Literature Review

The association of traumatic brain injury with neurologic and psychiatric illnesses among individuals experiencing homelessness: a systematic review and meta-analysis1

Grant Rigney, MSc
Jordan Leith, BS
Matthew Lennon, MD
Aaron Reeves*, PhD
Ben Chrisinger*, PhD

* indicates co-senior authorship

Grant Rigney, **Aaron Reeves**, and **Ben Chrisinger** are affiliated with the Department of Social Policy and Intervention, University of Oxford, Oxford, UK. Grant Rigney is also affiliated with the Harvard Medical School, Boston, MA. **Jordan Leith** is affiliated with the Weill Cornell School of Medicine, New York City, NY. **Matthew Lennon** is affiliated with the University of New South Wales, NSW, Australia, and the Department of Psychiatry, University of Oxford, Oxford, UK. Please address all correspondence to: Grant Rigney, 32 Mill St., Cambridge, MA 02138; Email: grigney@hms.harvard.edu.

Running Head
TBI and Neuropsychiatric Illness amongst Homeless

Tables: 2
Figures: 3
References: 42

Abbreviations:
TBI - Traumatic Brain Injury; OR – odds ratio

1 The authors refer to supplementary material (an appendix) which is available at an external site: https://drive.google.com/file/d/1_T7kYMVM7rgrsDKSCJz2o3RSAwZjeAjA/view?usp=sharing).

Abstract: Homeless individuals are more likely than others to experience a traumatic brain injury (TBI), but it is uncertain if such individuals are more likely to experience neuropsychiatric illnesses. **Methods**. A systematic review was performed with searches in Medline, Embase, and PsychINFO for studies reporting on homeless persons with TBI and neuropsychiatric illnesses. A random-effects model was used to calculate odds ratios for having any neuropsychiatric diagnosis. **Results**. Of 420 articles indexed, 19 were included for systematic review and 17 for meta-analysis reporting on 11,474 and 8,757 individuals, respectively. The pooled odds of a homeless individual with a TBI having any neurologic illness were 2·57 (95% CI [1·97, 3·44]; I^2 = 68·0%) and 2·01 (95% CI [1·81, 2·25]; I^2 = 79·2%) for any psychiatric illness. **Conclusions**. The odds of having a neuropsychiatric illness among homeless individuals with TBI are substantially higher than in the domiciled population with TBI.

Key words: Traumatic brain injury, homeless, housing, head injury, neuropsychiatric, psychiatry, neurology.

Abbreviations

TBI: traumatic brain injury

OR: odds ratio

Introduction

Homelessness is a chronic public health problem that has been notoriously difficult to treat,[1] with recent estimates suggesting that over six million individuals are homeless in the United States and European Union today.[2,3] Homeless and marginally housed individuals experience myriad mental and physical health problems associated with their lack of stable housing,[4] which are compounded and sometimes caused by inadequate access to regular primary and specialty health care.[5,6]

Traumatic brain injury (TBI) among the homeless constitutes a silent epidemic.[7] Traumatic brain injury is "caused by a bump, blow, or jolt to the head, or penetrating head injury." [8 [para. 1]] Importantly, not all head strikes result in TBI. The key differentiator is that a TBI must induce an alteration in brain function. Traumatic brain injuries vary in severity from mild (a transient alteration in mental status or consciousness) to severe (extended period of unconsciousness or amnesia).[9] A recent systematic review and meta-analysis estimated the lifetime prevalence of TBI among homeless individuals to be 53·1%.[10] In comparison, a 2013 meta-analysis of TBI prevalence found that lifetime prevalence was 14.3% among U.S. adults, approximately a quarter (26·1%) of the reported rate in the homeless population.[11]

Concerning the total body of literature on TBIs and neuropsychiatric illness, few studies have documented the association between neuropsychiatric illness among the current homeless population and a history of TBI. Among domiciled individuals, prior TBI has been associated with significantly increased risk of neurological and psychiatric illness, with specific increases in the risk for Alzheimer's disease, Parkinson's disease, mild cognitive impairment, depression, mixed affective disorders, and bipolar disorders.[12] The aim of this study was to quantitatively examine the association of TBI with neuropsychiatric illnesses among individuals experiencing homelessness.

Methods

Search strategy and selection criteria. This study is a systematic review and meta-analysis conducted in accordance with PRISMA guidelines.[13] Search strings were developed by GR in conjunction with a medical sciences librarian of the Bodleian Libraries of Oxford (appendix, p. 1, see title page for link). MEDLINE, PsychINFO, and EMBASE were searched according to the PRISMA and PRESS guidelines.[14] Manual forward and backward reference searching was performed on all included studies to identify additional relevant literature. All searches were performed on March 25, 2020 for studies published between September 1, 1960 and March 25, 2020. Studies were exported to Covidence for de-duplication and screening the following day.[15]

Studies were included in the review if they had an identifiable set or subset of individuals experiencing homelessness or marginal or precarious housing; if the sample had data on the ascertainment of TBI; and if quantitative data on current or lifetime neuropsychiatric diagnoses were available. Studies were excluded if an English translation was not readily available or if they did not include enough observational data to calculate an odds ratio (i.e., reviews or case studies). Gray literature was included to limit publication bias. Trial registries were not searched for this review, nor did we need to contact any authors (see online supplementary material p. 16 for full inclusion/exclusion criteria; see title page for link).

Screening of all abstracts and full texts was conducted independently by two authors (GR, JL). Conflicts were resolved by senior authors (AR or BC). Data were extracted to an Excel spreadsheet. The National Institutes of Health National Heart, Lung, and Blood Institute's *Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies* was used to assess the risk of bias and overall quality of data in the included studies (appendix p. 3; see title page for link).[16] This review was prospectively registered on PROSPERO (CRD42020171932).

Data were extracted on a custom Excel spreadsheet and included first author and year of publication, study design, setting of data collection (e.g., homeless shelter, street), country

of data collection, sample size, average age of participants, percent male and female, prevalence of TBI, mean age at first TBI, definition of homelessness used in each study, number of participants who received a TBI prior to, after, or during the same year as their first episode of homelessness, any neurologic or psychiatric conditions reported, method of diagnosis (e.g., self, by a physician), the number of individuals with a diagnosis with and without a TBI, the number of individuals without a diagnosis with and without a TBI, the method of TBI diagnosis, the definition used to classify TBI in each study, the severity of reported TBIs, the method of TBI attainment (e.g., violence, accident), type of diagnosis (neurologic or psychiatric), and any additional pertinent information unique to a particular study.

The main outcome of this review was the diagnosis of reported neurologic and/or psychiatric illness among homeless individuals with a history of TBI. All neurologic and psychiatric conditions with data available in at least two primary studies were included. Where questions arose about whether a condition was psychiatric or neurologic in nature, the Diagnostic and Statistical Manual of Mental Disorders 5th edition (DSM V) was consulted for clarity.

Data analysis. Where data were reported in two or more studies from the same cohort, the study with the lowest risk of bias was chosen for meta-analysis. If two or more studies reporting on the same cohort had comparable risks of bias, the study with the largest patient population was chosen. Odds ratios for individual studies were combined using a random-effects meta-analysis on the number of individuals with neuropsychiatric illnesses where two or more studies reported data on the same condition. All outcomes, including all subgroups with sufficient data, were also reported via a narrative synthesis. Moderator analysis on the study design, method of diagnosis of illness, average age, sample size, and method of diagnosis of TBI was conducted via a meta-regression separately for all neurological and

psychiatric diagnoses reported (this portion of the analysis was not pre-recorded in the Prospero protocol).

If data were available from two or more independent studies, odds ratios were synthesized by the following subgroups: (1) by severity and/or number of TBIs; (2) by method of illness diagnosis (i.e. self-report, clinician-based, screening tool); (3) by whether the homeless individual received their first TBI prior to or after their first episode of homelessness; (4) by state of homelessness (i.e. rough sleeping, in a shelter, marginal housing); and (5) by the mechanism of TBI attainment.

Publication bias was assessed using Egger's test for asymmetry and displayed via funnel plots for each outcome.[17] A p value < ·05 was considered statistically significant. The leave-one-out sensitivity test was performed to evaluate the influence of individual studies and diagnoses (appendix p. 7; see title page for link). Heterogeneity was assessed via the I^2 statistic.[18] Analyses were performed in R version 3·6·0 using the "metafor" and "tidyverse" packages.[19]

Role of the funding source. The funders of this 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

Database indexing yielded 420 articles, of which 89 were duplicates. Subsequent screening of 331 titles and abstracts yielded 87 studies eligible for full-text screening. After applying inclusion/exclusion criteria, 19 studies were included for systematic review, reporting on 11,474 individuals. Of these, four were reports with data from the same parent study. The largest study with the lowest overall risk of bias was chosen for inclusion in the meta-analysis.[20] One of the four studies[21] with overlapping data reported on individuals experiencing schizophrenia,

which was not reported in the other three studies. Thus, it was included for meta-analysis (Figure 1). Seventeen studies were included for meta-analysis, reporting on 8,757 individuals.

[production: Please insert Figure 1 about here.]

The mean age of participants was 42·4 ± 6·7 years. Over half (61·7%, n = 7,079) were male and the rest (n = 4,395) were female. The number of individuals who had obtained a TBI (from the 17 studies meta-analysed) totalled 5,483 (unweighted prevalence of 62·6%). Four of five studies reported on the mean (one of five reported a median[22]) age at which the first TBI was obtained.[23–26] The average of the measure of central tendency for the age at first TBI was 18·2 years old (SD = 4·4; n = 5133 participants). Over half (58·1%, 932/1,603) of participants from four studies obtained their first TBI prior to becoming homeless, 6·9% (110/1,603) during the same year as their first episode of homelessness, and 35% (561/1603) after becoming homeless.[23–26] Traumatic brain injury was diagnosed primarily via screening questionnaires (Table 1).

[**Production: Please insert Table 1 about here**.]

Eight studies reported on the severity of TBIs obtained in each cohort.[21,24,26–31] Out of 792 patients with one or more TBIs, 54·9% (n = 435 participants) had mild TBIs and 42·8% (n = 339) had moderate to severe TBIs, 1·64% (n = 13) did not report severity data, and 0·063% (n = 5) were classified as "possible" TBIs. Four studies (n = 97 individuals) reported on the number of TBIs sustained by each individual.[26–28,31] Over one quarter (26·8%, n = 26 individuals) had sustained one TBI, 16·5% (n = 16) had two TBIs, and 56·7% (n = 55) had experienced three or more TBIs.

Four studies reported on the method by which TBI was attained.[24,26,30,31] Of 194 individuals with 405 TBIs, 39·5% (n = 160 TBIs) were due to assault, 13·1% (n = 53) were from sports or biking accidents, 12·1% (n = 49) were from falls, 11·6% (n = 47) were from motor vehicle accidents, 4·4% (n = 18) were from drug or alcohol blackouts, 4·9% (n = 20) were from pedestrian accidents, 4·4% (n = 18) were due to bouts of syncope, 9·1% (n = 37)

were from other accidents, and 0·74% (n = 3) were of unknown origin (appendix p. 12; see title page for link).

Nine studies reporting on 7,326 total homeless individuals were used to calculate an overall odds ratio of 2·57 for having a neurological diagnosis concurrent with a history of TBI (95% CI [1·93, 3·44]; I^2 = 68%) (Figure 2, Table 2). A diagnosis from one study (cognitive impairment) was removed after performing an outlier analysis (appendix p. 5; see title page for link).[32]

[**production: Please insert Figure 2 about here**.]

[**production: Please insert Table 2 about here**.]

One study reported odds ratios on individuals with varying severities of TBIs who experienced seizures. It found that those with mild TBIs had an OR of having seizures of 2·5 (95% CI [1·5, 4·2]), while those with moderate to severe TBIs had an OR of having seizures of 3·2 (95% CI [1·8, 5·6]).[23] Similarly, one study reported that those with mild TBIs had an OR for migraines of 1·8 (95% CI [0·8, 4·1]), and those with moderate/severe TBI had an OR of 2·0 (95% CI [1·0, 4·3]).[24]

Fifteen studies reporting on 9,530 participants were used to calculate a pooled odds ratio of 2·01 for having any psychiatric diagnosis (95% CI [1·81, 2·25]; I^2 = 79·2%) (Figure 3, Table 2). Three individual diagnoses from three different studies were removed after performing an outlier analysis (Appendix p. 6; see title page for link). One psychotic disorder diagnosis was removed as an outlier (OR = 0·63), as was one diagnosis of Schizophrenia Spectrum Disorder (SSD) (OR = 0·36).[20] Since only two diagnoses were found in the literature for SSD, the additional SSD diagnosis (OR = 3·48) was removed from the meta-analysis due to the low reliability associated with reporting data from only one study.[25]

[**production: Please insert Figure 3 about here**.]

One study reported data on "any psychiatric diagnosis" (OR of 1·52 [1·37, 2·14]).[33] Another study reported data on agoraphobia (OR = 3·46 [1·16, 10·3]), antisocial personality

disorder (OR = 1·56 [0·45, 5·40]), social phobia (OR = 2·83 [0·65, 12·3]), bulimia nervosa (OR = 0·28 [0·028, 2·79]), and obsessive compulsive disorder (OR = 3·33 [0·44, 25·4]).[29] Because no other studies reported any of these diagnoses, they were not included in the meta-analysis. A wide variety of questionnaires was used to diagnose the neuropsychiatric illnesses reported here.

Moderator analysis for psychiatric diagnoses revealed that the method of TBI diagnosis and the study sample size had negative and positive influences, respectively, on the outcome of interest (p = ·028 and ·0026, respectively). A categorical moderator analysis on the methods of diagnosis of neuropsychiatric illnesses suggests that self-reported illnesses confirmed via a physician diagnosis (represented by the psychiatric diagnoses made in only one study[25]) and those diagnosed via screening questionnaires were both positive moderators of the effect size (p = ·0002 and ·012, respectively) (refer to Appendix p. 10 for meta-analysis results categorized by method of illness diagnosis; see title page for link). For neurological diagnoses, study design and average age of the sample positively and negatively, respectively, contributed to the outcome of interest (p = ·046 and ·001, respectively). However, a categorical moderator analysis on the types of study designs suggests that none significantly moderated the outcome.

An important facet of non-randomized studies is their attempt to control for confounding variables. It is particularly important to control for all possible confounders in this context since homelessness, TBIs, and neuropsychiatric illnesses can all be risk factors for each other. 12/19 studies attempted to control for variables, such as age, sex, or concurrent illnesses, that could modify the association between TBI and neuropsychiatric illness. Among all studies included for systematic review, there was a moderate risk of bias, influenced primarily by uniform non-randomized study design (Appendix p. 3; see title page for link).

Publication bias was tested for using Egger's test with a significance threshold set at p < ·05. Each funnel plot generated—one for all neurological diagnoses and one for all psychiatric diagnoses—indicates that publication bias was unlikely (p = ·83 and p = ·74, respectively)

(Appendix p. 12; see title page for link). Results of the leave-one-out sensitivity analysis show that no one study or diagnosis had a substantial impact on the odds ratios presented here (Appendix p. 7 see title page for link).

Discussion

This systematic review and meta-analysis finds a strong association between TBI and current neuropsychiatric illness among homeless individuals. To the author's knowledge, this is the first systematic review to meta-analyse neuropsychiatric diagnoses among homeless individuals with TBI.

Our understanding of the true effect sizes of the pooled diagnoses and the individual diagnoses is hindered by considerable heterogeneity and varied methodological quality among studies. The moderator analysis performed suggests that the heterogeneity may be attributed to varied sample sizes and instruments used to diagnose TBIs and neuropsychiatric illnesses. Similar meta-analyses[10] found comparable levels of heterogeneity, although they report average age of the sample as a significant moderator of effect, which was only significant for neurological diagnoses in our study.

The directionality of the relationship between TBI and neuropsychiatric illness among homeless individuals remains unknown. The studies included in this review do not clarify whether neuropsychiatric conditions were diagnosed prior to or after one's first TBI or episode of homelessness. A meta-analysis among domiciled subjects suggests that a history of TBI is a risk factor for developing subsequent neuropsychiatric illness.[12] Data here show that most individuals received their first TBI prior to becoming homeless, which may suggest that TBI increases one's risk of becoming homeless. This is in contrast with some current literature, however, which suggests that TBI is not a risk factor for becoming homeless.[34]

There were very limited data supporting a dose-response relationship between TBI and neurologic illness. The odds of having seizures and migraines increase when comparing those with no TBI (OR=1 and 1, respectively) to mild TBI (OR=2·5, 1·8) to moderate/severe TBI

(OR=3·2, 2·0). However, any conclusions of causality are prevented by overlapping (insignificant) differences between odds ratios for these data.

The cognitive impairment estimate accounted for nearly all the heterogeneity seen in the three neurologic diagnoses (I^2 = 84·2% vs. 0% and 0·1%). This is perhaps because different tests were used both within and between studies to measure cognitive impairment. For instance, three different diagnostic methods were used (MINI, 3MS, and a neurologist diagnosis). Each uses different combinations of questions and tests to measure varying levels of cognitive impairment. This contrasts with measuring seizures and migraines which, although different questionnaires were used to diagnose them, primarily represents a binary diagnosis.

The psychotic disorder diagnosis accounted for the largest amount of heterogeneity among all psychiatric diagnoses (I^2 = 86·6%). The substantial heterogeneity was possibly due to large differences in sample sizes among cohorts (largest 2732; smallest 205), although varying methods used to diagnose illnesses is also suspect based on the moderator analysis performed.

One study described "self-reported memory issues" (OR = 2·52).[24] However, no other study reported on memory issues, dementia, Alzheimer's disease, or any other memory-related diagnosis. Hence, it was excluded from the meta-analysis. Others have found evidence that TBI is either a risk factor for or plays a causal role in the subsequent development of memory disorders in domiciled individuals.[12] Any measurement of memory disorders among homeless people with TBI should be viewed with caution, since the presence of memory issues is likely to co-occur with other factors such as alcohol and substance use disorder.[35] Further, the associations reported should also be viewed in light of existing knowledge that suggests a strong genetic link underlying the diseases studied, which was not included in this study.

The most reported psychiatric conditions, aside from alcohol and drug use disorder (n = 9 and 11 studies, respectively) were general mental health problems, anxiety disorder, and depression (n = 6, 5, 5 studies, respectively). Excluding these diagnoses, many of the

psychiatric illness diagnoses were reported in only two to four studies, which reduces our confidence that the true effect size is near the reported OR. Further, alcohol and drug use can be risk factors for some psychiatric illnesses (e.g., PTSD), which limits our understanding of the psychiatric data presented here.[36]

The data here are limited by studies that report diagnoses in slightly different ways. For example, "mood disorder" diagnoses were reported separately from "anxiety disorder" or "bipolar disorder" diagnoses, although these belong under the mood disorder umbrella. Additionally, these diagnoses were reached using different methods of diagnosis, further increasing heterogeneity among the estimates. Adding additional studies to the meta-analysis would likely reduce heterogeneity and increase confidence in the results.

Following recommendations recently published in a systematic review and meta-analysis to decrease the threshold required for referral to neuroimaging specialists,[10] the results here indicate that all homeless individuals with a suspected TBI should be screened for any neuropsychiatric illnesses and vice versa. Doing so could substantially improve access to medical resources and reduce the impairments that accompany TBI and neuropsychiatric illnesses.

Conclusions.

This review has brought to light the vast breadth of methodologies used to identify TBI and diagnose a neuropsychiatric illness. Service providers and researchers alike would benefit from convergence on a single or small set of questionnaires when diagnosing TBI and neuropsychiatric illnesses.[37] This would permit direct comparison of TBI severity across populations and might reduce heterogeneity stemming from varying diagnostic thresholds used in questionnaires.

The odds of having a concurrent neuropsychiatric illness among homeless individuals with a history of TBI are high. The level of comorbidities among this study sample is high, lending little insight into the directionality of the relationships studied. Screening for TBI and

neuropsychiatric disease at the point of provision should become a priority for homeless service providers. Additional research is needed on the neuropsychiatric disease burden among homeless individuals with TBI to increase confidence and reduce heterogeneity in the results reported here.

References

1. Fransham M, Dorling D. Homelessness and public health. BMJ. 2018 Jan 29;360:k214.

2. 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 Lond Engl. 2014 Oct 25;384(9953):1529–40.

3. Fazel S, Khosla V, Doll H, Geddes J. The Prevalence of Mental Disorders among the Homeless in Western Countries: Systematic Review and Meta-Regression Analysis. PLoS Med [Internet]. 2008 Dec [cited 2020 Feb 6];5(12). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2592351/

4. Greenberg GA, Rosenheck RA. Mental Health Correlates of Past Homelessness in the National Comorbidity Study Replication. J Health Care Poor Underserved. 2010 Nov 19;21(4):1234–49.

5. Elwell-Sutton T, Fok J, Albanese F, Mathie H, Holland R. Factors associated with access to care and healthcare utilization in the homeless population of England. J Public Health. 2017 Mar 1;39(1):26–33.

6. Baggett TP, O'Connell JJ, Singer DE, Rigotti NA. The Unmet Health Care Needs of Homeless Adults: A National Study. Am J Public Health. 2010 Jul 1;100(7):1326–33.

7. Ahmed S, Venigalla H, Mekala HM, Dar S, Hassan M, Ayub S. Traumatic brain injury and neuropsychiatric complications. Indian J Psychol Med. 2017;39(2):114–21.

8. Report to Congress: Traumatic Brain Injury in the United States | Concussion | Traumatic Brain Injury | CDC Injury Center [Internet]. 2019 [cited 2019 Nov 25]. Available from: https://www.cdc.gov/traumaticbraininjury/pubs/tbi_report_to_congress.html

9. Sherer M, Struchen MA, Yablon SA, Wang Y, Nick TG. Comparison of indices of traumatic brain injury severity: Glasgow Coma Scale, length of coma and post-traumatic amnesia. J Neurol Neurosurg Psychiatry. 2008 Jun 1;79(6):678–85.

10. Stubbs JL, Thornton AE, Sevick JM, Silverberg ND, Barr AM, Honer WG, et al. Traumatic brain injury in homeless and marginally housed individuals: a systematic review and meta-analysis. Lancet Public Health. 2020 Jan 1;5(1):e19–32.

11. Frost RB, Farrer TJ, Primosch M, Hedges DW. Prevalence of traumatic brain injury in the general adult population: a meta-analysis. Neuroepidemiology. 2013;40(3):154–9.

12. Perry DC, Sturm VE, Peterson MJ, Pieper CF, Bullock T, Boeve BF, et al. Association of traumatic brain injury with subsequent neurological and psychiatric disease: a meta-analysis. J Neurosurg. 2016;124(2):511–26.

13. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ. 2009 Jul 21;339:b2535.

14. McGowan J, Sampson M, Salzwedel DM, Cogo E, Foerster V, Lefebvre C. PRESS Peer Review of Electronic Search Strategies: 2015 Guideline Statement. J Clin Epidemiol. 2016;75:40–6.

15. Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org.

16. National Heart, Lung, and Blood Institute. Study quality assessment tools: quality assessment tool for observational cohort and cross-sectional studies. [Internet]. 2014 [cited 2020 Apr 17]. Available from: https://scholar.google.com/scholar_lookup?hl=en&publication_year=2014&author=National+Heart%2C+Lung%2C+and+Blood+Institute&title=Study+quality+assessment+tools%3A+quality+assessment+tool+for+observational+cohort+and+cross-sectional+studies

17. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997 Sep 13;315(7109):629–34.

18. Higgins J, Thomas J, Chandler J, Li T, Page M, Welch V (editors). The Cochrane Handbook for Systematic Reviews of Interventions. 2nd ed. Chichester (UK): John Wiley & Sons; 2019.

19. R Core Team. R: A language and environment for statistical computing [Internet]. Vienna, Austria: R Foundation for Statistical Computing; 2014. Available from: http://www.R-project.org/

20. Topolovec-Vranic J, Schuler A, Gozdzik A, Somers J, Bourque P-É, Frankish CJ, et al. The high burden of traumatic brain injury and comorbidities amongst homeless adults with mental illness. J Psychiatr Res. 2017;87:53–60.

21. Bacciardi S, Maremmani AGI, Nikoo N, Cambioli L, Schütz C, Jang K, et al. Is bipolar disorder associated with tramautic brain injury in the homeless? Riv Psichiatr. 2017 Feb;52(1):40–6.

22. To MJ, O'Brien K, Palepu A, Hubley AM, Farrell S, Aubry T, et al. Healthcare Utilization, Legal Incidents, and Victimization Following Traumatic Brain Injury in Homeless and Vulnerably Housed Individuals: A Prospective Cohort Study. J Head Trauma Rehabil. 2015 Aug;30(4):270–6.

23. Hwang SW, Colantonio A, Chiu S, Tolomiczenko G, Kiss A, Cowan L, et al. The effect of traumatic brain injury on the health of homeless people. CMAJ Can Med Assoc J J Assoc Medicale Can. 2008 Oct 7;179(8):779–84.

24. Schmitt T, Thornton AE, Rawtaer I, Barr AM, Gicas KM, Lang DJ, et al. Traumatic Brain Injury in a Community-Based Cohort of Homeless and Vulnerably Housed Individuals. J Neurotrauma. 2017;34(23):3301–10.

25. Mackelprang JL, Harpin SB, Grubenhoff JA, Rivara FP. Adverse outcomes among homeless adolescents and young adults who report a history of traumatic brain injury. Am J Public Health. 2014 Oct;104(10):1986–92.

26. Topolovec-Vranic J, Ennis N, Howatt M, Ouchterlony D, Michalak A, Masanic C, et al. Traumatic brain injury among men in an urban homeless shelter: observational study of rates and mechanisms of injury. CMAJ Open. 2014 Apr 25;2(2):E69–76.

27. Andersen J, Kot N, Ennis N, Colantonio A, Ouchterlony D, Cusimano MD, et al. Traumatic brain injury and cognitive impairment in men who are homeless. Disabil Rehabil. 2014;36(26):2210–5.

28. Ares K. Traumatic brain injury in homeless youth: how attachment and a history of reported head injury relate to psychopathology and executive dysfunction | The Homeless Hub [Internet]. 2016 [cited 2020 May 28]. Available from: https://www.homelesshub.ca/resource/traumatic-brain-injury-homeless-youth-how-attachment-and-history-reported-head-injury

29. Brenner LA, Hostetter TA, Barnes SM, Stearns-Yoder KA, Soberay KA, Forster JE. Traumatic brain injury, psychiatric diagnoses, and suicide risk among Veterans seeking services related to homelessness. Brain Inj. 2017;31(13–14):1731–5.

30. Marcantonis E. The prevalence of traumatic brain injury in battered women residing in northern New Jersey shelters. 2004;

31. Gargaro J, Gerber GJ, Nir P. Brain Injury in Persons With Serious Mental Illness Who Have a History of Chronic Homelessness: Could This Impact How Services Are Delivered? Can J Commun Ment Health. 2016 Jun;35(2):69–77.

32. Vila-Rodriguez F, Panenka WJ, Lang DJ, Thornton AE, Vertinsky T, Wong H, et al. The hotel study: multimorbidity in a community sample living in marginal housing. Am J Psychiatry. 2013 Dec;170(12):1413–22.

33. Jae Song M, Nikoo M, Choi F, Schütz CG, Jang K, Krausz RM. Childhood Trauma and Lifetime Traumatic Brain Injury Among Individuals Who Are Homeless. J Head Trauma Rehabil. 2018 Jun 5;33(3):185–90.

34. Nilsson SF, Nordentoft M, Hjorthøj C. Individual-Level Predictors for Becoming Homeless and Exiting Homelessness: a Systematic Review and Meta-analysis. J Urban Health. 2019 Oct 1;96(5):741–50.

35. Decker M. Exploring the Connections Between Alcohol Abuse and Cognitive Deficits: A Review of Alcohol's Effects on Brain Development and Memory Formation. 2020;

36. Samuelson KW, Neylan TC, Metzler TJ, Lenoci M, Rothlind J, Henn-Haase C, et al. Neuropsychological functioning in posttraumatic stress disorder and alcohol abuse. Neuropsychology. 2006;20(6):716.

37. Russell LM, Devore MD, Barnes SM, Forster JE, Hostetter TA, Montgomery AE, et al. Challenges Associated With Screening for Traumatic Brain Injury Among US Veterans Seeking Homeless Services. Am J Public Health. 2013 Dec 2;103(S2):S211-3.

38. Hurstak E, Johnson JK, Tieu L, Guzman D, Ponath C, Lee CT, et al. Factors associated with cognitive impairment in a cohort of older homeless adults: Results from the HOPE HOME study. Drug Alcohol Depend. 2017;

39. Noël F, Moniruzzaman A, Somers J, Frankish J, Strehlau V, Schütz C, et al. A longitudinal study of suicidal ideation among homeless, mentally ill individuals. Soc Psychiatry Psychiatr Epidemiol. 2016 Jan 1;51(1):107–14.

40. Somers J, Moniruzzaman A, Russolillo A, Rezansoff S. CORRELATES AND ANTECEDENTS OF ALCOHOL DEPENDENCE AND SUBSTANCE DEPENDENCE IN A HOMELESS SAMPLE WITH MENTAL DISORDERS: 225. Alcohol Clin Exp Res [Internet]. 2012 Jun [cited 2021 Feb 1];36. Available from: insights.ovid.com

41. Svoboda T, Ramsay JT. High rates of head injury among homeless and low-income housed men: A retrospective cohort study. Emerg Med J. 2014 Jul;

42. 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):E19–26.

Tables and Figures

Table 1 Summary of studies. NR: not reported.

Study	Study Design	Country	Setting	Sample Size (n)	Mean Age (years)	Male/ Female (%)	Prevalence of TBI of any severity	Method of TBI Ascertainment
Vila-Rodriguez 2013	Prospective Longitudinal	Canada	Single room occupancy (SRO) hotels	293	>75	NR	31/293 (10.6%)	Custom Questionnaire, evidence of TBI on MRI, or history of TBI (LOC greater than or equal to 5 minutes or confusion for one or more days with TBI-related symptoms)
Hwang 2008	Cross-sectional	Canada	Homeless shelters (90%) and meal programs (10%)	904	37.4	67/33	475/904 (52%)	Self-diagnosis through screening questionnaire asking "Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?"
Topolovec-Vranic 2017*	Cross-sectional	Canada	Shelters, drop-in centres, outreach teams, inpatient programs, criminal justice programs	2088	41	68/32	1098/2088 (53%)	Self-diagnosis through screening questionnaire asking "Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?", "Were you, in fact, knocked out or unconscious after this (or any of these if more than 1 head injury(ies)?", and "About how long were you unconscious or knocked out after this head

								injury (if 1)/these head injuries (if >1)?"
Schmitt 2017	Cross-sectional	Canada	SRO hotels and downtown community cohorts	205	43.5	77.1/22.9	100/205 (48.8%)	Self-diagnosis through screening questionnaire asking, "Have you ever had a serious head/face injury?" along with MRI confirmation
Topolovec-Vranic 2014	Observational Cohort	Canada	Men's homeless shelter	111	54.2	100/0	50/111 (45%)	Screening questionnaire (Brain Injury Screening Questionnaire)
To 2015	Prospective Longitudinal	Canada	Homeless shelters, meal programs, SRO hotels, random rooming houses, meal programs, drop-in centres, and community health centres	1181	43 (median)	66.2/32.4	718/1181 (61%)	Self-diagnosis through screening questionnaire asking, "Have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?"
Andersen 2014	Cross-sectional	Canada	Men's homeless shelter	34	58.8	NR	12/34 (35.3%)	Screening questionnaire (Brain Injury Screening Questionnaire)
Ares 2016	Graduate Dissertation	USA	Night ministry or teen living program	93	19.3	50.5/49.5	37/93 (39.8%)	Self-diagnosis through screening questionnaire

			(night shelters) VA medical centre clinics for veterans seeking homeless services overnight shelters, homeless encampments, meal programs, and recycling centres					
Brenner 2017	Cross-sectional	USA		309	52.3	96.4/3.6	282/309 (91.3%)	Screening questionnaire (OSU TBI-ID questionnaire)
Hurstak 2017[38]	Cross-sectional	USA		343	58 (median)	76.7/23.3	149/343 (43.4%)	Self-diagnosis through screening questionnaire; asked to provide information on number of head injuries experienced
Mackelprang 2014	Cross-sectional	USA	Homeless shelters, drop-in centres, shelters for domestic violence survivors, and streets	2732	21.8	36.7/63.3	1145/2694 (42.5%)	Self-diagnosis through screening questionnaire asking "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?"
Noël 2016* [39]	Prospective Longitudinal	Canada	Shelters, drop-in	497	40.8	72.2/27.8	NR	NR

			centres, outreach teams, inpatient programs, criminal justice programs					
Somers 2012* [40]	Abstract	Canada	N/A	332	NR	NR	229/332 (68.9%)	NR
Svoboda and Ramsay 2014[41]	Retrospective Cohort	Canada	Annex et shelter program; hostel for men and three low income housing sites	170	43.7	100/0	39/170 (22.9%)	Diagnosis by a physician via emergency department records
Nikoo 2017[42]	Prospective Longitudinal	Canada	Shelters, meal programs, meal programs, community health centres, drop-in centres, low cost and transitional housing	1190	42.2	67.6/32.4	718/1190 (60.3%)	Self-diagnosed through screening questionnaire asking "have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?"

Song 2018	Cross-sectional	Canada	Homeless outreach services, shelters, and streets	500	37.9	59.8/40.2	318/500 (63.6%)	Self-diagnosed through screening questionnaire (single question) asking "have you ever had an injury to the head which knocked you out or at least left you dazed, confused, or disoriented?"
Marcantonis 2003	Graduate Dissertation	USA	Battered women's shelters	28	28	0/100	7/28 (25%)	Screening questionnaire (Traumatic Brain Injury Questionnaire)
Bacciardi 2017*	Cross-sectional	Canada	Homeless shelters, drop-in centres, homeless outreach teams, hospitals, community mental health teams, and criminal justice programs	416	39.9	71.9/28.1	277/416 (66.6%)	Self-diagnosis through screening questionnaire asking "Have you ever had an injury to the head which knocked you out or at least left you dazed, confused or disoriented?" In addition, "A mild TBI was defined as a head injury that left the person dazed, confused, or disoriented, but resulted in no unconsciousness or unconsciousness for less the 30 minutes. A moderate or severe TBI was defined as a head injury that resulted in unconsciousness for more than 30 minutes."
Gargaro 2016	Cross-sectional	Canada	Homeless people seeking assistance from Assertive	48	43.4	68.7/31.3	27/48 (56.3%)	Screening questionnaire (OSU TBI-ID)

	Community
	Treatment
	Teams

* denotes studies which were published from the same parent database

Table 2 Meta-analysis outcomes.

Condition being Analysed	Number of Studies Meta-Analysis	Number of Participants in Meta-Analysis	OR (95% CI)	Heterogeneity (I^2, %)
Neurologic Conditions				
Seizures	7	4,441	3.16 (2.57, 3.90)	0.01%
Migraines	2	2,293	2.58 (2.15, 3.08)	0%
Cognitive Impairment	3	592	2.21 (0.77, 6.38)	84.2%
Pooled Statistics	9	7,326	2.57 (1.93, 3.44)	68.0%
Psychiatric Conditions				
Alcohol Dependence	9	9,176	1.84 (1.40, 2.40)	81.3%
Anxiety Disorder	5	679	2.49 (1.05, 5.90)	47.0%
Bipolar Disorder	2	3,417	2.60 (2.17, 3.10)	0.0%
Depression	5	5,157	2.42 (2.05, 2.86)	0.0%
Mental Health Problems	6	3,340	1.49 (1.28, 1.73)	0.0%
Mood Disorder	2	2,293	1.84 (1.47, 2.30)	0.0%
Panic Disorder	2	2,395	2.37 (1.92, 2.93)	0.0%
Psychotic Disorder	3	3,206	1.99 (0.67, 5.95)	86.6%
PTSD	4	5,296	3.10 (2.68, 3.59)	0.0%
Substance/Drug Use Disorder	11	9,157	1.75 (1.39, 2.21)	76.0%
Suicidal Ideation	3	4,987	2.85 (2.24, 3.62)	50.3%
Suicide Attempts	3	4,826	1.79 (1.30, 2.47)	76.8%
Pooled Statistics	15	9,530	2.01 (1.81, 2.25)	79.2%

Figure 1 PRISMA flow diagram detailing selection process for included studies.

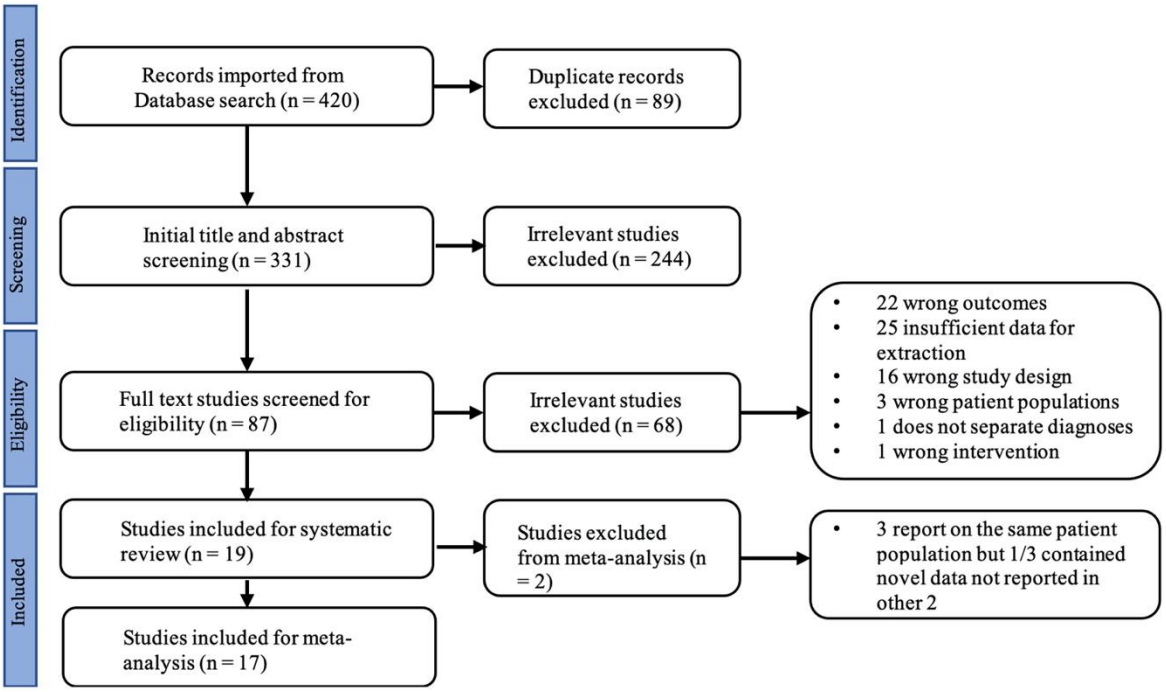

Figure 2 Forest plot of all neurologic illnesses reported in included studies.

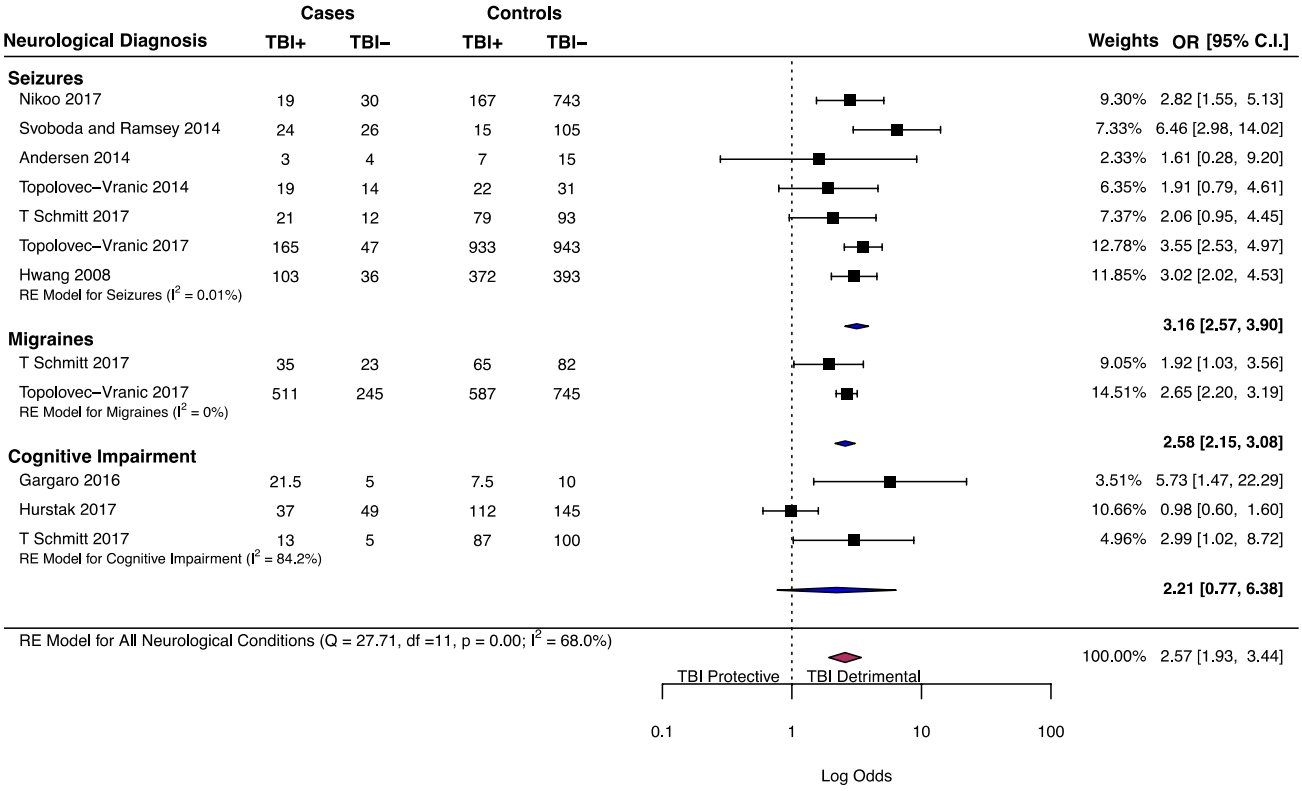

Figure 3 Forest plots of all psychiatric diagnoses reported in included studies.