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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,
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 prevalence with a questionnaire, 60% reported a history of TBI prevalence [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%) 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 < 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.
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 –
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**


Traumatic Brain Injury in the General Adult Population


