggests that supporting this population to achieve residential stability may \(\textit{reduce/mitigate}\) the risk of future TBI events.

Younger age was also associated with increased \(\textit{risk odds}\) of incident TBI during the follow-up period. More involvement \(\textit{There is a higher prevalence of younger individuals involved in interpersonal violence and physical aggression compared to other age groups, which could explain this finding}\) \(^\text{14,15}\).

Results of this study have several important implications for policymakers and healthcare professionals serving homeless and vulnerably housed populations. They supporting \(\textit{residential stability among this population may reduce their risk of future TBI events and their negative consequences. Social and community support programs may have a role in addressing modifiable risk factors such as substance use and residential instability by providing assistance for those who have functional impairments related to TBI. There may be a role for low threshold prevention and treatment programs addressing substance use disorders in this population as a measure to prevent future incident TBIs.}\)

Also, selected groups of homeless individuals especially those with strong risk factors such as lifetime prevalence of TBI, substance use and mental health conditions may benefit more from preventive measures for TBI as well as treatment of associated neuropsychological impairments through cognitive rehabilitation. Moreover, residential instability is another modifiable risk factor of incident TBIs and supporting this
population to achieve residential stability will likely also reduce their risk of future TBI events and their negative consequences. Social and community support programs may have a role in addressing modifiable risk factors such as substance use and residential instability and providing assistance for those who have impairment in function related to TBI. Finally, preventing future events of TBI and addressing its consequences through rehabilitation programs is a measure for improving the overall health of this vulnerable population as well as therapeutic interventions for TBI. A good example of such therapeutic interventions targeting associated neuropsychological impairments is cognitive rehabilitation recommended in previous studies.

**Strengths and limitations**

We enrolled a large representative sample of homeless or vulnerably housed individuals in three major Canadian cities. We used rigorous methods to select participants randomly at each site and followed them for 3 years. We also assessed TBI incidence during the follow-up period and evaluated its associated risk factors. Certain limitations of this study should be noted. Data on TBI were collected retrospectively through self-report, which was subject to recall bias. In addition, the full history, nature, and severity of TBI among participants were not ascertained. We did not collect data on cognitive function or detailed mental health symptom data. It has been demonstrated that using screening questions may underestimate the number of TBI events in the past when compared to a structured clinical interview. Using such a structured diagnostic interview for collecting data on TBI instead of screening questions could improve the precision of our findings. We did not collect data on cognitive function...
or detailed mental health symptom data. Because we could not control for all potential plausible risk factors of incident TBIs, we should be extremely cautious with concluding any causal relationship between suggested associated factors and incident TBIs. All suggested factors must be investigated in future studies before drawing such conclusions.

Conclusion

Individuals with a lifetime history of TBI, history of mental health diagnoses, problematic alcohol and drug use, younger age, those with poorer mental health status and those with residential instability are at increased risk of future TBI events. Cognitive rehabilitation, Mental health support and addressing residential instability and problematic substance use may reduce further risk of TBI and its associated poor health and social outcomes in this population.
References


42. Karriker-Jaffe KJ, Foshee VA, Ennett ST, Suchindran C. The development of aggression during adolescence: Sex differences in trajectories of physical and


Incidence and Associated Risk Factors of Traumatic Brain Injury in a Cohort of Homeless and Vulnerably Housed Adults in Three Canadian Cities

Mohammadali Nikoo *, Anne Gadermann , Matthew J. To , Michael Krausz , Stephen W. Hwang , Anita Palepu

1) MD, Institute of Mental Health, Centre for Health Evaluation and Outcome Sciences, Department of Medicine, University of British Columbia, Vancouver, BC, Canada
2) PhD, Assistant Professor, Centre for Health Evaluation and Outcome Sciences, Department of Medicine, University of British Columbia, Vancouver, BC, Canada
3) BMSc, Research Coordinator, Centre for Research on Inner City Health, Li Ka Shing Knowledge Institute, St Michael’s Hospital, Toronto, Ontario, Canada
4) MD, PhD, FRCP, Professor of Psychiatry, UBC-Providence Leadership Chair for Addiction Research, Institute of Mental Health, University of British Columbia, Vancouver, BC, Canada
5) MD, MPH, Director, Centre for Research in Inner City Health, Li Ka Shing Knowledge Institute, St. Michael’s Hospital, Toronto, Ontario, Canada
6) MD, MPH, FRCP, MACP, Professor of Medicine, Head of Division of General Internal Medicine, Centre for Health Evaluation and Outcome Sciences, Department of Medicine, University of British Columbia, Vancouver, BC, Canada

* Corresponding author

Conflicts of interest and Funding Source:
The authors declare no conflict of interests. Canadian Institute of Health Research (CIHR) has funded the Health and Housing in Transition study (HHiT).

**Acknowledgement:**

We would like to acknowledge the following individuals from our community partner organizations: Laura Cowan, Liz Evans, Stephanie Gee, Clare Hacksel, Erika Khandor, and Wendy Muckle. The authors also thank the study coordinators and interviewers in each of the three cities as well as the shelter, drop-in, and municipal and provincial staff for their assistance with participant recruitment and follow-up. We would like to thank the Health and Housing in Transition study participants for their contribution to these data. We also acknowledge Marc Vogel, Fiona Choi and Kerry Jang and Monica Norena for their contribution to the idea formulation and discussion to develop this manuscript.
Abstract

Objective: To examine the factors associated with incident traumatic brain injury (TBI) among homeless and vulnerably housed persons over a three-year follow-up period.

Setting & participants: Data were obtained from the Health and Housing in Transition study, which tracked the health and housing status of 1190 homeless or vulnerably housed individuals in three Canadian cities for 3 years. Design & Main Measures: Main measure was self-reported incident TBI during the follow-up period. Factors associated with TBI were ascertained using mixed effects logistic regression. Results: During 1st, 2nd and 3rd years of follow-up, 187 (19.4%), 166 (17.1%) and 172 (17.9%) participants reported a minimum of one incident TBI, respectively. Among 825 participants with available data for all 3-years of follow-up, 307 (37.2 %) reported at least one incident TBI during the 3-year follow-up period. Lifetime prevalence of TBI, endorsing a history of mental health diagnoses at baseline, problematic alcohol and drug use, younger age, poorer mental health and residential instability were associated with increased risk of incident TBI during follow-up period. Conclusion: Mental health support and addressing residential instability and problematic substance use may reduce further risk of TBI and its associated poor health and social outcomes in this population.

Key words traumatic brain injury, homeless, risk factor, prevalence, incidence
Introduction

Lifetime prevalence of Traumatic brain injury (TBI) is higher among the homeless population than the general population and is associated with many adverse health-related outcomes. These adverse outcomes include but are not limited to physical and mental health conditions, cognitive impairment, substance use, suicidality, victimization and increased mortality, \(^1\) health care utilization and incarceration \(^2\). A high percentage of persons who are homeless experience their first TBI before the first homelessness episode \(^5\) and most of them experience multiple TBIs during their life \(^5\). Previous literature including a published paper on this sample \(^2\) has focused more on factors associated with lifetime prevalence of TBI among people who are homeless and its associated factors rather than incident TBI \(^1\)\(^-\)\(^7\)\(^,\)\(^9\). In some of these studies, the interval between age of first sustained TBI and the assessment was more than a decade, which increases the risk of recall bias. In addition, an individual’s risk factors for sustaining a TBI several years ago may not be the same as risk factors for incident TBI. For example, the increased risk of TBI due to unsafe household environment for a child will not remain the same a decade later. \(^6\)\(^,\)\(^7\). Identifying risk factors for incident TBI may inform policy makers and healthcare professionals about those individuals at higher risk of acquiring new TBI; provide a better understanding of what preventive measures may be beneficial to this population; and indicate the importance of cognitive rehabilitation in this population. We, therefore, sought to determine the underlying risk factors of incident TBI during follow-up among a cohort of homeless or vulnerably housed persons who participated in the Health and Housing in Transition (HHiT) study.
Methods

Participants and Recruitment

The data for these analyses were obtained from the HHiT study, a multi-site longitudinal study that tracked the health and housing status of a sample of homeless or vulnerably housed individuals in Canada. At baseline, 1,190 participants who were homeless or vulnerably housed and 18 years old and over were recruited in three major Canadian urban areas, i.e. Vancouver, British Columbia; Ottawa, Ontario; and Toronto, Ontario, from January to December 2009. Individuals were re-interviewed every 12 months for a 3-year time period. A homeless participant was defined as a person living in a shelter, public space and motor vehicle, abandoned building, or not having their own place. A vulnerably housed participant was defined as a person living in their own room, apartment or place, but had been homeless and/or had two or more moves over the past 12 months. The sampling procedure of the study is described in detail elsewhere. Briefly, homeless participants were recruited in shelters and meal programs. Vulnerably housed participants were randomly selected from the stock of low-cost housing in Ottawa and Toronto and single room occupancy (SRO) hotels in Vancouver. Due to challenges in gaining access to residents at these sites, our sampling plan for vulnerably housed participants was modified to also recruit from meal programs, community health centers, and drop-in centers.

Ethical Considerations

Informed consent was obtained from each participant before inclusion in the study. The participants were paid an honorarium ($20 CAD) following the interview. Research
Ethics Boards at St. Michael’s Hospital (Toronto), the University of Ottawa, and the University of British Columbia (Vancouver) approved the study.

**Study Instrument and Measures**

The complete description of the survey questionnaire and its application has been previously published. Data were obtained through structured in-person interviews with trained interviewers, which lasted approximately 60-90 minutes. From baseline assessments, we ascertained socio-demographic characteristics (age, gender, self-reported ethnicity/cultural group, education), city of recruitment, lifetime prevalence of TBI and epilepsy, problematic drug and alcohol use, lifetime prevalence of mental health diagnoses, mental health status, and lifetime duration of homelessness.

Lifetime prevalence of TBI was determined using the question “Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?”. The question is part of the National Survey of Homeless Assistance Providers and Clients (NSHAPC) and has been used in several studies with homeless and vulnerably housed populations to measure self-reported TBI in the past as well as among prison inmates. These studies have demonstrated that self-reported TBI in response to this question was associated with other measures in theoretically expected directions, indicating the construct validity of this question to assess self-reported TBI. Participants were asked to report any chronic health conditions (adapted from the Canadian Community Health Survey) that had lasted or were expected to last 6 months or more and had been diagnosed by a healthcare professional. Mental health status of participants was measured using Mental Component Summary (MCS) of 12-item Short Form Health Survey (SF-12). To assess lifetime prevalence of mental health diagnoses,
participants were asked: “Have you ever been diagnosed with a mental health problem?”

The 10-item Drug Abuse Screening Test (DAST-10) was used to screen for drug use with problematic drug use defined as a DAST-10 score ≥ 6, which indicate potentially clinically significant drug use and would merit intensive assessment. The Alcohol Use Disorders Identification Test (AUDIT) 17, a 10-item questionnaire, was used to screen for alcohol use disorder (positive screen ≥ 8) and we defined problematic alcohol use as an AUDIT score of ≥ 20 18. These instruments have been validated for use in previous studies of vulnerable populations 19,20.

**Follow-up**

Participants had annual follow-up interviews from which we ascertained incident TBI events during the follow-up period. They provided primary and alternative contact information at the baseline survey so that they could be located for follow-up visits. Our outcome variable was whether participants had at least one incident TBI during the past year at each of three follow-up years. At each follow-up, participants were asked: “Have you had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented during the past year?” Positive response to these questions was considered as a TBI event during the prior year. We also ascertained participants’ problematic alcohol use during past year as an AUDIT score of ≥ 20 17,18, problematic drug use during past year defined as a DAST-10 score ≥ 6 and mental health status during last 4 weeks measured by the SF-12 MCS score 16 at each follow-up interview. Lifetime prevalence of TBI at each follow-up year was defined as positive lifetime history of TBI at the baseline and/ or TBI incidence during previous follow-up years. Residential stability during the past year was defined as being functionally housed and staying in the same location
without interruption for more than 180 days during the past year at each follow-up interview following the methods described by Tsemberis. Further details on the description of housing variables in this study is provided on the study website.

**Statistical analysis**

Descriptive statistics were used to summarize all continuous and categorical variables. Continuous variables were described as mean (standard deviation) and categorical variables were described as frequency (percentage).

We fit mixed effects logistic regression models to ascertain the factors associated with incident TBI during each year for the 3-year follow-up period. Initially, mixed effects logistic regression analyses were conducted separately to examine the unadjusted association between each fixed and time-varying predictor with incident TBI during follow-up years. Fixed predictors were only assessed at baseline and included age, gender (those who identified themselves as transgender were not included in the regression analysis because of their small number [1.4%]), ethnicity (White, Black/African-Canadian, First Nations/Indigenous, Mixed ethnicity, other [Asian and Hispanic]), education (post-secondary or higher, completed high school or equivalent, some high school), city of recruitment, lifetime duration of homelessness, lifetime prevalence of epilepsy, lifetime prevalence of mental health diagnoses, and lifetime prevalence of TBI.

We included baseline age and duration of homelessness in 5-year intervals in the regression analyses. Time-varying predictors included problematic alcohol use and drug use during past year, residential stability during past year, lifetime prevalence of TBI and SF-12 MCS during past 4 weeks. We followed the methodology provided by UCLA: statistical consulting group for building the mixed effects logistic regression model.
The clusters were the multiple observations collected per participant. We set p-value ≤ 0.1 as a cut-off for the bivariate analyses. Age, gender and other variables that met the cut-off were included in a final multivariable mixed effects logistic regression model. Results of this model were summarized with adjusted odds ratios (95% Confidence interval). Statistical tests were 2-tailed and P ≤ .05 was considered statistically significant. All analyses were performed using R version R-3.3.0 for Mac.

Results

A total of 1190 participants were recruited and interviewed at baseline in this study. A total of 968, 970 and 962 participants attended the 1st, 2nd and 3rd follow-up interviews, respectively. At baseline, the mean age was 42.2 years (SD=10.6) and 385 (32.4%) were female. Lifetime prevalence of TBI was 60.8 % (n=718) at the baseline interview. Data on incident TBI during follow-up interviews were available for 965, 969 and 961 participants for the 1st, 2nd and 3rd follow-up interviews with 187 (19.4%), 166 (17.1%) and 172 (17.9%) participants reporting a minimum of one incident TBI during the 1st, 2nd and 3rd years of follow-up, respectively. Data regarding incident TBI during any of follow-up years were available for 1084 participants and 363 (33.5%) incident TBIs were recorded for them. Data regarding incident TBI during all 3-years of follow-up were available for 825 participants and 307 (37.2 %) reported at least one incident TBI during the follow-up period. Among those with incident TBI during the follow-up period, 60 (19.5%) had not reported a lifetime history of TBI at baseline and experienced their first TBI during the 3-year follow-up period. Characteristics of the study sample with available data on incident TBI at each follow-up interview are presented in Table 1.
In the bivariate mixed effects logistic regression analyses, ethnicity, city, lifetime prevalence of TBI, history of epilepsy, history of mental health diagnosis, SF-12 MCS, problematic alcohol use, problematic drug use and residential stability during the past year met the cut-off for the final model. Results of the bivariate and multivariable models regarding factors associated with incident TBI during follow-up period are summarized in Table 2. The final multivariable analysis showed that lifetime prevalence of TBI [AOR = 3.10; 95% CI: 2.20, 4.38], mental health diagnoses at baseline [AOR = 1.38; 95% CI: 1.02, 1.88], problematic alcohol [AOR = 2.42; 95% CI: 1.68, 3.47] and drug use [AOR = 1.35; 95% CI: 1.01, 1.82] were independently associated with increased odds of incident TBI during the follow-up period after adjustment for gender, ethnicity, city and history of epilepsy. In contrast older age [AOR = 0.93; 95% CI: 0.88, 0.99], better mental health summary score [AOR = 0.97; 95% CI: 0.96, 0.98] and residential stability [AOR = 0.75; 95% CI: 0.57, 0.99] were associated with decreased odds of experiencing incident TBI during the follow-up period after adjustment for the above-mentioned variables.

[Please place Table 2 here]

**Discussion**

At each follow-up year, 17.1%-19.4% of participants reported a minimum of one incident TBI while during the 3-year follow-up period, a total of 37.2% of participants reported at least one incident TBI. Based on our results, we estimate the minimum self-reported annual rate of incident TBI among homeless or vulnerably housed individuals during the yearly follow-up period to be at least 17,100 per 100,000. This is relatively high compared to the general population annual TBI incident rate of 500 per 100,000.24.
Among those with incident TBI during our study, 60 (19.5%) experienced their first TBI during the follow-up period. This indicates that a high percentage of the recorded TBIs (approximately 1 in 5) occurred as the first lifetime event, which highlights their vulnerability and the importance of preventive measures for TBI in this population. In the final multivariable model, lifetime prevalence of TBI, endorsing a mental health diagnoses at baseline, problematic alcohol and drug use, younger age, lower mental health summary score and residential instability were independently associated with incident TBI.

Problematic alcohol use and problematic drug use were both independently associated with higher odds of incident TBI during the 3-year follow-up period. Previous studies in the general population have also found an increased risk of incident TBI related to substance use. A literature review on substance use and TBI showed that substance use was not only associated with an increased risk of TBI, but also with increased morbidity and excessive substance use after the TBI. The authors noted that risk-taking behaviour was a factor that was closely associated with substance use and might also be contributing to the higher risk of incident TBI. These findings suggest that substance use interventions targeting persons who are homeless or vulnerably housed could be an effective approach for reducing the risk of incident and recurring TBI in this population.

A history of previous TBI demonstrated the strongest association of incident TBI during follow-up. After a first TBI there is a two-fold increase risk of a subsequent TBI and a second TBI is associated with an eightfold increased risk of yet another TBI. Varamo
et al followed 827 subjects who presented to the Emergency Department with head
trauma for 10 years or until death. They concluded that alcohol-related head trauma is
more likely to predispose the subject to subsequent TBI than is the severity of the index
trauma itself 29. There might be other persisting factors among persons affected by TBI,
which puts them at further risk of subsequent TBI. For example, cognitive impairment
and domestic violence are among the risk factors shown to play significant roles in
incident TBI but not assessed in this study 8,30,31. Higher risk of incident TBI among those
with a lifetime history of TBI, consistent with the existing literature, suggests that TBI is
not usually a single occurrence. In contrast, it can predispose affected individuals to
future multiple consecutive TBI events 5,28, which increases the adverse consequences
related to TBI 28,32. Effective therapeutic interventions such as cognitive assessment and
rehabilitation of individuals with a lifetime history of TBI may also be an effective
preventive measure to avoid future TBI.

Endorsing a history of mental health diagnosis was associated with increased odds of
incident TBI during follow-up. Previous studies have demonstrated an association of TBI
with subsequent mental health diagnoses 33,34. There are a number of potential pathways
of how mental health conditions could be associated with increased risk of future TBI
including increased likelihood of high-risk behaviours 35, as well as the high prevalence
of concomitant substance use 36, which may put individuals with mental health conditions
at risk of further TBI; however, we adjusted for substance use in our model. Cognitive
impairment in mental health conditions such as schizophrenia and mood disorders 37
could also amplify increased risk of TBI 38. Hence, mental health support and
psychosocial interventions could be an option for reducing further risk of incident TBIs in this population.

Better mental health component summary scores were associated with lower odds of incident TBI. Participants with TBI have been shown to achieve lower scores on the Short Form-36, a detailed version of the SF-12 administered in this study. SF-36 scores were also significantly different between varying severities of TBI in previous studies. Residential stability was negatively associated with incident TBI during the follow-up period. This is consistent with previous literature demonstrating high prevalence of TBI among individuals who are homeless. It highlights that not only is unstable housing associated with lifetime prevalence of TBI, it is also associated with an ongoing increased odds of incident TBI during the follow-up period after adjustment for other risk factors. This suggests that supporting this population to achieve residential stability may mitigate the risk of future TBI events. Younger age was also associated with increased odds of incident TBI during the follow-up period. There is a higher prevalence of younger individuals involved in interpersonal violence and physical aggression compared to other age groups, which could explain this finding.

Results of this study have several important implications for policymakers and healthcare professionals serving homeless and vulnerably housed populations. Supporting residential stability among this population may reduce their risk of future TBI events and their negative consequences. Social and community support programs may have a role in addressing modifiable risk factors such as substance use and residential instability by
providing assistance for those who have functional impairments related to TBI. There
may be a role for low threshold prevention and treatment programs addressing substance
use disorders in this population as a measure to prevent future incident TBIs. Also,
selected groups of homeless individuals especially those with strong risk factors such as
lifetime prevalence of TBI, substance use and mental health conditions may benefit more
from preventive measures as well as therapeutic interventions for TBI. A good example
of such therapeutic interventions targeting associated neuropsychological impairments is
cognitive rehabilitation recommended in previous studies 41.

Strengths and limitations

We enrolled a large representative sample of homeless or vulnerably housed individuals
in three major Canadian cities. We used rigorous methods to select participants randomly
at each site and followed them for 3 years. We also assessed TBI incidence during the
follow-up period and evaluated its associated factors. Certain limitations of this study
should be noted, as well. Data on TBI were collected retrospectively through self-report,
which was subject to recall bias. In addition, the full history, nature, and severity of TBI
among participants were not ascertained. It has been demonstrated that using screening
questions may underestimate the number of TBI events in the past when compared to a
structured clinical interview 42. Using such a structured diagnostic interview for
collecting data on TBI instead of screening questions could improve the precision of our
findings. We did not collect data on cognitive function or detailed mental health symptom
data. Because we could not control for all potential plausible risk factors of incident
TBIs, we should be extremely cautious with concluding any causal relationship between
suggested associated factors and incident TBIs. All suggested factors must be investigated in future studies before drawing such conclusions.

**Conclusion**

Individuals with a lifetime history of TBI, history of mental health diagnoses, problematic alcohol and drug use, younger age, those with poorer mental health status and those with residential instability are at increased risk of future TBI events. Mental health support and addressing residential instability and problematic substance use may reduce further risk of TBI and its associated poor health and social outcomes in this population.
References


16. Ware JE, Kosinski M, Keller SD, QualityMetric I, New England Medical Center H, Health Assessment L. *SF-12: how to score the SF-12 physical and mental health summary scales*. Lincoln, R.I.; Boston, Mass.: QualityMetric Inc.; Health Assessment Lab; 2002.


1997;315(7108):569-572.


Table 1. Characteristics of participants, those with and without incident TBI during the 3-year follow-up period

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Year 1 (N=965)</th>
<th>Year 2 (N=969)</th>
<th>Year 3 (N=961)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident TBI during 1st year</td>
<td>Yes (N=187)</td>
<td>No (N=778)</td>
<td>Yes (N=166)</td>
</tr>
<tr>
<td>Incident TBI during 2nd year</td>
<td>Yes (N=166)</td>
<td>No (N=809)</td>
<td>Yes (N=173)</td>
</tr>
<tr>
<td>Incident TBI during 3rd year</td>
<td>Yes (N=173)</td>
<td>No (N=788)</td>
<td>Yes (N=173)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>Yes (N=672)</td>
<td>102 (10.73)</td>
<td>Yes (N=477)</td>
</tr>
<tr>
<td>Black/African-Canadian</td>
<td>Yes (N=67)</td>
<td>18 (27.06)</td>
<td>Yes (N=75)</td>
</tr>
<tr>
<td>First Nations/Indigenous</td>
<td>Yes (N=38)</td>
<td>12 (31.58)</td>
<td>Yes (N=38)</td>
</tr>
<tr>
<td>Mixed ethnicity</td>
<td>Yes (N=9)</td>
<td>2 (22.22)</td>
<td>Yes (N=4)</td>
</tr>
<tr>
<td>Other</td>
<td>Yes (N=6)</td>
<td>1 (16.67)</td>
<td>Yes (N=3)</td>
</tr>
<tr>
<td>Missing</td>
<td>Yes (N=4)</td>
<td>0 (0)</td>
<td>Yes (N=2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
<th>Other</th>
<th>Missing</th>
<th>Median Age (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (N=187)</td>
<td>118 (63.10)</td>
<td>63 (33.69)</td>
<td>6 (3.21)</td>
<td>4 (2.14)</td>
<td>25.50 (12.93)</td>
</tr>
<tr>
<td>No (N=778)</td>
<td>519 (66.71)</td>
<td>250 (32.12)</td>
<td>9 (1.16)</td>
<td>12 (1.54)</td>
<td>29.59 (14.00)</td>
</tr>
<tr>
<td>Yes (N=166)</td>
<td>533 (66.38)</td>
<td>259 (32.25)</td>
<td>8 (1.74)</td>
<td>14 (1.74)</td>
<td>29.26 (14.12)</td>
</tr>
<tr>
<td>No (N=809)</td>
<td>517 (65.52)</td>
<td>262 (33.21)</td>
<td>13 (1.65)</td>
<td>16 (1.65)</td>
<td>29.17 (14.12)</td>
</tr>
<tr>
<td>Yes (N=173)</td>
<td>114 (66.28)</td>
<td>56 (32.56)</td>
<td>3 (1.74)</td>
<td>3 (1.74)</td>
<td>26.2 (12.57)</td>
</tr>
<tr>
<td>No (N=788)</td>
<td>517 (65.52)</td>
<td>262 (33.21)</td>
<td>13 (1.65)</td>
<td>16 (1.65)</td>
<td>29.17 (14.12)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Yes (N=187)</th>
<th>No (N=778)</th>
<th>Yes (N=166)</th>
<th>No (N=809)</th>
<th>Yes (N=173)</th>
<th>No (N=788)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD)</td>
<td>25.50 (12.93)</td>
<td>29.59 (14.00)</td>
<td>29.26 (14.12)</td>
<td>29.17 (14.12)</td>
<td>26.2 (12.57)</td>
<td>29.17 (14.12)</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Year 1 (N=965)</td>
<td>Year 2 (N=969)</td>
<td>Year 3 (N=961)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incident TBI during 1st year</td>
<td>Yes (N=187)</td>
<td>Yes (N=181)</td>
<td>Yes (N=182)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No (N=778)</td>
<td>No (N=788)</td>
<td>No (N=779)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incident TBI during 2nd year</td>
<td>Yes (N=166)</td>
<td>Yes (N=161)</td>
<td>Yes (N=161)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No (N=803)</td>
<td>No (N=798)</td>
<td>No (N=800)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incident TBI during 3rd year</td>
<td>Yes (N=172)</td>
<td>Yes (N=165)</td>
<td>Yes (N=164)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No (N=789)</td>
<td>No (N=794)</td>
<td>No (N=787)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Education

<table>
<thead>
<tr>
<th>Level</th>
<th>Year 1 (N=965)</th>
<th>Year 2 (N=969)</th>
<th>Year 3 (N=961)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some high school n (%)</td>
<td>82 (43.86)</td>
<td>355 (45.64)</td>
<td>70 (42.17)</td>
</tr>
<tr>
<td>Completed high school n (%)</td>
<td>38 (20.32)</td>
<td>175 (22.49)</td>
<td>39 (23.49)</td>
</tr>
<tr>
<td>Some post-secondary or higher n (%)</td>
<td>66 (35.29)</td>
<td>243 (31.23)</td>
<td>52 (31.33)</td>
</tr>
</tbody>
</table>

### City

<table>
<thead>
<tr>
<th>City</th>
<th>Year 1 (N=965)</th>
<th>Year 2 (N=969)</th>
<th>Year 3 (N=961)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toronto n (%)</td>
<td>49 (26.20)</td>
<td>268 (34.45)</td>
<td>40 (24.10)</td>
</tr>
<tr>
<td>Ottawa n (%)</td>
<td>72 (38.51)</td>
<td>266 (34.19)</td>
<td>60 (36.14)</td>
</tr>
<tr>
<td>Vancouver n (%)</td>
<td>66 (35.29)</td>
<td>244 (31.36)</td>
<td>66 (39.76)</td>
</tr>
</tbody>
</table>

### Lifetime duration of Homelessness

<table>
<thead>
<tr>
<th>Mean (SD)</th>
<th>Year 1 (N=965)</th>
<th>Year 2 (N=969)</th>
<th>Year 3 (N=961)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5.81 (6.99)</td>
<td>5.26 (5.99)</td>
<td>5.29 (6.39)</td>
</tr>
</tbody>
</table>

### Lifetime prevalence of TBI

<table>
<thead>
<tr>
<th>Yes n (%)</th>
<th>Year 1 (N=965)</th>
<th>Year 2 (N=969)</th>
<th>Year 3 (N=961)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>163 (87.17)</td>
<td>431 (55.40)</td>
<td>138 (83.13)</td>
</tr>
<tr>
<td>No</td>
<td>163 (87.17)</td>
<td>431 (55.40)</td>
<td>138 (83.13)</td>
</tr>
</tbody>
</table>

### Missing n (%)

<table>
<thead>
<tr>
<th>Missing n (%)</th>
<th>Year 1 (N=965)</th>
<th>Year 2 (N=969)</th>
<th>Year 3 (N=961)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1 (0.53)</td>
<td>5 (0.64)</td>
<td>5 (3.01)</td>
</tr>
<tr>
<td>No</td>
<td>162 (86.47)</td>
<td>426 (55.05)</td>
<td>133 (79.72)</td>
</tr>
</tbody>
</table>

### Education

<table>
<thead>
<tr>
<th>Year</th>
<th>Yes (N=187)</th>
<th>Yes (N=172)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>96 (51.33)</td>
<td>78 (45.11)</td>
</tr>
<tr>
<td>Year 2</td>
<td>87 (46.23)</td>
<td>76 (44.51)</td>
</tr>
<tr>
<td>Year 3</td>
<td>89 (47.86)</td>
<td>76 (44.51)</td>
</tr>
</tbody>
</table>

### Missing n (%)

<table>
<thead>
<tr>
<th>Missing n (%)</th>
<th>Year 1 (N=965)</th>
<th>Year 2 (N=969)</th>
<th>Year 3 (N=961)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1 (0.53)</td>
<td>5 (0.64)</td>
<td>5 (3.01)</td>
</tr>
<tr>
<td>No</td>
<td>162 (86.47)</td>
<td>426 (55.05)</td>
<td>133 (79.72)</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Year 1 (N=965)</td>
<td>Year 2 (N=969)</td>
<td>Year 3 (N=961)</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Incident TBI during 1st year</td>
<td>Yes (N=187)</td>
<td>Yes (N=166)</td>
<td>Yes (N=172)</td>
</tr>
<tr>
<td></td>
<td>No (N=778)</td>
<td>No (N=803)</td>
<td>No (N=789)</td>
</tr>
<tr>
<td>History of epilepsy</td>
<td>No (N (%))</td>
<td>167 (89.30)</td>
<td>152 (91.57)</td>
</tr>
<tr>
<td></td>
<td>Yes (N (%))</td>
<td>19 (10.16)</td>
<td>13 (7.83)</td>
</tr>
<tr>
<td>History of mental health diagnosis</td>
<td>No (N (%))</td>
<td>66 (35.30)</td>
<td>56 (33.73)</td>
</tr>
<tr>
<td></td>
<td>Yes (N (%))</td>
<td>118 (63.10)</td>
<td>107 (64.46)</td>
</tr>
</tbody>
</table>

SF-12 Mental Health Summary Score: [Mean (SD)]

- 1st year: 36.16 (12.37)
- 2nd year: 42.5 (12.69)
- 3rd year: 36.77 (12.49)

Problematic alcohol use: [Yes (N (%)]

- 1st year: 40 (40.21)
- 2nd year: 21 (21.59)
- 3rd year: 22 (22.22)

History of problematic alcohol use: [Yes (N (%)]

- 1st year: 12 (12.24)
- 2nd year: 15 (15.63)
- 3rd year: 12 (12.24)

Missing n (%):

- Year 1: 5 (2.67)
- Year 2: 15 (1.93)
- Year 3: 2 (1.20)

Incident TBI during 1st year: [Yes (N=187) No (N=778) Yes (N=166) No (N=803) Yes (N=172) No (N=789)]

Incident TBI during 2nd year: [Yes (N=166) No (N=803) Yes (N=19) No (N=30) Yes (N=13) No (N=37) Yes (N=407) No (N=414) Yes (N=35) No (N=402) Yes (N=10) No (N=12)]

Incident TBI during 3rd year: [Yes (N=172) No (N=789) Yes (N=19) No (N=30) Yes (N=13) No (N=37) Yes (N=407) No (N=414) Yes (N=10) No (N=12)]

History of epilepsy: [Yes (N=187) No (N=788)]

SF-12 Mental Health Summary Score: [Mean (SD)]

- 1st year: 36.16 (12.37)
- 2nd year: 42.5 (12.69)
- 3rd year: 36.77 (12.49)

Problematic alcohol use: [Yes (N=40) No (N=21) Yes (N=22) No (N=12)]

History of problematic alcohol use: [Yes (N=12) No (N=15) Yes (N=12) No (N=2)]

Missing n (%):

- Year 1: 5 (2.67)
- Year 2: 15 (1.93)
- Year 3: 2 (1.20)
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Year 1 (N=965)</th>
<th>Year 2 (N=969)</th>
<th>Year 3 (N=961)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident TBI during 1st year</td>
<td>Yes (N=187)</td>
<td>No (N=778)</td>
<td>Yes (N=172)</td>
</tr>
<tr>
<td>Problematic drug use</td>
<td>Yes n (%)</td>
<td>No n (%)</td>
<td>Yes n (%)</td>
</tr>
<tr>
<td></td>
<td>38.50%</td>
<td>61.50%</td>
<td>68.02%</td>
</tr>
<tr>
<td>Residential stability</td>
<td>Yes n (%)</td>
<td>No n (%)</td>
<td>Yes n (%)</td>
</tr>
<tr>
<td></td>
<td>59.36%</td>
<td>40.64%</td>
<td>68.82%</td>
</tr>
<tr>
<td>Problematic drug use</td>
<td>Yes n (%)</td>
<td>No n (%)</td>
<td>Yes n (%)</td>
</tr>
<tr>
<td></td>
<td>59.36%</td>
<td>40.64%</td>
<td>68.82%</td>
</tr>
</tbody>
</table>

Variables with less than 2% missing in all columns: missing percentage for these variables can be calculated by subtracting sum of percentages of each column from 100.

Variable explanations:
- §: Time-varying variables which were measured only at the baseline and follow-up interviews.
- a: Problematic alcohol use and problematic drug use were defined as an AUDIT score $\geq 20$ and a DAST-10 score $\geq 6$.
- b: Problematic alcohol use and problematic drug use were defined as an AUDIT score $\geq 20$ and a DAST-10 score $\geq 6$.
- c: Whether or not the individual was functionally housed and stayed in the same location without interruption for more than 180 days during the past year at each follow-up interview.

Acronyms:
- SD = Standard Deviation
- SF-12 = 12-item Short Form Health Survey
- TBI = Traumatic Brain Injury
Table 2. Mixed effects logistic regression model of factors associated with incident TBI over time (3-year follow-up).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unadjusted Odds Ratio (95% CI)</th>
<th>P-value</th>
<th>Adjusted Odds Ratio (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Mean (SD))</td>
<td>¥ 0.88 (0.83, 0.94)</td>
<td>¥ 0.01</td>
<td>¥ 0.87 (0.83, 0.94)</td>
<td>¥ 0.01</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>¥ 0.43 (0.22, 0.85)</td>
<td>¥ 0.01</td>
<td>¥ 0.83 (0.45, 1.54)</td>
<td>¥ 0.56</td>
</tr>
<tr>
<td>Education</td>
<td>¥ 0.93 (0.61, 1.39)</td>
<td>¥ 0.71</td>
<td>¥ 0.92 (0.67, 1.28)</td>
<td>¥ 0.63</td>
</tr>
<tr>
<td>Female</td>
<td>¥ 0.67 (0.29, 1.51)</td>
<td>¥ 0.23</td>
<td>¥ 0.67 (0.29, 1.51)</td>
<td>¥ 0.33</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level.
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unadjusted Odds Ratio</th>
<th>95% CI</th>
<th>P-value</th>
<th>Adjusted Odds Ratio</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>City</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ottawa</td>
<td>1.59</td>
<td>(1.08, 2.36)</td>
<td>&lt;0.01*</td>
<td>1.12</td>
<td>(0.77, 1.63)</td>
<td>0.56</td>
</tr>
<tr>
<td>Vancouver</td>
<td>1.71</td>
<td>(1.16, 2.54)</td>
<td>0.01</td>
<td>1.19</td>
<td>(0.82, 1.72)</td>
<td>0.08</td>
</tr>
<tr>
<td>Toronto</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Lifetime duration of Homelessness</td>
<td>¥</td>
<td>*5-year</td>
<td>increments</td>
<td>¥</td>
<td>*5-year</td>
<td>increments</td>
</tr>
<tr>
<td>¥</td>
<td>1.08</td>
<td>(0.95, 1.22)</td>
<td>0.36</td>
<td>1.08</td>
<td>(0.95, 1.22)</td>
<td>0.36</td>
</tr>
<tr>
<td>¥</td>
<td>1.19</td>
<td>(1.06, 1.34)</td>
<td>&lt;0.01*</td>
<td>1.19</td>
<td>(1.06, 1.34)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td>¥</td>
<td>1.22</td>
<td>(1.14, 1.35)</td>
<td>&lt;0.01*</td>
<td>1.22</td>
<td>(1.14, 1.35)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td>¥</td>
<td>1.29</td>
<td>(1.14, 1.54)</td>
<td>&lt;0.01*</td>
<td>1.29</td>
<td>(1.14, 1.54)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td>¥</td>
<td>1.36</td>
<td>(1.17, 1.60)</td>
<td>&lt;0.01*</td>
<td>1.36</td>
<td>(1.17, 1.60)</td>
<td>&lt;0.01*</td>
</tr>
</tbody>
</table>

* Significant P-value ≤ 0.05
§ Fixed variables which were measured only at the baseline. Due to the small number of individuals who identified as transgender (1.4%), we did not include them in the regression analyses.

Acronyms: SD = Standard Deviation, SF-12 = 12-item Short Form Health Survey, TBI = Traumatic Brain Injury.