Traumatic brain injury in homeless and marginally housed individuals: a systematic review and meta-analysis


Summary

Background Homelessness is a global public health concern, and traumatic brain injury (TBI) could represent an underappreciated factor in the health trajectories of homeless and marginally housed individuals. We aimed to evaluate the lifetime prevalence of TBI in this population, and to summarise findings on TBI incidence and the association between TBI and health-related or functioning-related outcomes.

Methods For this systematic review and meta-analysis, we searched without date restrictions for original research studies in English that reported data on the prevalence or incidence of TBI, or the association between TBI and one or more health-related or function-related outcome measures. Studies were included if they had a group or clearly identifiable subgroup of individuals who were homeless, marginally housed, or seeking services for homeless people. With use of random-effects models, we calculated pooled estimates of the lifetime prevalence of any severity of TBI and the lifetime prevalence of moderate or severe TBI. We used meta-regression and subgroup analysis to evaluate potential moderators of prevalence estimates and the leave-one-out method for sensitivity analyses. We then summarised findings from all studies that evaluated TBI incidence and the association between TBI and health-related or functioning-related outcomes. All statistical analyses were done using R version 3.5.1. The study is registered with PROSPERO, number CRD42019119678.

Findings Of 463 potentially eligible studies identified by the search, 38 studies were included in the systematic review and 22 studies were included in the meta-analysis. The lifetime prevalence of any severity of TBI in homeless and marginally housed individuals (18 studies, n=9702 individuals) was 53.1% (95% CI 46.4–59.7; I²=97%) and the lifetime prevalence of moderate or severe TBI (nine studies, n=5787) was 22.5% (13.5–35.0; I²=99%). The method used to ascertain TBI history, the age of the sample, and the sample size significantly moderated estimated lifetime prevalence of any severity of TBI. TBI was consistently associated with poorer self-reported physical and mental health, higher suicidality and suicide risk, memory concerns, and increased health service use and criminal justice system involvement.

Interpretation The lifetime prevalence of TBI is high among homeless and marginally housed individuals, and a history of TBI is associated with poorer health and general functioning. Health-care providers and public health officials should have an increased awareness of the burden of TBI in this population. Prospective and longitudinal studies are needed to better understand how the health of this population is affected by TBI.

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Introduction

More than 6 million people experience homelessness annually in the USA and the EU.1 Homeless individuals experience markedly poorer mental and physical health than the general population, including a high prevalence of psychotic disorders, major depression, and drug and alcohol dependence;2 and a high prevalence of infectious diseases, including HIV, hepatitis C, and tuberculosis.3 Homeless and similarly marginalised individuals also have substantially higher all-cause mortality than the general population.4 Traumatic brain injury (TBI) is a pervasive and under-recognised public health problem.5 TBI is associated with a number of deleterious outcomes, with meta-analytic evidence providing a link for the subsequent development of neurological and psychiatric disorders.6 TBI is often preventable, and thus might represent a modifiable risk factor for serious psychiatric illness and neurodegenerative disease.

Obtaining reliable estimates of TBI incidence and lifetime prevalence in the homeless and marginally housed population, as well as in the general population, has been challenging. Reported incidence of TBI varies widely across counties,7 and the methods of sampling participants and defining TBI cases differ between reports. Considerably higher rates of TBI have been reported in population-based studies that capture injuries for which medical attention is not sought,8 as compared with studies that gather data from medical records or emergency departments.9,10 Additional sources of bias also exist, including in the common definitions of TBI,11,12
Evidence before this study
Previous studies and a previous systematic review have suggested that the lifetime prevalence and incidence of TBI might be considerably higher in homeless and marginally housed individuals than in the general population. Moreover, many of these studies report that TBI is associated with poorer health or functioning in these individuals. Marked methodological variation exists among previous studies, including in the tools used to ascertain a history of TBI, in the study-specific definitions of TBI, and in the outcome measures assessed. This variation limits our understanding of the prevalence, incidence, and impact of TBI in this population. To date, no meta-analyses have been done to evaluate the prevalence of TBI in homeless and marginally housed individuals, nor have any quantitative analyses of heterogeneity among previous studies been done. In preparation for this review, we did systematic searches in MEDLINE, Embase, PsycINFO, CINAHL, and Web of Science for studies that evaluated TBI in homeless or marginally housed study samples. Specific database search terms are outlined in the appendix. Studies were eligible for inclusion if they evaluated the prevalence or incidence of TBI, or the association between TBI and health-related or functioning-related outcome measures, and they were original peer-reviewed studies in the English language. No date restrictions were applied.

Added value of this study
To our knowledge, this is the first meta-analysis to evaluate the prevalence of TBI in homeless and marginally housed individuals and the first quantitative assessment of heterogeneity among studies that assess TBI in this population. We show that homeless and marginally housed individuals experience a high lifetime prevalence of TBI, and notably, a lifetime prevalence of moderate or severe TBI that is approximately ten-times higher than estimates in the general population. We found high heterogeneity among studies and our meta-regression analyses identified several factors that moderated individual study findings. Our review also found that TBI is associated with poorer self-reported health, higher suicidality and suicide risk, increased health service use, and increased criminal justice system involvement.

Implications of all the available evidence
TBI is a pervasive and largely under-recognised factor associated with the poorer health and functioning experienced by homeless and marginally housed populations. Our findings suggest that health-care providers who work with these individuals should be aware of the high prevalence of TBI and associated effects on health and functioning. Additionally, given the high prevalence of moderate or severe TBI, and the considerable number of individuals with evidence of traumatically-induced lesions visible with MRI, the threshold for referral to neuroimaging specialists after head injury should be reduced in this population. Further research is urgently needed to address limitations to our understanding of the burden of TBI in at-risk and multimorbid populations. However, in light of the significant moderating factors that we identified, future studies should carefully consider and clearly describe all aspects of study design to maximise validity and clinical relevance.

Research in context

Evidence before this study
Previous studies and a previous systematic review have suggested that the lifetime prevalence and incidence of TBI might be considerably higher in homeless and marginally housed individuals than in the general population. Moreover, many of these studies report that TBI is associated with poorer health or functioning in these individuals. Marked methodological variation exists among previous studies, including in the tools used to ascertain a history of TBI, in the study-specific definitions of TBI, and in the outcome measures assessed. This variation limits our understanding of the prevalence, incidence, and impact of TBI in this population. To date, no meta-analyses have been done to evaluate the prevalence of TBI in homeless and marginally housed individuals, nor have any quantitative analyses of heterogeneity among previous studies been done. In preparation for this review, we did systematic searches in MEDLINE, Embase, PsycINFO, CINAHL, and Web of Science for studies that evaluated TBI in homeless or marginally housed study samples. Specific database search terms are outlined in the appendix. Studies were eligible for inclusion if they evaluated the prevalence or incidence of TBI, or the association between TBI and health-related or functioning-related outcome measures, and they were original peer-reviewed studies in the English language. No date restrictions were applied.

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function or day-to-day functioning, such as employment) in these individuals.

Evaluating the prevalence and burden of TBI in individuals who are homeless or marginally housed is critical to understanding the unique challenges and health-care needs of this population. Furthermore, identifying factors that contribute to heterogeneity across studies is integral to establishing standardised approaches for future research and in finding targets for the prevention of TBI and treatment of its sequelae in this population. In this study, we aimed to estimate the lifetime prevalence of TBI in homeless and marginally housed individuals, to quantitatively evaluate factors that moderate estimates of prevalence, and to systematically review the association between TBI and health and functioning-related outcome measures in this population.

Methods
Search strategy and selection criteria
We did a systematic review and meta-analysis following the PRISMA and MOOSE guidelines. Studies were included in the review if they had a sample that exclusively comprised individuals of any age who were homeless, marginally housed, or seeking services for homeless people at the time of assessment (or if there was a clearly identifiable subgroup of individuals who were homeless, marginally housed, or seeking services for homeless people at the time of assessment and data was able to be extracted for this subgroup), and if they examined the prevalence of TBI, the incidence of TBI, or the association between TBI and one or more health-related or functioning-related outcome measures. Our definition of functioning was deliberately broad to evaluate the full scope of the effects of TBI in this population, and was considered to be any non-health-related outcome measure or any outcome related to day-to-day functioning in society (eg, neurocognition or involvement in the criminal justice system). Studies were excluded from the review if they were not published in English, were not peer-reviewed, or were not original research studies with unique observational data (ie, reviews or meta-analyses).

The decision to conduct a meta-analysis was made after doing the literature search to ensure that a sufficient number of studies were available that had recorded lifetime prevalence of TBI. Studies were excluded from the meta-analysis if they did not have prevalence data that could be extracted or obtained through corresponding authors, had a sample size smaller than 25, or if they were judged to be from the same study sample as another study included in the analysis by consensus of two study authors (JLS and WJP). For studies that were identifiable from the same study sample, we included the study with the largest sample size in the meta-analysis.

We did a systematic search without date restrictions in MEDLINE, Embase, PsycINFO, CINAHL, and Web of Science using a search strategy developed in conjunction with a librarian specialising in systematic review searches. The search strategy was piloted in MEDLINE by iteratively adding and refining relevant search terms and by ensuring that the included search terms returned studies we knew to exist on this topic. Our search strategy was consistent across all databases, and the strategy used in MEDLINE (Ovid interface) is reported in the appendix (p 1). Manual forward and backward reference searching was done on studies of particular importance in the opinion of JLS and WJP and on the previous review on this topic. Searches of all databases and retrieval of results from each database were done on Dec 14, 2018, with no date restrictions.

Screening of titles and abstracts of all records returned by the search strategy, screening of full texts eligible for inclusion, and the risk of bias assessment for included studies were independently conducted by two study authors (JLS and JMS). Inter-rater reliability for both the title and abstract and full text screening was calculated using Cohen’s κ. Risk of bias for individual studies was assessed using the US National Heart, Lung, and Blood Institute’s Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. Discrepancies were resolved through discussion between study authors to reach a consensus, or with a third study author (WJP) if necessary.

The protocol for our systematic review was registered in the PROSPERO database (CRD42019119678).

Data analysis
All variables of interest were independently extracted by two study authors (JLS and JMS) using a customised form. The form was piloted and refined on ten of the studies selected for inclusion. All extracted variables are described in the appendix (p 2).

For studies included in the meta-analysis, we quantitatively evaluated several potential moderators of estimated prevalence of TBI using meta-regression and subgroup analysis. First, we evaluated whether the measure of central tendency of age of the sample (subsequently referred to as age of the sample) or the total sample size was associated with estimated prevalence. Second, we assessed whether the method of ascertaining TBI history moderated estimated prevalence by stratifying TBI ascertainment methods into five categories: (1) a non-specific self-report question or series of questions to ascertain TBI; (2) medical record; (3) questionnaire or screening tool specifically designed to ascertain TBI; (4) the Ohio State University TBI Identification (OSU TBI-ID) structured interview; and (5) other ascertainment method. Third, we evaluated whether studies that used self-reported loss of consciousness as a minimum criterion for defining TBI, as opposed to a more liberal definition (eg, self-report of a period of being dazed or confused), were associated with lower estimated prevalence. Finally, we evaluated whether the site of participant recruitment—stratified into studies that recruited participants from a shelter or hostel.
versus studies that recruited participants from a service or clinic for homeless individuals—was associated with different estimates of prevalence.

We did two separate analyses to evaluate the lifetime prevalence of TBI. The first aimed to measure the overall lifetime prevalence of TBI, encompassing all levels of severity, and including studies that did not stratify by severity. The second aimed to measure the lifetime prevalence of moderate or severe TBI, encompassing studies that stratified participants into moderate or severe TBI categories, studies that examined only moderate or severe TBI, or studies that assessed TBI without explicitly defining severity but which we deemed were predominantly focused on more significant brain injury. We deemed that two studies that did not explicitly evaluate TBI severity focused predominantly on moderate or severe TBI; one study assessed “definite TBI” on the basis of MRI evidence and persistent sequelae attributable to the TBI. The other study defined TBI as brain injury resulting in lasting impairment or contributing to disability. Therefore, we evaluated these two studies alongside others that explicitly examined moderate or severe TBI. We used random-effects models for each analysis to calculate a pooled estimate of prevalence, with the Clopper-Pearson method used to generate 95% CIs for individual studies and the inverse variance method to weight each study. We also calculated 95% prediction intervals (PIs) for our summary estimates to provide a range for the predicted estimate of prevalence for new studies.

Heterogeneity between studies was quantified with the $I^2$ statistic. For studies that did not report age of the sample, and for which these data could not be obtained from the corresponding author (n=2), we imputed the weighted mean age of participants from all other studies that were included in the analysis. We conducted sensitivity analyses using the leave-one-out method. We evaluated small-study effects visually with a funnel plot and statistically with Egger’s test.

Finally, we used subgroup analysis and meta-regression to evaluate moderators of individual study estimates of the lifetime prevalence of TBI. We used univariable meta-regression to evaluate unadjusted effects in the analyses of lifetime prevalence and the lifetime prevalence of moderate or severe TBI, and we included all potential moderators, for which appropriate data were available, in a multivariable meta-regression to evaluate adjusted effects in the analysis of lifetime prevalence. We used mixed effects models for all meta-regression analyses.

All statistical analyses were performed in R (version 3.5.1) with the packages meta (version 4.9-4) and metafor (version 2.0-0).

Role of the funding source
The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results
Our database searches identified 463 potentially eligible studies. After removal of duplicates, 260 study titles and abstracts were screened (figure 1). We assessed 51 full text articles for eligibility, of which 13 were excluded from the systematic review (appendix p 1) and an additional 16 were excluded from the meta-analysis. There was a high inter-rater reliability for screening titles and abstracts ($\kappa=0.95$) and full texts ($\kappa=0.96$).

38 studies were included in the systematic review (table 1). The included studies were published between 1995 and 2018, and recruited participants from Australia, Canada, Japan, South Korea, the UK, and the USA. The predominant recruitment settings were through homeless shelters or hostels (18 studies) and services or clinics that serve homeless populations (16 studies). Six (16%) of 38 studies were conducted in populations of military service members who were homeless or seeking services for homeless people, and the remainder of studies recruited participants from civilian populations. Of the 38 studies included in the systematic review, we included 22 in the meta-analysis (figure 1). 18 (82%) of 22 studies (n=9702) assessed the lifetime prevalence of TBI, and nine (41%, n=5787) assessed the lifetime prevalence of moderate or severe TBI.

The risk of bias assessment for all studies included in the systematic review is shown in the appendix (pp 2, 3). In general, studies had a clear research objective, recruited participants from similar populations, and clearly described dependent variables. However, 17 (45%) of 38 studies did not provide a clear definition of homelessness or marginal housing, and 23 (61%) did not report whether the participation rate of eligible persons was more than 50%. Of note, 20 (53%) of 38 studies did not clearly describe the specific definition used to categorise participants as having TBI. Studies were generally comprised of predominantly male samples, and eight studies were comprised of exclusively male samples.

The overall pooled estimate of the lifetime prevalence of TBI was 53.1% (95% CI 46.4–59.7, 95% PI 25.9–78.6; figure 2). There was a significant amount of heterogeneity between studies ($I^2=97\%$, $p=0.0001$). The funnel plot is reported in the appendix (p 4) and did not show evidence of small-study effects, which was supported by Egger’s test ($p=0.96$). The results of the leave-one-out sensitivity analyses are reported in the appendix (p 5), and show that no single study, nor the studies for which we imputed mean age, had a disproportionate effect on the pooled estimate of prevalence of TBI.

The results from our univariable and multivariable meta-regression analyses are reported in table 2, with raw coefficients reported in the appendix (p 6). The overall
The pooled estimate of the lifetime prevalence of moderate or severe TBI was 22·5% (95% CI 13·5–35·0, 95% I²=99%, p<0·0001). The funnel plot is equivocal, whereby findings were either mixed or the outcome was evaluated by only a small number of studies. Furthermore, history of TBI was associated with poorer self-reported physical and mental health, increased health service use and criminal justice involvement, and showed no asymmetry (p=0·56). The leave-one-out sensitivity analyses are reported in the appendix (p 9), and show that no single study, nor the studies that did not explicitly evaluate severity but which we deemed to be focused predominantly on moderate or severe TBI, had a disproportionate effect on the pooled estimate of lifetime prevalence of moderate or severe TBI. None of the moderators (as previously described for overall lifetime prevalence of TBI) were statistically significantly associated with estimated prevalence of moderate or severe TBI in univariable meta-regression analyses.

In this review, 28 (74%) of 38 studies assessed the association between a history of TBI and health-related or functioning-related outcomes. A summary of results is reported in the panel, and a study-level breakdown of results is presented in the appendix (pp 9–12). The association between TBI and many outcome measures was equivocal, whereby findings were either mixed or the outcome was evaluated by only a small number of studies. However, despite the heterogeneity in study methodology and outcomes assessed, history of TBI was consistently associated with poorer self-reported physical and mental health, increased health service use and criminal justice involvement, and younger age at first experience of homelessness in all studies that evaluated TBI and these outcomes. Furthermore, history of TBI was associated with suicidal ideation and higher suicide risk in four of five studies that evaluated suicidality, and self-reported memory concerns in five of six studies that evaluated memory concerns. The most common mechanism of injury was assault across all five studies that evaluated mechanism of injury. Age at first TBI ranged from 15 years to 19·9 years, and we calculated a weighted mean age of first TBI of 15·8 years. In one large marginally housed cohort who underwent MRI scans, 28·0% of participants had incidental neuroimaging findings (eg, aneurysms or infarcts), with 6·9% reported TBI across those three studies with a more inclusive definition (ie, self-reporting a period of being dazed, confused, or experiencing memory loss). Individual study and pooled estimates of lifetime TBI prevalence stratified by TBI ascertainment method are shown in the appendix (p 7). Heterogeneity among studies that ascertained history of TBI using OSU TBI-ID structured interviews (I²=95%) and other screening tools (I²=94%) was high, although it was lower than the heterogeneity observed across all studies (I²=97%).

Figure 1: Study selection
TBI=traumatic brain injury.
<table>
<thead>
<tr>
<th>Country</th>
<th>Study design</th>
<th>Population description</th>
<th>Sample size</th>
<th>Age, years*</th>
<th>Female, n/N (%)</th>
<th>Any severity, n/N (%)</th>
<th>Moderate or severe, n/N (%)</th>
<th>TBI ascertainment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andersen et al (2014)†</td>
<td>Canada</td>
<td>Cross-sectional Shelter for homeless men</td>
<td>27</td>
<td>34</td>
<td>1/34</td>
<td>12/34 (35.3%)</td>
<td>11/34 (32.4%)</td>
<td>Questionnaire or screening tool: Brain Injury Screening Questionnaire</td>
</tr>
<tr>
<td>Baccardi et al (2017)†</td>
<td>Canada</td>
<td>Cross-sectional Community agencies that serve homeless individuals (shelters, drop-in centres, outreach teams, inpatient programmes, and criminal justice programmes)</td>
<td>416</td>
<td>39.9</td>
<td>117/416 (28.1%)</td>
<td>277/416 (66.6%)</td>
<td>108/398 (54.5%)</td>
<td>—</td>
</tr>
<tr>
<td>Barnes et al (2015)</td>
<td>USA</td>
<td>Cross-sectional VA service clinics for veterans seeking homeless services</td>
<td>28</td>
<td>51.8</td>
<td>9/229 (3.9%)</td>
<td>207/229 (90.4%)</td>
<td>63/229 (27.5%)</td>
<td>—</td>
</tr>
<tr>
<td>Brenner et al (1996)†</td>
<td>UK</td>
<td>Cross-sectional Hostel for homeless men</td>
<td>62</td>
<td>NR</td>
<td>0/62</td>
<td>29/62 (46.8%)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Brenner et al (2017)‡</td>
<td>USA</td>
<td>Cross-sectional VA service clinics for veterans seeking homeless services</td>
<td>309</td>
<td>52.3</td>
<td>11/309 (3.6%)</td>
<td>282/309 (91.3%)</td>
<td>90/309 (29.1%)</td>
<td>—</td>
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<tr>
<td>Brown et al (2013)‡</td>
<td>USA</td>
<td>Cross-sectional Emergency, transitional, and day shelters</td>
<td>250</td>
<td>56.2</td>
<td>48/250 (19.2%)</td>
<td>147/250 (58.8%)</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Bynaster et al (2017)‡ †</td>
<td>USA</td>
<td>Cross-sectional Health care clinic sites for a US county homeless programme</td>
<td>127</td>
<td>48</td>
<td>40/127 (31.5%)</td>
<td>97/127 (76.4%)</td>
<td>38/127 (29.9%)</td>
<td>—</td>
</tr>
<tr>
<td>Cotman et al (1997)‖</td>
<td>USA</td>
<td>Pre-test/post-test Residential programme to assist recovery from homelessness</td>
<td>24</td>
<td>30.6</td>
<td>11/24 (45.8%)</td>
<td>2/24 (8.3%)</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Gargaro et al (2016)</td>
<td>Canada</td>
<td>Cross-sectional Clients seeking support from an Assertive Community Treatment Team in a downtown urban setting</td>
<td>48</td>
<td>43.4</td>
<td>15/48 (31.3%)</td>
<td>27/48 (56.3%)</td>
<td>—</td>
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<tr>
<td>Gonzalez et al (2001)‡</td>
<td>USA</td>
<td>Cross-sectional Health care clinic associated with community shelter and outreach programme for homeless individuals</td>
<td>60</td>
<td>39.8</td>
<td>24/60 (40.0%)</td>
<td>23/60 (38.3%)</td>
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<tr>
<td>Hurstak et al (2017)‖</td>
<td>USA</td>
<td>Cross-sectional Overnight shelters, homeless encampments, meal programmes, and recycling centres</td>
<td>282</td>
<td>34.8</td>
<td>248/282 (87.9%)</td>
<td>69/282 (24.5%)</td>
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<tr>
<td>Hux et al (2009)† †</td>
<td>USA</td>
<td>Cross-sectional Homeless shelters and domestic violence facility</td>
<td>282</td>
<td>34.8</td>
<td>248/282 (87.9%)</td>
<td>69/282 (24.5%)</td>
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<tr>
<td>Hwang et al (2008)‡ †</td>
<td>Canada</td>
<td>Cross-sectional Shelters and meal programmes</td>
<td>904</td>
<td>37.4</td>
<td>303/904 (33.5%)</td>
<td>475/904 (52.5%)</td>
<td>109/904 (12.1%)</td>
<td>—</td>
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<tr>
<td>Kim et al (2007)†</td>
<td>South Korea</td>
<td>Retrospective case-control Hospital neurosurgical department</td>
<td>76</td>
<td>53% were &gt;50</td>
<td>5/76 (6.6%)</td>
<td>—</td>
<td>—</td>
<td>Medical record</td>
</tr>
</tbody>
</table>

(Table 1 continues on next page)
<table>
<thead>
<tr>
<th>Country</th>
<th>Study design</th>
<th>Population description</th>
<th>Setting</th>
<th>Sample size</th>
<th>Age, years*</th>
<th>Female, n/N (%)</th>
<th>Any severity, n/N (%)</th>
<th>Moderate or severe, n/N (%)</th>
<th>Incidence of TBI</th>
<th>TBI ascertainment method</th>
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<tr>
<td>Kozloff et al (2016)44†</td>
<td>Canada</td>
<td>Cross-sectional Community agencies that serve homeless individuals (shelters, drop-in centres, outreach teams, inpatient programmes, and criminal justice programmes) in five Canadian cities</td>
<td>2255</td>
<td>40·9</td>
<td>730/2255 (32·4%)</td>
<td>145/52255 (65·4%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Single question or series of questions: “Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?”</td>
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</tbody>
</table>
| LePage et al (2014)44† | USA    | Retrospective case-control VA North Texas Health Care System                            | 2205                                                                 | 53·6        | 121/2205 (5·5%) | –                | –                      | 0·5% over 1 year         | Medical record: ICD-9 codes
| Mackelpang et al (2014)44‡ | USA    | Cross-sectional Homeless shelters, drop-in centres, domestic violence shelters, streets | 2732                                                                 | 21·8        | 1730/2732 (63·3%) | 1175/2732 (43·0%) | –                      | –                        | –                  | Single question or series of questions: “Have you ever been hit in the head so hard that you saw stars or were knocked unconscious—for example, from a blow, a fall, or a motor vehicle accident?” and “After your head injury, did you start having problems with headaches, concentration or memory, understanding, excessive worry, sleeping, or getting along with people?” |
|            |                    |                                                                                       |                                                                         |             |              |                   |                        |                          |                   |                                                                                          |
| Kozloff et al (2016)44† | Canada | Cross-sectional Community agencies that serve homeless individuals (shelters, drop-in centres, outreach teams, inpatient programmes, and criminal justice programmes) in five Canadian cities | 7830 hospital admissions in 2010-11                                      | 38·7        | 347/1590 (21·8%) | –                | –                      | 2·1% of hospital admissions (2010-11) in the homeless group were for head injury | Medical record: National Health Service hospital episode statistics in England |
| LePage et al (2014)44† | USA    | Retrospective case-control VA North Texas Health Care System                            | 11909                                                                | NR          | NR           | –                | –                      | –                        | –                  | Medical record: ICD-9 codes |
| Mackelpang et al (2014)44‡ | USA    | Cross-sectional Homeless shelters, drop-in centres, domestic violence shelters, streets | 2205                                                                 | 53·6        | 121/2205 (5·5%) | –                | –                      | 0·5% over 1 year         | Medical record: ICD-9 codes |
|            |                    | (Continued from previous page)                                                          |                                                                         |             |              |                   |                        |                          |                   |                                                                                          |
|           |                    |                                                                                       |                                                                         |             |              |                   |                        |                          |                   |                                                                                          |
| Montgomery et al (2015)44‡ | USA    | Retrospective case-control Veterans Health Administration clinical and administrative systems | 1590                                                                 | 40·5        | 347/1590 (21·8%) | –                | –                      | 13·5% over 30 years      | Medical record: ICD-9 and ICD-10 codes
| Nielsens et al (2018)44‡ | Australia | Retrospective chart review Mental health clinics in three hostels for homeless individuals | 2988                                                                 | 42·3        | 156/2388 (6·5%) | –                | –                      | –                        | –                  | Medical record |
| Nikoo et al (2015)44† | Canada | Cross-sectional Emergency shelter and streets                                           | 500                                                                  | 37·9        | 200/500 (40·0%) | 318/500 (63·6%) | –                      | –                        | –                  | Medical record: ICD-9 codes |
| Nikoo et al (2017)44‡ | Canada | Prospective longitudinal Shelter, meal programmes, community health centre, and drop-in centres in three Canadian cities | 1190                                                                 | 42·2        | 38/1190 (32·4%) | 718/1190 (60·3%) | –                      | –                        | –                  | Single question or series of questions: “Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?” |
| Noel et al (2016)44† | Canada | Prospective longitudinal Community agencies that serve homeless individuals (shelters, drop-in centers, outreach teams, inpatient programmes, and criminal justice programmes) in five Canadian cities | 497                                                                  | 40·8        | 138/497 (27·8%) | –                | –                      | –                        | –                  | Single question or series of questions: “Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?” |
| Oddy et al (2012)44‡ ‡ | UK    | Cross-sectional Dry hostels, wet hostels, and day centres for homeless individuals     | 100                                                                  | 32·7        | 25/100 (25·0%)  | 48/100 (48·0%)  | 12/65 (18·5%)          | –                        | –                  | Single question or series of questions: “Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?”; with additional questions regarding the number of injuries, LOC and whether participants went to the hospital for the first three injuries |
|            |                    |                                                                                       |                                                                         |             |              |                   |                        |                          |                   |                                                                                          |

Table 1 continues on next page
### Table 1. Population description, lifetime prevalence of TBI, incidence of TBI, and TBI ascertainment method across studies

<table>
<thead>
<tr>
<th>Country</th>
<th>Study design</th>
<th>Population description</th>
<th>Sample size</th>
<th>Age, years*</th>
<th>Female, n/N (%)</th>
<th>Any severity, n/N (%)</th>
<th>Moderate or severe, n/N (%)</th>
<th>TBI ascertainment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>Cross-sectional</td>
<td>Homeless outreach services, including a VA medical centre and drop-in centre for veterans experiencing homelessness</td>
<td>103</td>
<td>53.7</td>
<td>0/103</td>
<td>–</td>
<td>–</td>
<td>Structured interview and questionnaire or screening tool: OSU TBI-ID and TBI-4 tools</td>
</tr>
<tr>
<td>USA</td>
<td>Cross-sectional</td>
<td>Metropolitan VA hospital</td>
<td>678</td>
<td>51.9</td>
<td>36/678 (5.3%)</td>
<td>285/313 (91.1%)</td>
<td>–</td>
<td>Structured interview and questionnaire or screening tool: OSU TBI-ID and TBI-4 tools</td>
</tr>
<tr>
<td>Canada</td>
<td>Cross-sectional</td>
<td>Single-room occupancy hotel rooms and downtown community court</td>
<td>283</td>
<td>43.5</td>
<td>47/205 (2.2%)</td>
<td>100/283 (35.3%)</td>
<td>49/283 (17.3%)</td>
<td>Single question or series of questions: “Have you ever had a serious head/face injury?”, with additional questions regarding LOC, confusion, or memory loss post injury</td>
</tr>
<tr>
<td>USA</td>
<td>Cross-sectional</td>
<td>Homeless shelter</td>
<td>90</td>
<td>41</td>
<td>0/90</td>
<td>42/90 (47.8%)</td>
<td>16/90 (12.8%)</td>
<td>Single question or series of questions: specific questions NR</td>
</tr>
<tr>
<td>Canada</td>
<td>Cross-sectional</td>
<td>Shelter, homeless outreach services, and streets in three Canadian cities</td>
<td>500</td>
<td>38</td>
<td>200/500 (40.0%)</td>
<td>318/500 (63.6%)</td>
<td>–</td>
<td>Single question or series of questions: “Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?”</td>
</tr>
<tr>
<td>Canada</td>
<td>Cross-sectional</td>
<td>Community agencies that serve homeless individuals (shelters, drop-in centres, outreach teams, inpatient programmes, and criminal justice programmes) in five Canadian cities</td>
<td>1500</td>
<td>41.1</td>
<td>477/1500 (31.8%)</td>
<td>–</td>
<td>688/1500 (45.9%)</td>
<td>Single question or series of questions: specific questions NR</td>
</tr>
<tr>
<td>Canada</td>
<td>Retrospective cohort</td>
<td>Wet shelter programme, hostel for homeless individuals, and three low-income housing sites</td>
<td>170</td>
<td>43.7</td>
<td>0/170</td>
<td>–</td>
<td>–</td>
<td>Medical record: broad criteria to capture “head injury”</td>
</tr>
<tr>
<td>Canada</td>
<td>Prospective longitudinal</td>
<td>Shelters and meal programmes for homeless individuals</td>
<td>1181</td>
<td>43</td>
<td>38/1181 (32.3%)</td>
<td>718/1181 (60.8%)</td>
<td>–</td>
<td>Single question or series of questions: “Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?”</td>
</tr>
<tr>
<td>Canada</td>
<td>Cross-sectional</td>
<td>Shelter for homeless men</td>
<td>111</td>
<td>54.2</td>
<td>0/111</td>
<td>50/111 (45.0%)</td>
<td>46/111 (41.4%)</td>
<td>Questionnaire or screening tool: Brain Injury Screening Questionnaire</td>
</tr>
<tr>
<td>Canada</td>
<td>Cross-sectional</td>
<td>Community agencies that serve homeless individuals (shelters, drop-in centers, outreach teams, inpatient programmes, criminal justice programmes) in five Canadian cities</td>
<td>2088</td>
<td>40.9</td>
<td>65/2088 (31.5%)</td>
<td>1098/2088 (52.6%)</td>
<td>–</td>
<td>Single question or series of questions: “Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?”</td>
</tr>
</tbody>
</table>

(Table 1 continues on next page)
Table 1: Summary of included studies

<table>
<thead>
<tr>
<th>Country</th>
<th>Study design</th>
<th>Population description</th>
<th>Setting</th>
<th>Sample size</th>
<th>Age, years*a</th>
<th>Any severity n/N (%)</th>
<th>Moderate or severe n/N (%)</th>
<th>Incidence of TBI</th>
<th>TBI ascertainment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Prospective longitudinal Vila-Rodriguez et al (2013)‡</td>
<td>Single-room occupancy hotel rooms</td>
<td>293 (23.2%)</td>
<td>441</td>
<td>22·5 (13·5–35·0)</td>
<td>10·6 (7·3–14·7)</td>
<td>41·4 (32·2–51·2)</td>
<td>17·8 (10·5–27·3)</td>
<td>Questionnaire or screening tool: HELPS screening tool</td>
</tr>
<tr>
<td>USA</td>
<td>Cross-sectional Zlotnick et al (1995)†</td>
<td>Central nervous system clinic patients</td>
<td>62 (60%)</td>
<td>60 (57·5–63·1)</td>
<td>48·0 (37·9–58·2)</td>
<td>91·1 (87·3–94·0)</td>
<td>40·4 (37·9–58·2)</td>
<td>63·6 (59·2–67·8)</td>
<td>Single question or series of questions: specific questions NR</td>
</tr>
<tr>
<td>USA</td>
<td>Retrospective chart review Brenner et al (2017) 31</td>
<td>Rehabilitation programme for homeless individuals recovering from substance misuse</td>
<td>127</td>
<td>127</td>
<td>41·4 (32·2–51·2)</td>
<td>65·4 (63·4–67·4)</td>
<td>40·4 (37·9–58·2)</td>
<td>63·6 (59·2–67·8)</td>
<td>Questionnaire or screening tool: EDWES screening tool</td>
</tr>
<tr>
<td>Canada</td>
<td>Prospective longitudinal Vila-Rodriguez et al (2013)‡</td>
<td>Single-room occupancy hotel rooms</td>
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<td>41·4 (32·2–51·2)</td>
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<td>63·6 (59·2–67·8)</td>
<td>Questionnaire or screening tool: EDWES screening tool</td>
</tr>
</tbody>
</table>

Figure 2: Forest plots of prevalence estimates for any severity of TBI and for moderate or severe TBI
Box size for each study is based on the weight for random-effects analysis, calculated using the inverse of the variance. Prevalence estimate from Oddy et al (2012) derived from first injury only. TBI=traumatic brain injury. PI=prediction interval.

meta-analysis of the incidence of TBI in this population. Estimated incidence of TBI in homeless and marginally housed individuals varied considerably between studies and ranged from 0·5% over 1 year to 28% over 1 year. Although we did not quantitatively assess moderators of these estimates, TBI ascertainment method appeared to be associated with estimated incidence. For example, Nikoo and colleagues did a comprehensive baseline interview with each participant and assessed incident TBI at yearly follow-up interviews, and found that 17·1–19·4% of participants sustained TBI per year. By contrast, LePage and colleagues and McMillan and colleagues used ICD-9 codes, ICD-10 codes, or both to ascertain TBI. LePage and colleagues found that 0·5% of participants sustained TBI over 1 year, and McMillan and colleagues found that 13·5% of participants sustained TBI over the 30-year study period (approximately 0·5% per year). A study-level summary of results from studies evaluating incidence of TBI is presented in the appendix (p 13). Homelessness was associated with a higher incidence of TBI in comparison with non-homeless control groups. Similarly, residential instability was
associated with a higher incidence of TBI. Lifetime history of TBI, receiving a TBI in the previous year, mental health diagnoses and poorer mental health, drug and alcohol misuse, and younger age were also associated with incident TBI over a 1-year period.

### Discussion

The results of our systematic review and meta-analysis suggest that more than half of homeless and marginally housed individuals have a lifetime history of TBI, and that almost a quarter have a history of moderate or severe TBI. Thus, the lifetime prevalence of TBI in homeless and marginally housed individuals is between 2-5-times and 4-0-times higher than estimates in the general population. Moreover, the lifetime prevalence of moderate or severe TBI in this population is nearly ten-times higher than estimates in the general population. We also found that TBI was associated with increased suicidal ideation and suicide risk, poorer self-reported physical and mental health, and increased health service and criminal justice system involvement. However, heterogeneity across estimates limits our ability to establish the true prevalence of TBI in this population.

We identified high statistical heterogeneity and considerable methodological limitations across many of the included studies, which hinders a clear understanding of the magnitude of the impact of TBI in this population. This heterogeneity can be attributed in part to the age of the study sample, because study samples with a higher proportion of older individuals evaluate individuals with a longer time at risk of TBI. This heterogeneity is also explained in part by study design factors, such as the tool used to ascertain TBI history, which reflects that standardised and reproducible research methods were not always used in previous studies on this topic. Three studies in our review had identifiable subgroups defined only by loss of consciousness. These studies suggest that using only loss of consciousness as a screening criterion might result in lower estimated prevalence than the standard WHO criteria, which also include confusion and memory loss. In the general population, excluding individuals with a head injury and alteration (but not loss) of consciousness would miss approximately 80% of all injuries considered to be TBIs by commonly used definitions. Notably, the use of OSU TBI-ID to ascertain TBI history was associated with an estimated prevalence that was nearly 30% higher than in studies that used a single question. Although they have inherent limitations, clinical interviews such as the OSU TBI-ID considered to be the preferred method for ascertaining TBI history. Clinical interviews also allow a trained researcher to use an approach tailored to the study population to obtain the level of detail required for an expert assessment of the evidence. Thus, ascertainment method might represent one of the most important design considerations in studies evaluating history of TBI. Consequently, our summary estimate of prevalence in this population is limited by inadequate ascertainment methods that appear to underestimate the prevalence of TBI in this population. If prevalence estimates ascertained through structured interviews represent the most accurate estimate of prevalence, our pooled estimate of prevalence

<table>
<thead>
<tr>
<th>Studies</th>
<th>Participants</th>
<th>Estimated prevalence, % (95% CI)</th>
<th>Heterogeneity</th>
<th>Change in estimated prevalence from univariable meta-regression analysis*</th>
<th>Change in estimated prevalence from multivariable meta-regression analysis*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure of central tendency of age for the study sample</td>
<td>18 9702</td>
<td>52.1% (46.4-59.7)</td>
<td>97%</td>
<td>&lt;0.0001</td>
<td>1.5% (-4.7 x 10⁻² to 3.3)</td>
</tr>
<tr>
<td>Sample size</td>
<td>18 9702</td>
<td>52.1% (46.4-59.7)</td>
<td>97%</td>
<td>&lt;0.0001</td>
<td>5.3 x 10⁻⁶% (-6.6 x 10⁻³ to 2.6 x 10⁻⁴)</td>
</tr>
<tr>
<td>Site of study recruitment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service or clinic</td>
<td>6 2855</td>
<td>64.7% (48.2-78.3)</td>
<td>95%</td>
<td>&lt;0.0001</td>
<td>Reference</td>
</tr>
<tr>
<td>Shelter or hostel</td>
<td>12 6847</td>
<td>47.4% (41.4-53.7)</td>
<td>95%</td>
<td>&lt;0.0001</td>
<td>-39.4% (-66.7 to -12.1)</td>
</tr>
<tr>
<td>TBI ascertainment method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single question or series of questions</td>
<td>13 8821</td>
<td>50.1% (43.7-56.5)</td>
<td>97%</td>
<td>&lt;0.0001</td>
<td>-25.0% (-57.6 to 7.7)</td>
</tr>
<tr>
<td>Other screening tool (HELPS or BISQ)</td>
<td>2 393</td>
<td>33.8% (17.1-55.9)</td>
<td>94%</td>
<td>&lt;0.0001</td>
<td>-47.8% (-90.8 to -4.8)</td>
</tr>
<tr>
<td>OSU TBI-ID structured interview</td>
<td>3 488</td>
<td>78.0% (54.4-91.6)</td>
<td>95%</td>
<td>&lt;0.0001</td>
<td>73.6% (37.4 to 100.0)</td>
</tr>
</tbody>
</table>


Table 2: Meta-regression results evaluating potential moderators of estimated lifetime TBI prevalence

![Image](www.thelancet.com)
Panel: Associations between history of TBI and health-related or functioning-related outcomes

Physical health (12 studies)
• Associated with having seizures in three studies\(^{39,43,60}\) and not associated with seizures in two studies\(^{34,61}\).
• Associated with poorer self-reported physical health in three studies\(^{31,35,59}\) and more chronic health conditions in one study\(^{27}\).
• Associated with dizziness in two studies\(^{31,53}\).
• Associated with headaches or migraine headaches in three studies\(^{34,53,55}\).
• Associated with memory problems in five studies\(^{35,38,43,53,61}\) and not associated with memory problems in one study\(^{34}\).
• Associated with evidence of traumatically induced lesions visible on structural MRI, lower fractional anisotropy, and lower total cortical grey matter in one study\(^{31}\).
• Not associated with geriatric syndromes in one study\(^{32}\), Charlson comorbidity score in one study\(^{53}\), and not associated with diagnosed anxiety disorder in one study\(^{35}\), not associated with memory problems in one study\(^{35}\), and not associated with seizures in two studies\(^{53,59}\), and not associated with manic or hypomanic bipolar disorder in two studies,\(^{28,43}\) manic or hypomanic, and associated with self-reported anxiety in two studies\(^{35,38}\), and associated with post-traumatic stress disorder in one study\(^{53}\), and not associated with psychotic disorder in four studies\(^{31,43,53,55}\) and a history of mental illness in one study\(^{59}\), and not associated with having seizures in one study\(^{34}\), and not associated with suicide attempts in two studies\(^{60}\), and not associated with suicide attempts in one study\(^{60}\).

Mortality (two studies)
• The standardised mortality ratio was significantly higher in homeless participants admitted to hospital with head injury than in non-homeless participants in one study\(^{43}\).
• In another study, 30-day mortality for homeless participants recruited from a neurosurgical unit was not significantly different to that of non-homeless participants\(^{43}\).

Mental health (11 studies)
• Associated with a diagnosis of schizophrenia in one study\(^{43}\) and clinical cognitive impairment in one study\(^{19}\).
• Associated with neurocognition in six studies\(^{34,35,38,53,55,59}\) and not associated with having seizures in one study\(^{31}\), and not associated with alcohol misuse in five studies,\(^{39,43,53,58,60}\) and not associated with suicidal ideation and clinical cognitive impairment in one study\(^{19}\).
• Associated with higher frequency of emergency room visits and hospital admissions in three studies\(^{43,58,60}\) and not associated with outpatient days in the previous 6 months in one study\(^{43}\).
• Associated with a history of intimate partner violence\(^{43}\).
• Associated with lower than expected educational attainment in one study\(^{41}\) and a history of special education in one study\(^{41}\), not associated with education in two studies\(^{34,53}\).
• Associated with a higher likelihood of reporting victimisation in one study\(^{41}\).
• Associated with lower odds of psychotic disorder in one study\(^{49}\) and not associated with psychotic disorder in one study\(^{49}\).
• Associated with polysubstance use in one study\(^{46}\).
• Associated with drug misuse in four studies\(^{54,43,53,60}\) and not associated with drug misuse in four studies\(^{34,53,55,59}\).
• Associated with alcohol misuse in five studies,\(^{35,53,58,60}\) and not associated with alcohol misuse in two studies\(^{53,55}\).
• Associated with mood disorders in one study\(^{43}\) and mood disorder with psychotic features in one study\(^{43}\).
• Associated with lower odds of self-reported depression in two studies\(^{53}\), and diagnosed depressive disorder in two studies\(^{43,60}\).
• Associated with self-reported anxiety in two studies\(^{35,58}\), and not associated with diagnosed anxiety disorder in one study\(^{35}\).
• Associated with post-traumatic stress disorder in two studies\(^{59,60}\) and not associated with post-traumatic stress disorder in one study\(^{43}\).
• Associated with lower than expected educational attainment in one study\(^{41}\) and a history of special education in one study\(^{41}\), not associated with education in two studies\(^{34,53}\).
• Associated with self-reported anxiety in two studies\(^{53,58}\), and not associated with diagnosed anxiety disorder in one study\(^{35}\).
• Associated with higher frequency of emergency room visits and hospital admissions in three studies\(^{43,58,60}\) and not associated with outpatient days in the previous 6 months in one study\(^{43}\).
• Associated with having access to a physician in two studies\(^{59,60}\).
• Associated with having access to a physician in one study\(^{59}\).
• Associated with a higher risk for suicide or suicidal ideation in one study\(^{43}\).

Neurocognition (nine studies)
• Associated with lower neurocognitive scores in one study\(^{53}\). and not associated with psychotic disorder in one study\(^{53}\).
• Associated with having access to a physician in two studies\(^{59,60}\).
• Associated with having access to a physician in one study\(^{59}\).
• Associated with having access to a physician in two studies\(^{59,60}\).
• Associated with having access to a physician in one study\(^{59}\).
• Associated with a higher frequency of emergency room visits and hospital admissions in three studies\(^{43,58,60}\) and not associated with outpatient days in the previous 6 months in one study\(^{43}\).
• Associated with having access to a physician in two studies\(^{59,60}\).
• Associated with arrest, incarcerations, or criminal justice involvement in five studies\(^{34,35,38,44}\).

Temporal relationship to homelessness (six studies)
• Between 51% and 92% of participants experienced their first TBI before their first experience of homelessness or marginal housing\(^{34,43,53,55,59}\).

Other outcomes (seven studies)
• Associated with a higher likelihood of reporting victimisation in one study\(^{41}\).
• Associated with difficulties with activities of daily living in one study\(^{49}\).
• Associated with a history of childhood trauma, physical abuse, and emotional abuse in one study,\(^{60}\) and associated with a history of childhood physical abuse, sexual abuse, and neglect in one study\(^{43}\).
• Associated with a history of intimate partner violence\(^{43}\).
• Associated with lower than expected educational attainment in one study\(^{41}\) and a history of special education in one study\(^{41}\), not associated with education in two studies\(^{34,53}\).
• Associated with employment and a higher monthly income in one study\(^{43}\) and not associated with employment in one study\(^{43}\).
• Associated with higher frequency of emergency room visits and hospital admissions in three studies\(^{43,58,60}\) and not associated with outpatient days in the previous 6 months in one study\(^{43}\).
• Associated with having access to a physician in two studies\(^{59,60}\).
• Associated with arrest, incarcerations, or criminal justice system involvement in five studies\(^{34,35,38,44}\).

(Continues on next page)
might be a considerable underestimate of the true prevalence of TBI in this population. Despite considerable statistical and methodological heterogeneity between studies, we found that a history of TBI is associated with various aspects of poor health and functioning. Additionally, several characteristics of homeless and marginally housed populations (eg, residential instability or substance use) were associated with sustaining TBI. Some relationships might be bidirectional: for example, TBI could increase the risk for homelessness, and homelessness could increase the risk for incident TBI. Establishing whether TBI is a risk factor for poor outcomes (eg, homelessness or serious health conditions) will be important to understand and address the impact of TBI in this population.

Our results suggest that physicians and care providers working with homeless and marginally housed populations should have an increased awareness of TBI. Previous studies have shown that homeless and marginally housed individuals have a frequency of actionable incidental findings on brain MRI that substantially exceed that expected of the general population. For example, Vila-Rodriguez and colleagues reported that the prevalence of aneurysms was 8-6% and of brain infarcts was 11% in homeless and marginally housed individuals. By contrast, the expected rates in similarly aged samples from the general population are less than 1% for aneurysms and less than 3% for brain infarcts. In an overlapping sample, Schmitt and colleagues reported visible encephalomalacia on neuroimaging that was deemed likely to be caused by traumatic injury in 6-9% of the cohort, and found that evidence of trauma on neuroimaging was associated with poorer cognition and executive functioning in this population. Clinicians might therefore consider lowering the threshold for referral to neuroimaging specialists after head injury in homeless and marginally housed patients, because depending on the resources available, an assessment that complements self-reporting might be indicated. Confirmation of structural brain damage caused by TBI might facilitate triage and referral to specialised services, such as cognitive rehabilitation, which could improve functional outcomes. Furthermore, imaging findings might positively inform the patient–caregiver relationship (eg, by increasing understanding of challenging behaviours that might be attributable to damage visible on neuroimaging).

To our knowledge, this is the first study to quantitatively evaluate the lifetime prevalence of TBI and to comprehensively summarise the associations between TBI and health-related or functioning-related outcomes in homeless and marginally housed individuals. However, our study has some limitations. Firstly, the included studies were almost exclusively retrospective in design, which precludes interpretation about the directionality of the relationships. Future prospective studies are needed in order to adequately evaluate, for example, whether TBI leads to substance use or homelessness, or whether factors such as substance use or homelessness lead to TBI. Secondly, we limited our search to peer-reviewed publications and elected not to search the so-called grey literature. In the screening process for this study, we encountered several theses and book chapters; however, we elected to exclude these in order to limit our results to only peer-reviewed studies.

TBI is prevalent among homeless and marginally housed individuals and might be a common factor that contributes to poorer health and functioning than in the general population. Primary care providers and those working with this group should be aware of the prevalence and associated consequences of TBI. Evaluating history of TBI might be relevant to a comprehensive assessment of homeless and marginally housed patients, who often have complex comorbidities. In addition, public health research and practice should focus on TBI prevention and more accurately characterising the scope and effects of TBI in this vulnerable population. Although to our knowledge no studies have been done to evaluate whether incident TBI is reduced with housing interventions, randomised trial evidence shows that rent supplements in combination with intensive case management substantially improve living situation, safety, and community functioning. These findings suggest that the provision of stable housing might also lower the risk for TBI. High-quality studies are urgently needed to elucidate the true prevalence and incidence of TBI, and the directionality of the relationship between TBI and outcomes in the homeless and marginally housed population.
Articles

Contributors

JLS led the title and abstract screening, full-text screening, risk of bias assessment, data extraction, statistical analysis, and drafting of the manuscript. JMS participated in the title and abstract screening, full-text screening, risk of bias assessment, and data extraction. JLS, AET, NDS, AMB, WGH, and WJP interpreted the results and participated in the drafting of the manuscript. All authors approved the final manuscript.

Declaration of interests

NDS is a paid advisory board of Highmark Interactive, received consulting or speaking fees from WorkSafeBC and Yukon WCB, the National Hockey League, and Major League Soccer, and has received fees for expert testimony in neuropsychology. WGH has received consulting fees or on paid advisory boards for the Canadian Agency for Drugs and Technology in Health, AltexSights, Guidepoint, In Silico, Translational Life Sciences, Otsuka, Luxbeck, and Newton. WJP is the founder and chief executive officer of Translational Life Sciences, an early stage biotechnology company. He is also on the scientific advisory board of Medipure Pharmaceuticals and Vitality Biopharma, and on the past has been on the board of directors for Abattis Biotechnological and on the advisory board for Vinergy Resources; these companies are early stage biotechnology enterprises with no relation to brain injury. All other authors declare no competing interests.

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