Review

Neuro
epidemiology

Neuroepidemiology 2013;40:154–159
DOI: 10.1159/000343275

Received: May 28, 2012
Accepted: August 31, 2012
Published online: December 18, 2012

Prevalence of Traumatic Brain Injury in the General Adult Population: A Meta-Analysis

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Key Words
Traumatic brain injury · General population prevalence · Prevalence

Abstract
Traumatic brain injury (TBI) is a significant public-health concern. To understand the extent of TBI, it is important to assess the prevalence of TBI in the general population. However, the prevalence of TBI in the general population can be difficult to measure because of differing definitions of TBI, differing TBI severity levels, and underreporting of sport-related TBI. Additionally, prevalence reports vary from study to study. In this present study, we used meta-analytic methods to estimate the prevalence of TBI in the adult general population. Across 15 studies, all originating from developed countries, which included 25,134 adults, 12% had a history of TBI. Men had more than twice the odds of having had a TBI than did women, suggesting that male gender is a risk factor for TBI. The adverse behavioral, cognitive and psychiatric effects associated with TBI coupled with the high prevalence of TBI identified in this study indicate that TBI is a considerable public and personal-health problem.

Introduction

An estimated 1.5–2 million people sustain a traumatic brain injury (TBI) every year in the USA alone [1], where TBIs account for approximately 1.4 million emergency room visits, 275,000 hospital admissions, and 52,000 deaths each year [2]. The resultant personal and social costs are high, with some estimates suggesting that costs associated with TBI are between 9 and 10 billion dollars annually [1].

While incidence rates for TBI are readily available, there is comparatively little information about the prevalence of TBI in the general population. TBI presents several unique issues when attempting to estimate prevalence. One problem in estimating the prevalence of TBI is the amorphous nature of head injury: TBI diagnosis can range from mild to severe, with signs and symptoms varying across and within severity levels. Further, the distinction between mild and moderate and moderate and severe TBI is often unclear. A second area of concern is that multiple methods are used to diagnose TBI severity, including Glasgow Coma Scale (GCS) scores, length of posttraumatic amnesia (PTA), and presence or absence of loss of consciousness (LOC) at the time of injury [3]. The definitional and diagnostic ambiguity surrounding TBI results in inconsistent reports about incidence rates and residual effects of TBI [4]. Finally, TBI is associated with specific subgroups of the population – the young,

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the elderly, adolescent males, lower socioeconomic groups, minorities and those who drink alcohol are all at greater risk of TBI than is the general population [5, 6].

Given the difficulties in diagnosing TBI, it can be difficult to estimate accurate TBI prevalence; understandably, TBI prevalence varies from study to study, particularly when attempting to estimate TBI prevalence in the general population. For example, in one sample of 20 healthy African-American males with an average age of 32.6 years and an average of 12.7 years of education assessed with a questionnaire, 60% reported a history of TBI [7]. In contrast, using a large cross-sectional community sample and operationalizing TBI as having had a serious head injury with resultant loss of consciousness of 15 min or more, Butterworth et al. [8] found a TBI prevalence of only 5.7% in 7,488 subjects. To better understand the prevalence of TBI in the general population, we performed a meta-analysis of published studies that reported TBI prevalence in the general adult population.

Method

Source Study Identification and Selection

To identify studies reporting TBI prevalence in the general population, we searched for peer-reviewed articles published through May 2011 using Pubmed from the National Library of Medicine, PsychINFO and Google Scholar. The following search terms were used: *TBI in general population*, *traumatic brain injury prevalence*, *TBI prevalence*, *TBI* AND *non-clinic groups*, *TBI* AND *self-reported measures*, and *TBI in control groups*. We also searched the references from identified studies for additional articles.

We included articles if they reported the prevalence of TBI regardless of sex in a general adult (age ≥18 years) population group, that is, in a sample not selected for TBI. Studies were excluded if they only reported prevalence rates of TBI in a psychologically symptomatic or a clinical group. For example, we excluded several studies that reported data on prevalence rates in homeless people or in criminals but that did not include a control group because these groups have abnormally high prevalence rates of TBI that would likely bias our results [9, 10]. We also excluded studies that only reported prevalence rates of non-TBI, neurological injury, such as stroke or anoxic injuries. Finally, we included only those studies in which TBI had resulted in LOC and excluded studies if it was unclear whether the TBI had resulted in LOC. Restricting source studies to those that report prevalence of TBI with LOC provided a standardized, well-accepted threshold for TBI [3] and helped restrict the variable operational definitions of TBI between studies. From source studies meeting inclusion criteria, we extracted the percent of TBI and the sample percentage of females and males to examine the odds ratio by sex.

Statistical Analysis

We calculated a weighted mean prevalence of TBI across source studies by first summing the total number of subjects reporting a history of TBI and then dividing by the total number of subjects across samples. In order to calculate odds ratios of TBI by sex, we tabulated separate prevalence rates for males and females. We pooled the odds ratios by study into a summary odds ratio using a random-effects model in order to account for possible differences in true effect sizes between the source studies [11]. In the analysis of odds ratio by sex, we investigated the potential for publication bias with the Classic Fail-Safe test, Orwin's Fail-Safe test, and the Trim-and-Fill test. Comprehensive Meta-Analysis 2.0 (Biostat, Englewood, N.J., USA) was used for all analyses involving odds ratios.

Results

The search strategy initially yielded approximately 1,261 articles. We then searched through titles and abstracts for articles potentially meeting inclusion and exclusion criteria, which resulted in 39 potential source studies. Of these, 15 papers met inclusion and exclusion criteria. Common reasons for exclusion were duplication of data from another study publication, failure to report the presence or absence of LOC, the TBI being in homeless, incarcerated or mentally ill subjects, and the use of child or adolescent samples.

The 15 source studies meeting final inclusion criteria all appeared to originate in developed nations (table 1). The total sample consisted of 25,134 individuals, of which 3,044 had a lifetime history of TBI (12.1%). Several studies reported prevalence rates by sex. The total male sample (14 studies) consisted of 10,176 individuals with 1,697 (16.68%) reporting a lifetime history of TBI. For females (12 studies), 1,078 individuals out of 12,605 reported a TBI (8.55%).

Twelve of the source studies reported percentage of TBI by sex. This allowed us to calculate the odds of having a TBI for males compared to females using a random effects model. As reported in table 2, the summary odds ratio was 2.22 ($p \leq 0.001$), indicating that the odds of sustaining a TBI are 2.22 times higher in men than women. The nonsignificant Q statistic ($Q = 14.930$, $p = 0.186$) indicated that the source studies did not differ significantly from one another and that it was appropriate to pool them into a summary odds ratio. The Trim-and-Fill test indicated no publication bias; subsequently, no studies needed to be trimmed to correct for publication bias, consistent with the funnel plot showing no evidence of publication bias (fig. 1). The Classic Fail-Safe test indicated that the number of missing studies that would be needed to bring the p value to greater than α is 887. Orwin's Fail-Safe test showed that it would take 42 additional studies with an odds ratio of 1.0 to bring the pooled odds ratio to a trivial odds ratio of 1.2.

Table 1. Source studies in meta-analysis

Study	Total n	TBI n	Percent	Total male n	Male TBI n	Male TBI %	Total female n	Female TBI n	Female TBI %	Location
Boswell et al. [26], 2002	417	189	45.32	194	112	57.73	223	77	34.53	USA
Butterworth et al. [8], 2004	7,488	428	5.72	3,678	306	8.32	3,810	122	3.20	Australia
Demakis and Rimland [27], 2010	1,853	249	13.44	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	USA
Holmes and Buzzanga [28], 1991	835	89	10.66	320	43	13.44	515	46	8.93	USA
McGuire et al. [19], 1998	534	68	12.73	160	31	19.38	374	37	9.89	USA
McKinlay et al. [29], 2008	1,003	318	31.70	502	208	41.43	501	110	21.96	NZ
Perkes et al. [30], 2011	200	70	35.00	200	70	35.00	n.r.	n.r.	n.r.	Australia
Segalowitz and Lawson [31], 1995	2,321	215	9.26	541	90	16.64	1,710	125	7.31	Canada
Silver et al. [32], 2001	5,034	361	7.17	2,317	223	9.62	2,717	138	5.08	USA
Templer et al. [33], 1992	713	153	21.46	276	84	30.43	437	87	19.91	USA
Turkstra et al. [7], 2003	20	12	60.00	20	12	60.00	n.r.	n.r.	n.r.	USA
Ryan et al. [34], 1996	800	188	23.50	166	84	50.60	204	66	32.35	USA
Crovitz et al. [35], 1983	1,000	199	19.90	500	119	23.80	500	80	16.00	USA
Crovitz et al. [36], 1992	420	73	17.38	214	49	22.90	206	24	11.65	USA
Crovitz and Daniel [37], 1987	2,496	432	17.31	1,088	266	24.45	1,408	166	11.79	USA
Total	25,134	3,044	12.1	10,176	1,697	16.68	12,605	1,078	8.55	

n.r. = Not reported; NZ = New Zealand.

Table 2. Odd ratios of TBI for males compared to females with random effects model

Study	Odds ratio	Lower limit	Upper limit	Z value	p value
Boswell et al. [26], 2002	2.59	1.742	3.851	4.702	<0.001
Butterworth et al. [8], 2004	2.74	2.213	3.401	9.200	<0.001
Holmes and Buzzanga [28], 1991	1.58	1.018	2.461	2.038	0.042
McGuire et al. [19], 1998	2.19	1.303	3.676	2.961	0.003
McKinlay et al. [29], 2008	2.51	1.908	3.315	6.544	<0.001
Segalowitz and Lawson [31], 1995	2.53	1.893	3.383	6.265	<0.001
Silver et al. [32], 2001	1.99	1.597	2.480	6.132	<0.001
Templer et al. [33], 1992	1.76	1.243	2.492	3.187	0.001
Ryan et al. [34], 1996	2.14	1.404	3.268	3.532	<0.001
Crovitz et al. [35], 1983	1.64	1.196	2.248	3.072	0.002
Crovitz et al. [36], 1992	2.25	1.323	3.833	2.992	0.003
Crovitz and Daniel [37], 1987	2.42	1.957	2.996	8.138	<0.001
Summary	2.22	1.998	2.468	14.815	<0.001

Discussion

There are limited available data about the prevalence of TBI in the general population. To our knowledge, this is the first meta-analysis examining the prevalence of TBI in the general adult population. Our analysis suggests that approximately 12% of the general adult population has a history of TBI with LOC (16.7% for males and 8.5% for females). The odds of a history of a TBI resulting in the LOC are 2.2 times higher for males than females (CI = 1.998–2.468, $p < 0.001$). As such, male gender appears to be a risk factor for TBI. Publication bias – the

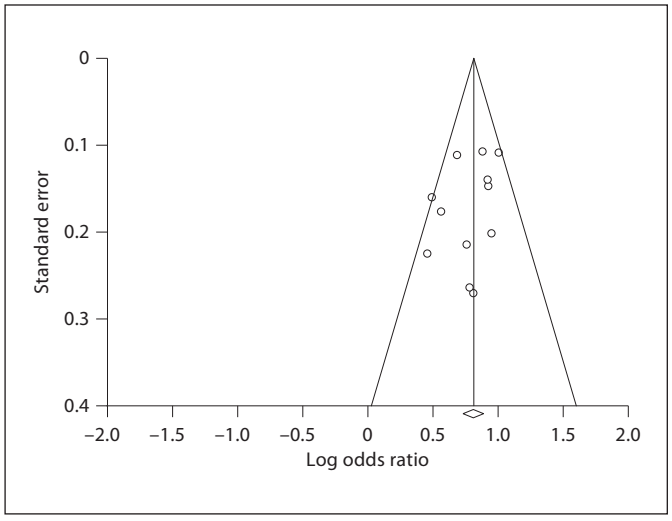

Fig. 1. Funnel plot of standard error by log odds ratio indicating minimal publication bias of source studies.

tendency for negative results to not be published – is an inherent threat to internal validity in meta-analysis. However, the results from the Trim-and-Fill test, the funnel plot, the Classic Fail-Safe test, and Orwin's Fail-Safe test suggested little evidence of publication bias in this case.

There are significant public-health implications for the suggestion that 12% of the general adult population has sustained a TBI with LOC. Current estimates suggest that the US prevalence of TBI-related disability after hospitalization is 3.2 million individuals [12] and that 43.3% of hospitalized TBI survivors will have long-term disability [13]. Behaviorally, TBI survivors report confusion, disorientation, alteration in psychomotor activity, mental inflexibility, emotional dysregulation, and increased agitation [14, 15]. Numerous studies also suggest that TBI has negative psychiatric consequences. Specifically, individuals with TBI are at an increased risk of developing major depression, mania, posttraumatic stress disorder, personality changes, generalized anxiety disorder and additional psychiatric disorders [16]. A systematic review found that after sustaining TBI approximately 25% of TBI survivors develop depression, 4.2% develop bipolar affective disorder, 22% develop substance abuse, 9% develop generalized anxiety disorder, 9% develop panic disorder, 14% develop posttraumatic stress disorder and 6.4% develop obsessive-compulsive disorder, all of which are increases from the respective prevalence in the general population [17]. The practical consequences can be quite large. For example, one study found that psychiatric inpatient admissions were 19% higher for patients with a history of mild TBI and that inpatient length of stay was significantly longer for those with mild TBI than for those without a history of TBI [18]. Psychiatric patients also report a higher rate of TBI than the general population and a higher rate of multiple TBIs [19]. Research also suggests that individuals who sustain one TBI are at an increased risk of sustaining additional TBIs [6]. Further, recurrent TBIs are associated with increased recovery time and utilization of services [20], and research consistently finds that TBI has a detrimental effect on an individual's neuropsychological functioning [12], especially in memory, attention and speed of processing [21].

The odds of having sustained a TBI are 2.2 times higher in males than females. This data is supported by other epidemiological studies of TBI suggesting a 2-to-1 ratio for men compared to women [22]. Research suggests that this increased risk is likely related to the fact that males often engage in more risk-taking behavior, contact sports and alcohol consumption. Because such risk factors were not consistently reported across source studies, our analysis was unable to confirm the reason for the relative risk for male TBIs.

There are important factors that limit our findings. Variations in the definitions of TBI are among the most important limitations of this study and could considerably affect its results. Because we restricted our analysis to source studies that defined TBI as having LOC, it is likely that the prevalence of all TBIs is higher than 12%. For example, most sports-related concussions do not result in LOC [22]. Consequently, our use of source studies restricted to TBI defined by LOC would have missed many sports-related concussions. In this regard, our methods are consistent with the Center for Disease Prevention and Control, which, even though there are approximately 300,000 sports-related concussions each year in the USA [23], does not include sports-related concussions in its published prevalence data for TBI. It is also important to note that approximately 80% of all TBIs are classified as mild and often do not result in LOC [4].

What constitutes TBI is hard to define due to a variety of reasons, including the gradient nature of brain injury, in which brain injury can range from mild to severe, and the use of multiple classification systems to define injury severity. Further, recall bias may affect self-reporting about TBI that may have occurred many years in the past. While the presence of TBI and its severity can be estimated using PTA, the GCS or LOC, we chose to define TBI as the presence of a head injury with LOC. The use of PTA

as a marker of TBI is problematic in that memories tend to diminish with time and are subject to contamination from the retelling of events. This can introduce bias about the duration of PTA, which could result in either a lower or a higher TBI estimate. Despite widespread use of the GCS, self-reported GCS scores are not ideal when determining the presence of TBI history in that GCS scores often change throughout the acute assessment and are essentially meaningless to the layperson, and, as such, may be remembered incorrectly, if at all, introducing the potential for recall bias. In contrast, LOC is a memorable and meaningful event, for either the individual with the TBI or for corroborating witnesses. Summarily, it is reasonable to assume that of the three methods of determining whether there is a history of TBI, LOC is the best to determine whether a significant TBI occurred in that it can be easily recalled and is dichotomous.

Another factor requiring consideration in interpreting our findings is that due to inconsistent reporting across the source studies we did not examine or control for the mechanism of brain injury. The Center for Disease Prevention and Control reports that the main causes of TBI are falls (35.2%), motor vehicle accidents (17.3%), struck by/against events (16.5%), assaults (10%), and other/unknown (21%) [22, 24]. We were unable to verify this with our analysis, even though the mechanism of brain injury is an important aspect in understanding risk, prevention and subsequent recovery in brain injury [25].

Finally, because all of the source studies in this meta-analysis came from developed countries, the results may not be generalizable to developing nations. Additional research about the prevalence of TBI in developing nations is needed. Considering the problems associated with estimating TBI prevalence, these results, however, could be of importance to developing nations in that there is little information about the prevalence of TBI in those regions of the world.

In conclusion, and in the context of the limitations of this meta-analysis, we found a prevalence of TBI in the general population of 12–16.7% in males and 8.5% in females. Men had more than twice the odds of having had sustained a TBI than women, suggesting that male gender is a risk factor for TBI. Given the adverse behavioral, cognitive and psychiatric effects associated with TBI, a 12% prevalence of TBI in the general population suggests that TBI remains a considerable personal and public-health concern.

Disclosure Statement

There are no disclaimers or conflicts of interest for any of the authors.

References

1 Consensus conference: Rehabilitation of persons with traumatic brain injury. NIH consensus development panel on rehabilitation of persons with traumatic brain injury. JAMA 1999;282:974–983.

2 Faul M, Xu L, Wald MM, Coronado VG: Traumatic brain injury in the United States: emergency department visits, hospitalizations and deaths 2002–2006. Atlanta, Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, 2010.

3 Roebuck-Spencer T, Sherer M: Moderate and severe traumatic brain injury; in Morgan JE, Ricker JH (eds): Textbook of Clinical Neuropsychology. New York, Taylor & Francis, 2008, pp 411–429.

4 Cassidy JD, Carroll LJ, Peloso PM, Borg J, von Holst H, Holm L, Kraus J, Coronado VG: Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre task force on mild traumatic brain injury. J Rehabil Med 2004;43(suppl)28–60.

5 Corrigan JD, Selassie AW, Orman JA: The epidemiology of traumatic brain injury. J Head Trauma Rehabil 2010;25:72–80.

6 Orman JAL, Kraus JF, Zaloshnja E, Miller T: Epidemiology; in Silver JM, McAllister TW, Yudofsky SC (eds): Textbook of Traumatic Brain Injury. Arlington, American Psychiatric Publishing, 2011, pp 3–22.

7 Turkstra L, Jones D, Toler HL: Brain injury and violent crime. Brain Inj 2003;17:39–47.

8 Butterworth P, Anstey K, Jorm AF, Rodgers B: A community survey demonstrated cohort differences in the lifetime prevalence of self-reported head injury. J Clin Epidemiol 2004;57:742–748.

9 Farrer TJ, Hedges DW: Prevalence of traumatic brain injury in incarcerated groups compared to the general population: a meta-analysis. Prog Neuropsychopharmacol Biol Psychiatry 2011;35:390–394.

10 Farrer TJ, Frost RB, Hedges DW: Prevalence of traumatic brain injury in juvenile offenders: a meta-analysis. Child Neuropsychol 2012, E-pub ahead of print.

11 Borenstein M, Hedges LV, Higgins JPT, Rothstein HR: Introduction to Meta-Analysis. Chichester, Wiley & Sons, 2009.

12 Zaloshnja E, Miller T, Langlois JA, Selassie AW: Prevalence of long-term disability from traumatic brain injury in the civilian population of the United States, 2005. J Head Trauma Rehabil 2008;23:394–400.

13 Selassie AW, Zaloshnja E, Langlois JA, Miller T, Jones P, Steiner C: Incidence of long-term disability following traumatic brain injury hospitalization, United States, 2003. J Head Trauma Rehabil 2008;23:123–131.

14 Larson MJ, Fair JE, Farrer TJ, Perlstein WM: Predictors of performance monitoring abilities following traumatic brain injury: the influence of negative affect and cognitive sequelae. Int J Psychophysiol 2011;82:61–68.

15 Rao V, Lyketsos C: Neuropsychiatric sequelae of traumatic brain injury. Psychosomatics 2000;41:95–103.

16 Rogers JM, Read CA: Psychiatric comorbidity following traumatic brain injury. Brain Inj 2007;21:1321–1333.

17 Van Reekum R, Cohen T, Wong J: Can traumatic brain injury cause psychiatric disorders? J Neuropsychiatry Clin Neurosci 2000; 12:316–327.
18 Mateo MA, Glod CA, Hennen J, Price BH, Merrill N: Mild traumatic brain injury in psychiatric inpatients. J Neurosci Nurs 2005; 37:28–33.
19 McGuire LM, Burright RG, Williams R, Donovick PJ: Prevalence of traumatic brain injury in psychiatric and non-psychiatric subjects. Brain Inj 1998;12:207–214.
20 Guskiewicz KM, McCrea M, Marshall SW, Cantu RC, Randolph C, Barr W, Onate JA, Kelly JP: Cumulative effects associated with recurrent concussion in collegiate football players: The NCAA Concussion Study. JAMA 2003;290:2549–2555.
21 Millis SR, Rosenthal M, Novack TA, Sherer M, Nick TG, Kreutzer JS, High WM Jr, Ricker JH: Long-term neuropsychological outcome after traumatic brain injury. J Head Trauma Rehabil 2001;16:343–355.
22 Langlois JA, Rutland-Brown W, Wald MM: The epidemiology and impact of traumatic brain injury: a brief overview. J Head Trauma Rehabil 2006;21:375–378.
23 Moser RS, Iverson GL, Echemendia RJ, Lovell MR, Schatz P, Webbe FM, Ruff RM, Barth JT: Neuropsychological evaluation in the diagnosis and management of sports-related concussion. Arch Clin Neuropsychol 2007;22:909–916.
24 Injury prevention and control: traumatic brain injury. Centers for Disease Control and Prevention, 2012. http://www.cdc.gov/traumaticbraininjury.
25 Bigler ED: Neuropsychology and clinical neuroscience of persistent post-concussive syndrome. J Int Neuropsychol Soc 2008;14: 1–22.
26 Boswell JE, McErlean M, Verdile VP: Prevalence of traumatic brain injury in an ED population. Am J Emerg Med 2002;20:177–180.
27 Demakis GJ, Rimland CA: Untreated mild traumatic brain injury in a young adult population. Arch Clin Neuropsychol 2010;25: 191–196.
28 Holmes CB, Buzzanga VL: Head-injury prevalence among community college students. Percept Mot Skills 1991;73:497–498.
29 McKinlay A, Grace RC, Horwood LJ, Fergusson DM, Ridder EM, MacFarlane MR: Prevalence of traumatic brain injury among children, adolescents and young adults: prospective evidence from a birth cohort. Brain Inj 2008;22:175–181.
30 Perkes I, Schofield PW, Butler T, Hollis SJ: Traumatic brain injury rates and sequelae: a comparison of prisoners with a matched community sample in Australia. Brain Inj 2011;25:131–141.
31 Segalowitz SJ, Lawson S: Subtle symptoms associated with self-reported mild head injury. J Learn Disabil 1995;28:309–319.
32 Silver JM, Kramer R, Greenwald S, Weissman M: The association between head injuries and psychiatric disorders: findings from the New Haven NIMH epidemiologic catchment area study. Brain Inj 2001;15:935–945.
33 Templer DI, Kasiraj J, Trent NH, Trent A, Hughey B, Keller WJ, Orling RA, Thomas-Dobson S: Exploration of head injury without medical attention. Percept Mot Skills 1992;75:195–202.
34 Ryan LM, O'Jile JR, Gouvier WD, Parks-Levy J, Betz B: Head injury in a college population: analysis of epidemiological factors. Appl Neuropsychol 1996;3:49–54.
35 Crovitz HF, Horn RW, Daniel WF: Inter-relationships among retrograde amnesia, post-traumatic amnesia, and time since head injury: a retrospective study. Cortex 1983;19: 407–412.
36 Crovitz HF, Diaco DS, Apter A: Consistency in recalling features of former head injuries: retrospective questionnaire versus interview retest. Cortex 1992;28:509–512.
37 Crovitz HF, Daniel WF: Length of retrograde amnesia after head injury: a revised formula. Cortex 1987;23:695–698.