Traumatic brain injury in precariously housed persons: Incidence and risks

Tiffany A. O'Connor,[a,b] William J. Panenka,[b,c] Emily M. Livingston,[a,b] Jacob L. Stubbs,[b,c] Julia Askew,[b,c] Charanveer S. Sahota,[a,b] Samantha J. Feldman,[d] Tari Buchanan,[c] Linwan Xu,[e] X. Joan Hu,[e] Donna J. Lang,[b,f] Melissa L. Woodward,[b,c] Wendy Loken Thornton,[a] Kristina M. Gicas,[b,c,d] Alexandra T. Vertinsky,[f] Manraj K. Heran,[f] Wayne Su,[b,c] G. William MacEwan,[c] Alasdair M. Barr,[b,g] William G. Honer,[b,c] and Allen E. Thornton[a,b,*]

[a]Department of Psychology, Simon Fraser University, Burnaby, BC, Canada
[b]British Columbia Mental Health and Substance Use Services Research Institute
[c]Department of Psychiatry, University of British Columbia, Vancouver, BC, Canada
[d]Department of Psychology, York University, Toronto, ON, Canada
[e]Department of Statistics and Actuarial Science, Simon Fraser University, Burnaby, BC, Canada
[f]Department of Radiology, University of British Columbia, Vancouver, BC, Canada
[g]Department of Anesthesiology, Pharmacology and Therapeutics, University of British Columbia, Vancouver, BC, Canada

eClinicalMedicine
2022;44: 101277
Published online 1 February 2022
https://doi.org/10.1016/j.eclinm.2022.101277

Summary

Background Homeless and precarious housed persons are particularly prone to traumatic brain injuries (TBIs), but existent incidence rates are hampered by poor case acquisition. We rigorously documented TBIs in precariously housed persons transitioning in and out of homelessness.

Methods Between December 2016 and May 2018, 326 precariously housed participants enrolled in a longitudinal study in Vancouver, Canada were assessed monthly for TBI occurrences after education on sequelae. Over one participant-year, 2433 TBI screenings were acquired for 326 person-years and variables associated with odds of incident TBI were evaluated.

Findings One hundred participants acquired 175 TBIs, yielding an observed incidence proportion of 30·7% and event proportion of 53·7%. Of the injured, 61% reported one TBI and 39% reported multiple injuries. Acute intoxication was present for more than half of the TBI events assessed. Additionally, 9·7% of TBI events occurred in the context of a drug overdose. Common injury mechanisms were falls (45·1%), assaults (25·1%), and hitting one's head on an object (13·1%). In this community-based but non-randomly recruited sample, exploratory analyses identified factors associated with odds of an incident TBI over one year of follow-up, including: schizophrenia disorders (odds ratio (OR) = 0·43, 95% confidence interval (CI) 0·19, 0·94), role functioning (OR = 0·69, 95% CI 0·52, 0·91), opioid dependence (OR = 2·17, 95% CI 1·27, 3·72) and those reporting past TBIs (OR = 1·99, 95% CI 1·13, 3·52).

Interpretation Given the ubiquity of TBIs revealed in this precariously housed sample, we identify an underappreciated and urgent healthcare priority. Several factors modified the odds of incident TBI, which can facilitate investigations into targeted prevention efforts.

Funding Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, William and Ada Isabelle Steel Research Fund, Simon Fraser University Vice-President Research Undergraduate Student Research Award and Simon Fraser University Psychology Department Research Grant.

Keywords: Head injury; Concussion; Homelessness; Prevalence; Risk factors; Marginalization; Comorbidity

*Correspondence to: Allen E. Thornton, Human Neuropsychology Laboratory, Department of Psychology, Simon Fraser University, 8888 University Drive, Burnaby, BC V5A 1S6, Canada.
E-mail address: aethornt@sfu.ca (A.E. Thornton).

Research in context

Evidence before this study

Our interests in the incidence rates of TBIs experienced in marginalized persons was spurred by concerns over prior case acquisition approaches, which was reinforced as we documented TBIs while conducting the "parent" 'Hotel Study', a broad investigation of the health of housing insecure persons. We subsequently published a *Lancet Public Heath* meta-analysis (Medline Embase, PsycINFO, CINAHL, Web of Science; search date Dec 14, 2018), which revealed a lifetime TBI prevalence in homeless and housing insecure samples exceeding 50% and identified TBI case acquisition limitations of past work, which we were positioned to address.

Added value of this study

Using standardized monthly TBI screenings conducted prospectively for one-year in precariously housed individuals, we more accurately documented TBIs. Rigorous methods, including missing data imputation, indicated that the annual incidence of TBI were unprecedently high. In the current study, we also identified several factors that were associated with odds of incident TBI, including greater odds with opioid use and past TBIs, and lesser odds associated with better role functioning and a diagnosis of schizophrenia disorders.

Implications of all the available evidence

This prospectively acquired data bolsters meta-analytic observations elucidating a community TBI endemic in at least some marginalized populations, while identifying factors apt to be relevant to injury risks and prevention. Considering that these community members often experience cognitive impairment, social and occupational challenges, and numerous morbidities (e.g., psychiatric and neurological), the high TBI incident rates observed serve as an impetus for studies into TBI-exacerbated neuropsychiatric decline, a potentially preventable source of disability in this and similar populations. To ensure that the full spectrum of TBI severity is captured, investigations will benefit from prospective TBI ascertainment methods optimized to the TBI experiences and reporting capacities of substance using, marginalized participants.

Introduction

Low-income tenants residing in substandard housing often as their only alternative to homelessness face high mortality and numerous mental and physical health challenges, including substance dependencies, psychiatric and neurological illnesses, and infectious diseases.[1-4] These persons also exhibit disproportionately high traumatic brain injury (TBI) incidence, with the most rigorously acquired annualized incidence rates approaching 20%.[5] Indeed, more than half of homeless and precariously housed persons report a TBI history, with one quarter of injuries characterized as moderate or severe as indicated by meta-analytically aggregated estimates.[6] These rates are several orders of magnitude higher than the <1% annualized incidence rates compiled from a comprehensive aggregation across multi-country studies.[7]

Yet, the extent of this problem remains elusive given numerous obstacles hampering accurate TBI ascertainment. Many studies of housing-insecure persons only incidentally document TBIs.[8] The use of well-validated ascertainment tools has been infrequent, and few studies comprehensively characterize mechanisms or risk factors.

Moreover, as in the broader TBI literature, ascertainment chiefly relies upon self-reports over timeframes where accurate recollection is often dubious. Report accuracy is likely further degraded in some populations of homeless and precariously housed persons because of compromised cognition[9] interfacing with limited participant knowledge and/or little recognition of TBI-associated symptoms.[10]

Increased data granularity and fidelity will improve TBI rate estimates and identify measures for prospective studies of risk factors. Accordingly, in precariously housed persons, our aims were to estimate TBI incidence and explore risks using a design that included the education of participants on TBI sequelae and a validated screening tool deployed repeatedly and proximate to injury. We explored putative risk factors specifically (e.g., opioid dependence) as opposed to broadly (e.g., substance dependence). Such work is vital given the potential of particularly deleterious impacts of TBIs, and their accumulation, in persons suffering from poor physical and mental health.[11,12]

Methods

Participants

As part of a longitudinal study, 524 individuals were recruited in Vancouver, Canada between November 2008 and May 2018 from four single room occupancy (SRO) hotels located in a low-income neighbourhood, the community court, and the emergency department of the catchment area hospital (see the "Hotel Study"[1] for baseline characteristics). Briefly, persons were eligible if they lived in the neighbourhood catchment area, were able to communicate in English, and had the capacity to and provided written informed consent. Between December 2016 and May 2018, a total of 326 of these individuals completed monthly TBI screening assessments (Figure 1). Participants received small honoraria after each screening. Ethics approval was obtained from the University of British Columbia – Providence Health Care Research Ethics Board (H16-01310) and the Simon Fraser University Office of Research Ethics (2016s0586).

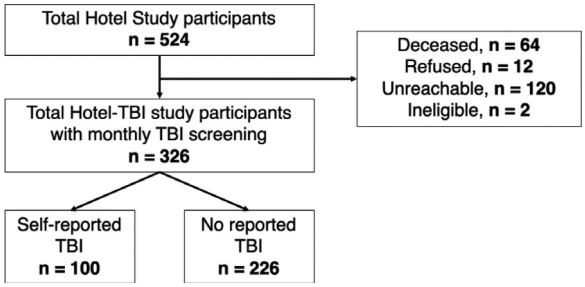

Figure 1. Flow diagram of participant inclusion.

Procedures

Traumatic brain injury screening was completed by trained research assistants supervised by a Neuropsychiatrist (WJP) and Psychologist (AET). At recruitment for the TBI sub-study, participants were provided with a pamphlet outlining common TBI causes and symptoms, as well as contact information for a nearby emergency room and several area clinics (available by request). Participants were encouraged to first seek medical service in the event of a head injury. Apart from two TBI events that were reported between scheduled monthly screenings, participants reported all events during monthly screenings that occurred over a one person-year period tailored to each person's enrolment date. A total of 2433 unique monthly screenings were completed across 326 person-years. On average, participants completed 7·73 screens (SD = 3·63; *median* = 8·00), with a range of 1 to 14 screens. Across the possible 326 person-years, data was present across 202·75 person-years (37·8% missing monthly data).

Prospective TBI occurrence was ascertained during monthly screening using the Ohio State University TBI Identification Method Interview Form,[13] which is a TBI Common Data Elements measure.[14] A supplemental questionnaire was used to augment injury details (Supplement A). To establish TBI occurrence, two definitions were employed. A standard, but more liberal definition,[15] operationalized TBI as a trauma to the head or neck, with known cause, resulting in one or more of loss of consciousness (LOC), post-traumatic amnesia (PTA), and/or being dazed and/or confused. A more conservative definition required a reported period of LOC, at minimum, to be considered a TBI. When participants affirmed TBI but lacked autobiographical event recollection sufficient to make a definitive TBI diagnosis, criteria were met if a witness had conveyed qualifying injury information that the participant disclosed, or if the participant presented with physical signs of head trauma. When TBI events were reported in duplicate, only one TBI occurrence was included in analyses. Lifetime TBI count was assessed using the Brain Injury Screening Questionnaire.[16] Finally, a post-study consensus review of "suspect" TBI events was conducted that identified events in which sensorial disruption reportedly occurred prior to head impact. These "suspect" events were often reported as entailing "passing out" with a subsequent head impact.

The mechanism of TBI was investigated, including whether the event occurred in the context of overdose or acute intoxication. Given the ubiquity of substance dependence, intoxication at the time of injury was defined using a questionnaire item probing self-reported intoxication by drugs or alcohol at the time of injury that was *beyond typical use*. Further, TBIs were considered to have occurred during non-alcohol induced overdose if there was, inclusively: (a) an observer report or observable sign of head trauma, (b) self-reported drug use at the time of injury, and (c) self-report of naloxone administration.

Several procedures were conducted that characterized the sample clinically and provided the basis for the evaluation of measures putatively associated with odds of incident TBI (Supplement B). Substance dependencies and psychiatric illnesses were diagnosed by interview with a psychiatrist using the Diagnostic and Statistical Manual of Mental Disorders[17] in consensus with the Best Estimate Clinical Evaluation and Diagnosis 2[18] and the most proximally conducted Mini International Neuropsychiatric Interview.[19] The Maudsley Addiction Profile physical and mental symptom scores were used to estimate health.[20] In structured interview, details on physical symptoms and illnesses were collected, which included neurological illnesses (e.g., stroke, epilepsy, and seizure history) and remote TBI histories (i.e., "*serious* head/face injury" with LOC).

Neurocognitive and functional capacity information, collected prior to monthly TBI screening, generated additional measures considered for association with TBI. Premorbid intelligence was estimated using the reading score, in combination with demographics, as implemented on the Wechsler Test of Adult Reading.[21] Two additional variables were created (see Supplement B). First, composite cognition was calculated from the Hopkins Verbal Learning Test – Revised[22] (immediate recall), the Stroop Color and Word Test[23] (color-word trial), and the Rapid Visual Information Processing Test[24] (signal detection, A′). Additionally, role functioning was captured by a sample-standardized composite derived from raw scores on the Role Functioning Scale[25] and the Social and Occupational Functioning Assessment Scale.[17] Lower scores on the role functioning composite reflect poorer working productivity, diminished independent living and self-care skills, and/or lesser engagement in immediate or extended social relationships.

Statistical Analysis

The *observed TBI rates* can be appreciated as a lower boundary, since observed rates are attenuated by missing data. In contrast, *estimated rates* achieved through

imputation, mitigate biases. Following the framework outlined by Richter and colleagues[26] for handling missing data in observational TBI research, longitudinal missing data patterns were examined. Generalized linear modeling examined whether relevant demographic, time variant, psychiatric, and TBI-related variables were associated with whether data was present versus missing across all possible time points, with each participant's scores as a cluster (see Supplement C). The missingness mechanism was determined.[27] Multiple imputation by chained equations[28] was performed to impute missing data. Of note, comparable longitudinal analyses were performed to determine if relevant variables were associated with whether participants came in to report a TBI or not; no variables were predictive.

In exploratory analyses, variables that were investigated as modifiers of odds for TBI were harvested from the closest available data collection point preceding each participant's first prospective TBI screening. Regressions were conducted to examine factors modifying the odds of TBI occurrence. For all analyses, assumptions were met and the number of TBI events per number of variables in the model was not found to exceed values thought to cause bias and/or precision errors.[29] All categorical variables were coded in reference to their absence (e.g., participants without schizophrenia disorders). Continuous variables were coded as changes in the odds of sustaining TBI with every unit change on the continuous variable.

To evaluate odds related to TBI occurrence, a series of hierarchical binomial logistic regressions were conducted. These exploratory models were constructed to provide coefficients adjusted for demographics and similar taxonomy risks (i.e., substance dependence, psychiatric disorders, neurological indicators, and psychological and daily functioning; see Figure 4, Blocks 2a-d). Specifically, age, sex, and education were entered on Block 1 and variables exclusive to each taxonomy were entered on Blocks 2a-d. The reported odds ratios are adjusted for demographics and for the factors exclusive to the taxonomy.

Generalized linear modeling and multiple imputation analyses were conducted using R version 3·6·3. All other statistical analyses were conducted using Statistical Package for the Social Sciences version 24·0. TBI screening data was double checked by select authors. Data was then entered into databases and checked and cleaned by research assistants and select authors. The study is reported in accordance with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Guidelines.[30]

Role of Funding Sources

Funders of this study played no part in research design, data collection/analysis, interpretation, or in writing the manuscript. All authors had access to the data and were responsible for the submission.

Results

Demographic and clinical characteristics of the sample are given in Table 1. Test-retest reliability was conducted on self-reported injury details from an available subsample of precariously housed persons enrolled in the study who repeated TBI screening (n = 42) for the same event at a later visit (*mean* = 7·88 days, *SD* = 4·78, range 4-19 days). Reliability estimates were calculated based on a single rating, absolute-agreement, two-way mixed effects model. Using Cicchetti guidelines,[31] reliabilities were excellent for self-report of TBI mechanism (intraclass correlation coefficient (*ICC*) = 0·950), as well as for LOC occurrence and its duration (*ICCs* = 0·908 and 0·973, respectively). Reliability was fair for the occurrence of PTA or being dazed and/or confused (*ICC* = 0·453), but poor for its duration (*ICC* = 0·126).

To establish the most comprehensive and accurate TBI rates, we examined the TBIs across the sample for the observation period using the observed and estimated (imputed) datasets. For analyses, the standard definition was deemed primary. For completeness, we also report *observed* TBIs using the conservative definition (requiring LOC; Table 2).

Over the possible 326 person-years, 175 TBI events were reported in 100 participants and 226 participants reported no events. Of those who acquired at least one event, 61% of participants reported only one TBI, and 39% reported two or more injuries (range 0 to 6; see Figure 2). Table 2 reveals an *observed* (unimputed) annual incidence proportion of 30·7% (100 of 326 individuals experienced TBI) and an observed event proportion of 53·7% (175 events in 326 individuals). The observed incidence rate (100 individuals with TBI over 202·75 person-years) was 0·49 persons per year and the observed event rate (175 events over 202·75 person-years) was 0·86 events per year. Fail-safe estimates of observed TBIs were established by removing the 27 "suspect" events (reported by 13 participants) that involved sensorial disruption that occurred prior to head impact (e.g., falling during an overdose). With this approach, the fail-safe observed incidence proportion (87 individuals with TBI out of 326 total individuals) was 26·7% versus 30·7% and the event proportion (148 TBI events out of 326 total individuals) was 45·4% versus 53·7%.

Finally, imputation that mitigates missing data biases under the missing at random (MAR) assumption yielded *estimates* that were 65 to 70% higher than that of the *observed* rates. Table 2 provides these *estimates*, with a TBI incidence proportion of 50·7% and an event proportion of 91·1%.

To appreciate the TBI events, we characterized their mechanisms and symptom features. One hundred forty-two of 175 events (81·1%) reported no LOC or a LOC of 30 minutes or less, 32 (18·3%) reported LOC longer than 30 minutes, and 1 (0·6%) was unknown. Table 3 reveals that the most common mechanisms

Clinical Characteristic	Total N	N	%
		M (SD)	
Demographics			
Age (years)	326	40·5 (11·3)	
Education (years)	326	10·5 (2·3)	
Monthly Income (Canadian dollars)	322	850·3 (415·3)	
Sex			
Males	326	239	73·3
Females	326	87	26·7
Ethnicity			
Caucasian	324	180	55·6
Indigenous	324	91	28·1
Other	324	53	16·4
Alcohol and Drug Dependence			
Alcohol	297	59	19·9
Stimulant	297	232	78·1
Opioid	297	129	43·4
Cannabis	297	113	38·0
Other	294	27	9·2
Psychiatric Disorders			
Depression	297	42	12·9
Bipolar spectrum disorder	296	32	10·8
Schizophrenia spectrum disorder	297	55	18·5
Substance induced psychotic disorder	297	47	15·8
Other	295	170	57·6
Neurological Disorders			
Lifetime traumatic brain injury count	326	Median = 3·00 (IQR = 4·0)	
Lifetime traumatic brain injury history	326	108	33·1
Pre-enrollment MRI-defined traumatic brain injury	283	15	5·3
History of seizures/epilepsy	323	50	15·5
History of stroke	321	13	4·0

***Table 1*: Sample Demographic and Clinical Characteristics.**
Note: Stimulant = cocaine and/or methamphetamine. Opioid = heroin and/or other opioid. Pre-enrollment Magnetic resonance imaging (MRI)-defined TBIs were determined from scans that were conducted prior to enrollment in monthly TBI screening.

TBI Definition	Incidence Proportion (per 100,000 population)	Event Proportion (per 100,000 population)	Incidence Rate (per 100,000 person-years)	Event Rate (per 100,000 person-years)
Standard				
Observed	30,674·85	53,680·98	49,321·82	86,313·19
Estimated	50,674·85	91,104·29	50,674·85	91,104·29
LOC required				
Observed	18,711·66	27,914·11	30,086·31	44,882·86

***Table 2*: Rates of Traumatic Brain Injury.**

were falls, assaults, and hitting one's head on an object. Seventeen events (9·7%) occurred in the context of a drug overdose. Acute intoxication was assessed for 79 TBI events (45·1% of all events) as this evaluation was initiated after the study was underway. Of these 79 events, 48 (60·8%) were acquired when the participant was intoxicated.

Females showed little difference compared to males in their odds for incident TBI (odds ratio (OR) = 1·111; 95% confidence interval (CI) ·778, 1·586; 99% CI ·695, 1·773). As for mechanisms, females were at higher odds than males for sustaining a TBI from falling (OR = 2·28; 95% CI 1·128, 4·607; 99% CI ·904 – 5·746), while males had higher odds than females for

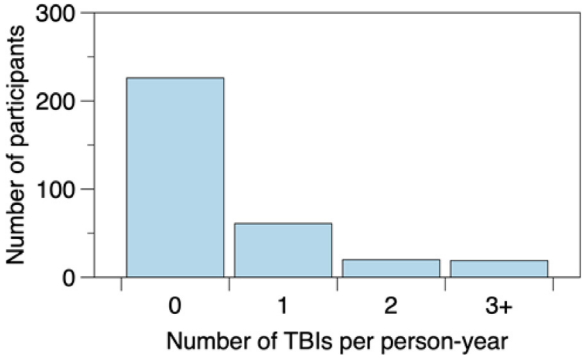

Figure 2. Frequency of Traumatic Brain Injury Count.

sustaining a TBI from assault (OR = 3·18; 95% CI 1·167, 8·703; 99% CI ·851, 11·934; see Figure 3).

As indicted in Figure 4, exploratory binomial logistic regression revealed associations with emergent TBI occurrence (standard definition) as reported by participants during the screening year. These odds ratios and their 95% CIs reveal that as education increased, the odds for TBI lessened (see Figure 4, Block 1). In terms of substance dependencies, participants with opioid dependence were at higher odds for incident TBI than those without (Block 2a), while other dependencies appeared less crucial. Persons in this sample with schizophrenia spectrum disorder, who often function more poorly, had lower odds for TBI occurrence compared to those without this disorder (see Block 2b).

Mechanism	Number of TBI Events	Percentage of Total TBI Events	Number in Context of Drug Overdose	Number in Context of Acute Intoxication
Fall	79	45·1	15	32
Assault	44	25·1	0	8
Hit head on Object	23	13·1	2	4
Hit by Object	10	5·7	0	2
Pedestrian Accident	9	5·1	0	1
Biking/Sports Related	6	3·4	0	1
Motor Vehicle Accident	1	0·6	0	0
Unknown	3	1·7	0	0
Other	0	0	0	0
Total	**175**	**100**	**17 (of 175; 9·7%)**	**48 (of 79*; 60·6%)**

***Table 3*: Mechanisms of Traumatic Brain Injury.**
Note: *Self-reports of acute intoxication were obtained for 79 of the total 175 injuries.

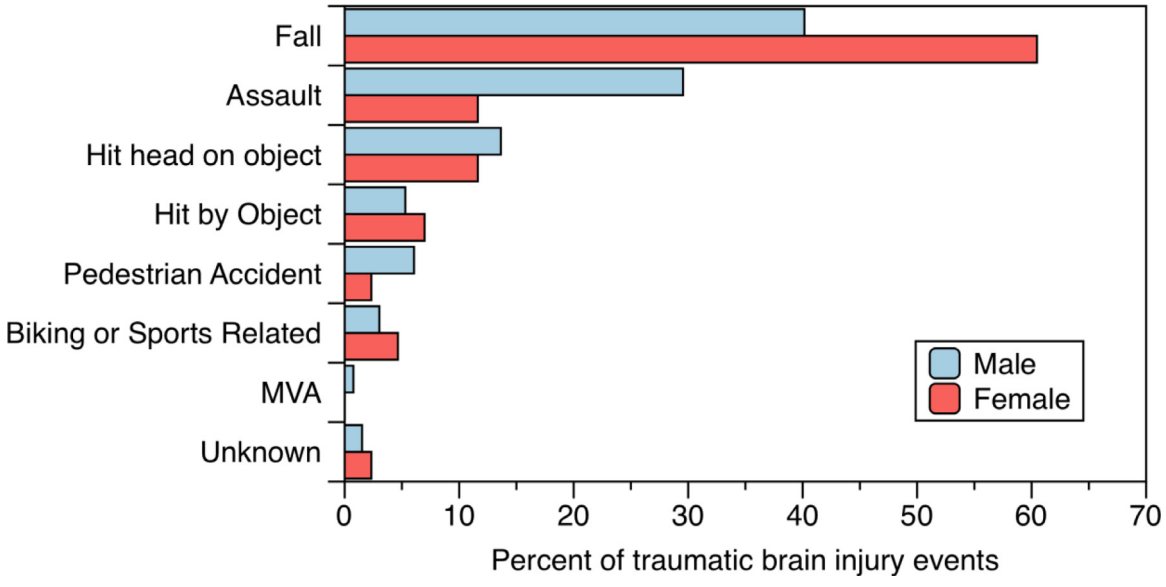

Figure 3. Mechanisms of Traumatic Brain Injury by Sex.

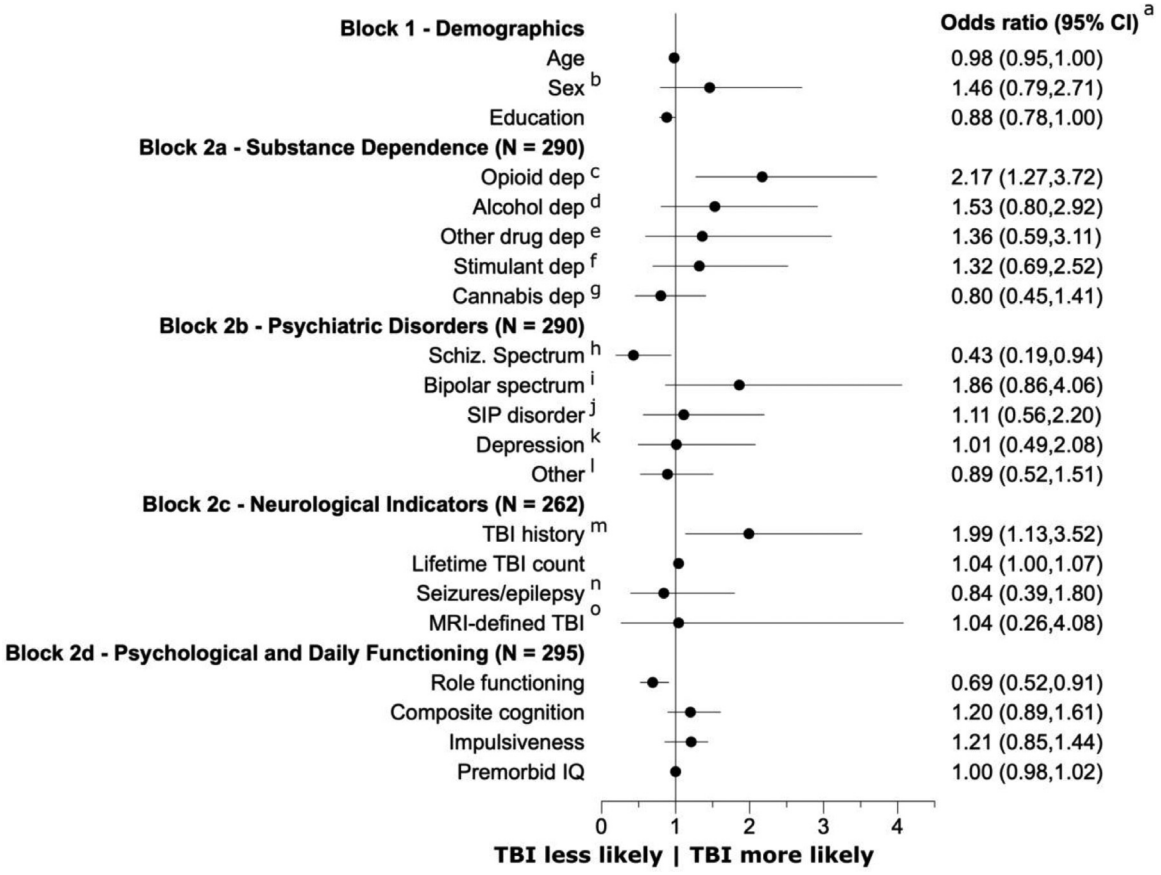

Figure 4. Binomial Logistic Regressions of Variables Tested for Association with Traumatic Brain Injury Occurrence with 95% confidence intervals.
Note: CI = confidence interval. [a] Adjusted for age, sex, and education. [b] N female = 87. Dep = dependence. [c] N = 129. [d] N = 59. [e] N = 27. [f] N = 232. [g] N = 113. Schiz = schizophrenia. [h] N = 55. [i] N = 32. SIP = substance induced psychosis. [j] N = 47. [k] N = 42. [l] N = 170. TBI = traumatic brain injury. [m] N = 108. [n] N = 50. MRI = magnetic resonance imaging. [o] N = 15. IQ = intelligence.

Select neurological indicators were also notable. Participants with prior "lifetime" TBI histories showed higher odds for incident TBI, and the odds for TBI increased with each "lifetime" TBI reported (i.e., TBI count; Block 2c). Finally, as composite role functioning increased, the odds for TBI lessened (Block 2d). See Supplement D for number of individuals with TBI occurrence by each variable tested for association. Note that after applying 99% CIs to the data, interval bounds for select OR that are highlighted above encompass one. Specifically, these indicators include the lower odds for TBI associated with more education and the diagnosis of schizophrenia disorders, and the higher odds associated with TBI history and lifetime TBI count (see Supplement E).

Discussion

The current study, using rigorous ascertainment procedures designed to capture TBI incidence and risks comprehensively, revealed that TBI rates in these precariously housed persons were higher than those of past reports. With a standard definition of TBI, the 31% *observed* incidence proportion was 1·6 to 1·8 times higher than that reported in other homeless and insecurely housed samples[5] and several orders of magnitude higher than a report derived from meta-analytically compiled population-based studies.[7] Importantly, studies often utilized administrative datasets and registries for TBI acquisition, likely missing mild TBIs cases. With bias-corrected imputation, our data indicates that ~51% of marginalized persons in the present sample experience at least one TBI annually (i.e., *estimated* incidence proportion). Given the screening duration, the *estimated* event rate indicated that that ~0·91 events occur for every person-year of observation.

Methodological improvements including proximal and repeated screening for brain injury likely contribute to these considerably higher self-reported TBI rates than have been previously reported in homeless and

housing-insecure samples. Existent research often screens for head injury only annually without standardized participant education. Such approaches likely miss mild and temporally distal injuries, thereby underestimating rates. The remarkably high TBI rates reported here reveal an underappreciated community endemic, warranting prioritization by health and research stakeholders through prevention efforts.

The injury mechanisms revealed, and the odds ratios for incident TBI, are germane to intervention approaches going forward. In terms of mechanisms, falls and assaults were frequently observed, with some evidence of sex differences, i.e., more fall-related TBIs in females and more assault-related TBIs in males. Opioid dependence increased odds for TBI and schizophrenia disorders lessened the odds. Two particularly concerning patterns were also apparent in exploratory analyses. First, remote *lifetime* TBI histories increased the odds for new occurrence and more *lifetime* TBIs incremented the odds further. Second, poorer role functioning conveyed higher odds for TBI, potentially indicating a bidirectional pattern. Over time these two patterns suggest a route for progressively acquired disability that emerges as functioning declines, presumably with the accumulated TBI exposures. Comprehensive educational and outreach approaches could be developed to prevent possible debilitating effects arising with the accumulation of TBIs. Managing health conditions, recognizing one's life stage, and providing choice and opportunity can improve an individual's role functioning.[32] Such interventions warrant further investigation.

There are several limitations that should be considered. In the acquisition of head injuries, we relied on self-report, a method susceptible to the response biases, limited insight, and memory errors. Although these inherent problems plague all self-reports of TBI, their impact here was likely mitigated by TBI education and repeated screening at short intervals. Of note is that a study subsample reliably reported critical injury details ensuring that participants were consistent in several aspects of event reporting. Second, participants received small monetary honoraria after each screening and a subset of participants received additional compensation after undergoing a neurocognitive evaluation (not reported here). This raises concern of false reports of TBI to acquire compensation. Yet, we did not detect any relevant variables associated with TBI reporting, suggesting that compensation seeking was not at play. Further, TBIs were often acquired in the context of acute intoxication *beyond typical use* or overdoses, potentially conflating substance-related effects with TBI-defining features. Consequently, false positive errors and greater severity designations because of contributory substance effects might occur. When TBIs were reported with insufficient self-reported recollection to provide a TBI diagnoses, we mitigated false positive ascertainment errors by requiring witness verification and/or observable signs of trauma. Nonetheless, the veracity of TBI reports is an intractable problem for this and similar community-based research, given that reports might often be conflated with brain dysfunction arising from intoxication/substance use which could interact with TBI-induced brain dysfunction. Future investigations that critically operationalize criteria for TBI diagnosis and characterization in persons with severe substance use disorders would be beneficial. Finally, like other reports directly investigating TBI incidence in homeless or marginally housed participants, sampling was non-random. Consequently, generalization of the results should be cautiously considered. The incidence statistics reported (i.e., observed and imputed) are estimates of the true rate of TBI in the present community-based sample, that shares demographic features with other (non-random) samples from the same neighbourhood, and in other Canadian cities.[2] Our findings may be less applicable to other populations comprised of unsheltered or emergency sheltered homeless persons. As with all non-random studies, probabilistic analyses of variables creating risk cannot be carried out.

Our understanding of TBIs in precariously housed and homeless persons is limited, especially given the apparent prior underestimates of its pervasiveness. The current observations suggest that precariously housed persons very frequently experience TBIs. Considering that this population also experiences high rates of existent cognitive impairment, social and occupational dysfunction, and often a host of concerning multimorbidities (e.g., psychiatric, neurological), the remarkable TBI rates should serve as an impetus for detailed investigation into their neurocognitive and functional impacts. This is particularly true for the typical mild injuries, given their potential for cumulative functional consequences.

Declaration of interests

WJP: Grant funding from the Canadian Institutes of Health Research, Brain Injury Canada and ACRM Task Force

LX: Grant funding from Simon Fraser University Undergraduate Student Research Award.

XJH: Grant funding from the Canadian Natural Science and Engineering Discovery Grant Program and Simon Fraser University Undergraduate Student Research Award.

WGH: Grant funding from the Canadian Institutes of Health Research

AET: Grant funding from the Canadian Institutes of Health Research; Simon Fraser University William and Ada Isabelle Steel Research Fund and Simon Fraser University Psychology Department Research Grant.

All other authors report no conflicts.

Contributors

All authors edited final versions of the manuscript with access to all the data. All authors approved that the manuscript be submitted for publication.

TAO contributed to conceptualisation, data curation, formal analysis, investigation, methodology, project administration, validation, visualisation, data verification, writing the original draft and editing.

WJP contributed to conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, supervision, validation, visualisation, and review and editing.

EML contributed to data curation, investigation, methodology, and project administration.

JLS contributed to data curation, investigation, methodology, visualization, and review and editing.

JA contributed to data curation, investigation, methodology, and project administration.

CSS contributed to data curation, investigation, and methodology.

SJF contributed to project administration, data curation, investigation, methodology, and review and editing.

TB contributed to project administration, supervision, data curation, investigation, and methodology.

LX contributed to formal analysis and methodology.

XJH contributed to formal analysis, methodology, supervision and review and editing.

DJL contributed to data curation, investigation, methodology, project administration and review and editing.

MLW contributed to data curation, investigation, and methodology.

WLT contributed to investigation, methodology, review and editing, and supervision.

KMG contributed to investigation, methodology, and review and editing.

ATV contributed to data curation and investigation.

MKH contributed to data curation and investigation.

WS contributed to data curation and investigation.

GWM contributed to conceptualisation, data curation, funding acquisition, investigation, methodology, project administration

AMB contributed to conceptualisation, funding acquisition, investigation, and methodology.

WGH contributed to conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, supervision, validation, visualisation, and review and editing.

AET contributed to conceptualisation, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, validation, visualisation, data verification, writing the original draft and editing.

Data Sharing Statement

Our individual level participant data collected from a specific community includes identifiers of age, gender, income, use of non-prescribed drugs and symptom severity scores, all of which are needed for analyses. We cannot provide this data due to potential privacy infringement and related ethical and legal obligations to participants as restricted by the University of British Columbia Clinical Research Ethics Board and Simon Fraser University's Research Ethics Board. For all requests regarding data, please contact the Clinical Research Ethics Board, University of British Columbia (ethics.research.ubc.ca) and the responsible authors at aethornt@sfu.ca and will.panenka@ubc.ca.

Acknowledgements

We would like to acknowledge the participants who volunteer for this study and the research assistants who contributed to the project.

Funding

Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, William and Ada Isabelle Steel Research Fund, Simon Fraser University Vice-President Research Undergraduate Student Research Award and Simon Fraser University's Psychology Department Research Grant.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.eclinm.2022.101277.

References

1 Vila-Rodriguez F, Panenka WJ, Lang DJ, et al. The Hotel Study: Multimorbidity in a community sample living in marginal housing. *Am J Psychiatry*. 2013;170(12):1413–1422. https://doi.org/10.1176/appi.ajp.2013.12111439.

2 Hwang SW, Aubry T, Palepu A, et al. The health and housing in transition study: A longitudinal study of the health of homeless and vulnerably housed adults in three Canadian cities. *Int J Public Health*. 2011;56(6):609–623. https://doi.org/10.1007/s00038-011-0283-3.

3 Jones AA, Vila-Rodriguez F, Leonova O, et al. Mortality from treatable illnesses in marginally housed adults: A prospective cohort study. *BMJ Open*. 2015;5(8):1–8. https://doi.org/10.1136/bmjopen-2015-008876.

4 Fazel S, Geddes JR, Kushel M. The health of homeless people in high-income countries: Descriptive epidemiology, health consequences, and clinical and policy recommendations. *Lancet*. 2014;384(9953):1529–1540. https://doi.org/10.1016/S0140-6736(14)61132-6.

5 Nikoo M, Gadermann A, To MJ, Krausz M, Hwang SW, Palepu A. Incidence and associated risk factors of traumatic brain injury in a cohort of homeless and vulnerably housed adults in 3 Canadian cities. *J Head Trauma Rehabil*. 2017;32(4):E19–E26. https://doi.org/10.1097/HTR.0000000000000262.

6 Stubbs JL, Thornton AE, Sevick JM, et al. Traumatic brain injury in homeless and marginally housed individuals: A systematic review and meta-analysis. *Lancet Public Heal*. 2020;5(1):e19–e32. https://doi.org/10.1016/S2468-2667(19)30188-4.

7 Nguyen R, Fiest KM, McChesney J, et al. The international incidence of traumatic brain injury: A systematic review and meta-analysis. *Can J Neurol Sci*. 2016;43(6):774–785. https://doi.org/10.1017/cjn.2016.290.

8 Topolovec-Vranic J, Ennis N, Colantonio A, et al. Traumatic brain injury among people who are homeless: A systematic review. *BMC Public Health*. 2012;12(1). https://doi.org/10.1186/1471-2458-12-1059.

9 Gicas KM, Vila-Rodriguez F, Paquet K, et al. Neurocognitive profiles of marginally housed persons with comorbid substance dependence, viral infection, and psychiatric illness. *J Clin Exp Neuropsychol*. 2014;36(10):1009–1022. https://doi.org/10.1080/13803395.2014.963519.

10 Willer B, Johnson WE, Rempel RG, Linn R. A note concerning misconceptions of the general public about brain injury. *Arch Clin Neuropsychol*. 1993;8(5):461–465. https://doi.org/10.1016/10887-6177(93)90009-P.

11 Schmitt T, Thornton AE, Rawtaer I, et al. Traumatic brain injury in a community-based cohort of homeless and vulnerably housed individuals. *J Neurotrauma*. 2017;34(23):3301–3310. https://doi.org/10.1089/neu.2017.5076.

12 Gicas KM, Jones AA, Thornton AE, et al. Cognitive decline and mortality in a community-based sample of homeless and precariously housed adults: 9-year prospective study. *BJPsych Open*. 2020;6(2):1–8. https://doi.org/10.1192/bjo.2020.3.

13 Corrigan JD, Bogner J. Initial reliability and validity of the *Ohio State University TBI Identification Method*. *J Head Trauma Rehabil*. 2007;22(6):318–329. https://doi.org/10.1097/01.HTR.0000300227.67748.77.

14 Hicks R, Giacino J, Harrison-Felix C, Manley G, Valadka A, Wilde EA. Progress in developing common data elements for traumatic brain injury research: Version Two-the end of the beginning. *J Neurotrauma*. 2013;30(22):1852–1861. https://doi.org/10.1089/neu.2013.2938.

15 Carroll LJ, Cassidy JD, Holm L, Kraus J, Coronado VG. Methodological issues and research recommendations for mild traumatic brain injury: The WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med Suppl*. 2004:(43):113–125. https://doi.org/10.1080/16501960410023877.

16 Dams-O'Connor K, Cantor JB, Brown M, Dijkers MP, Spielman LA, Gordon WA. Screening for traumatic brain injury: Findings and public health implications. *J Head Trauma Rehabil*. 2014;29(6):479–489. https://doi.org/10.1097/HTR.0000000000000099.

17 American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders (4th Ed.)*. 4th ed. Washington, DC: American Psychiatric Association; 2000. https://doi.org/10.1176/ajp.152.8.1228.

18 Endicott J. *Best Estimate Clinical Evaluation and Diagnosis Form (BECED)*. New York: Department of Research Assessment and Training, New York State Psychiatric Institute; 1988.

19 Sheehan D V, Lecrubier Y, Sheehan KH, et al. The *Mini-International Neuropsychiatric Interview* (MINI): The development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *J Clin Psychiatry*. 1998;59(Suppl 20):22–33.

20 Marsden J, Gossop M, Stewart D, et al. The *Maudsley Addiction Profile* (MAP): A brief instrument for assessing treatment outcome. *Addiction*. 1998;93(12):1857–1867. https://doi.org/10.1046/j.1360-0443.1998.931218571l.x.

21 Venegas J, Clark E. In: Kreutzer JS, DeLuca J, Caplan B, eds. *Encyclopedia of Clinical Neuropsychology*. New York, NY: Springer New York; 2011. https://doi.org/10.1007/978-0-387-79948-3.

22 Belkonen S. Hopkins Verbal Learning Test. In: Kreutzer JS, DeLuca J, Caplan B, eds. *Encyclopedia of Clinical Neuropsychology*. New York, NY: Springer New York; 2011:1264–1265. https://doi.org/10.1007/978-0-387-79948-3_1127.

23 Rozenblatt S. Stroop Color Word Test (adult). In: Kreutzer JS, DeLuca J, Caplan B, eds. *Encyclopedia of Clinical Neuropsychology*. New York, NY: Springer New York; 2011:2404–2405. https://doi.org/10.1007/978-0-387-79948-3_660.

24 Fray PJ, Robbins TW, Sahakian B. Neuropsychiatric applications of *CANTAB*. *Int J Geriatr Psychiatry*. 1996;11(4):329–336. https://doi.org/10.1002/(SICI)1099-1166(199604)11:4<329::AID-GPS453>3.0.CO;2-6.

25 Goodman SH, Sewell DR, Cooley EL, Leavitt N. Assessing levels of adaptive functioning: The *Role Functioning Scale*. *Community Ment Health J*. 1993;29(2):119–131. https://doi.org/10.1007/BF00756338.

26 Richter S, Stevenson S, Newman T, et al. Handling of missing outcome data in traumatic brain injury research: A systematic review. *J Neurotrauma*. 2019;36(19):2743–2752. https://doi.org/10.1089/neu.2018.6216.

27 Rubin DB. Inference and missing data. *Biometrika*. 1976;63(3):581–592. https://doi.org/10.1093/biomet/63.3.581.

28 Twisk J, dr Boer M, de Vente W, Heymans M. Multiple imputation of missing values was not necessary before performing a longitudinal mixed-model analysis. *Journal of Clinical Epidemiology*. 2013;66:1022–1028. https://doi.org/10.1016/j.jclinepi.2013.03.017.

29 Peduzzi P, Concato J, Feinstein AR, Halford TR. A simulation study of the number of events per variable recommended in multivariable regression analyses. *Control Clin Trials*. 1996;49(12):1373–1379. https://doi.org/10.1016/s0895-4356(96)00236-3.

30 Benchimol EI, Smeeth L, Guttmann A, et al. RECORD Working Committee. The reporting of Studies Conducted using Observational Routinely-Collected health Data (RECORD) statement. *PLoS Med*. 2015;12:(10):e1001885. https://doi.org/10.1371/journal.pmed.1001885.

31 Cicchetti D V. Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment insturments in psychology. *Psychol Assess*. 1993;6(4):284–290. https://doi.org/10.1037/1040-3590.6.4.284.

32 Anatchkova MD, Bjorner JB. Health and role functioning: the use of focus groups in the development of an item bank. *Qual Life Res*. 2010;19(2010):111–123. https://doi.org/10.1007/s11136-009-9570-3.