Title: Brain injury as the result of violence: A systematic scoping review

Short title – Violence-related TBIs: A scoping review

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Abstract

This scoping review investigated risk factors, impacts, outcomes and service implications of violence-related traumatic brain injury (TBI) for individuals and their informal caregivers. A systematic search (Web of Science, PubMed, PsycInfo, ProQuest, Medline, Informit; 1990-2015) identified 17 studies meeting the inclusion/exclusion criteria. Violence was the cause of between 3% and 26% of all TBIs. Males, a non-white racial background, pre-injury unemployment and pre-injury substance abuse problems all elevated the risk for sustaining a violence-related TBI compared to other-cause TBI. However, few differences were observed in 12 months post-injury outcomes. No studies investigated the impact of violence-related TBI on informal caregivers.

Introduction

Violence is an international public health issue resulting in premature death, disability and injury (Krug, Dahlberg, Mercy, Zwi, & Lozano, 2002) with as many as 14,249 deaths in the US reported as arising from violence (The Federal Bureau of Investigation, 2014). In Australia, violence is also an issue of national concern, with extensive media coverage of violence that results in the death of a person (e.g. Atkinson, 2014; Berg, 2014; Dow, 2013; Farrow, 2015). Additionally, it has been estimated that for each death by violence, there are 100 nonfatal violence-related injuries (Rosenberg & Fenley, 1991).

Traumatic brain injury (TBI) is one type of injury that can result from violence (Faul, Xu, Wald, & Coronado, 2010). TBI is a leading cause of disability globally (WHO Global Consultation on Violence and Health, 1996). A TBI can be defined as an injury to brain tissue that has occurred due to an external force resulting in marked cognitive, social, behavioral and physical changes that impact the individual and their family (Arango-Lasprilla et al., 2008; Harrison-Felix et al., 1998). The most common causes of TBI are motor vehicle crashes, falls, sporting injuries and violence-related mechanisms (Simpson, Simons, & McFadyen, 2002).

In the most recent research regarding violence-related TBI, investigators have broadly characterized violence as arising from physical assault or gunshot (Gerhart, Mellick, & Weintraub, 2003; Hanlon, Demery, Martinovich, & Kelly, 1999; Harrison-Felix et al., 1998; Kim, Colantonio, Bayley, & Dawson, 2011; Machamer, Temkin, & Dikmen, 2003; Schopp, Good, Barker, Mazurek, & Hathaway, 2006; Wenden, Crawford, Wade, King, & Moss, 1998). Although intentionality can be difficult to determine because it infers a state of mind, the construct of other-inflicted (harm caused by others) versus self-inflicted (harm caused by oneself) is also incorporated into definitions (Gerhart et al., 2003; Harrison-Felix et al., 1998; Kim & Colantonio, 2008; Kim et al., 2011; Schopp et al., 2006; Wagner, Sasser, Hammond,

Wiercisieswski, & Alexander, 2000). In general, the approach within these studies is consistent with the World Health Organisation (1996) definition of violence as "…the intentional use of physical force or power, threatened or actual, against oneself, another person, or against a group or a community, that either results in or has a high likelihood of resulting in injury, death, psychological harm, mal-development or deprivation".

Research into violence-related TBI found that there are a significant minority of individuals sustaining an injury as a result of violence. In the United States, physical assault accounted for 10% of all brain injuries from 2002 to 2006, with 21% of the most severe injuries requiring medical attention and hospitalization (Faul et al., 2010). Canada reports that 8-10% of hospital admissions are the result of physical assault (Colantonio et al., 2010; Kim & Colantonio, 2008), while in Australia in 2004-2005 16.8% of hospital admissions for TBI were the result of an assault (Helps, Henley, & Harrison, 2008). A range of significant impacts have been reported on individuals sustaining violence-related TBI including persisting neurological symptoms, neuropsychological impairments and poor psychosocial outcomes (Gerhart et al., 2003; Harrison-Felix et al., 1998; Machamer et al., 2003).

Families also face significant disruption when a relative sustains a TBI from any cause including violence. This includes experiencing elevated levels of depression and anxiety, carer burden, increased health seeking behavior, reductions in employment, and changes in family functioning and roles (Anderson, Simpson, & Morey, 2013; Boycott, Yeoman, & Vesey, 2013; Degeneffe, 2001; Hall et al., 1994; Ponsford, Olver, Ponsford, & Nelms, 2003). Research among other populations has found that vicarious strain can occur when the family or informal caregiver is a direct witness to the violence, hears the violence occurring or hears about the violence. In particular, violent crime victims (including assault) and their families are at greater risk of developing post-traumatic stress disorder (Freedy, Resnick, Kilpatrick, Danksy, & Tidwell, 1994) and it is important to ascertain whether the

same experience has been documented in families supporting relatives with violence-related TBI.

People who sustain violence-related TBIs may also experience challenges and disadvantage in navigating service systems to access needed rehabilitation and longer-term support services (Esselman, Dikmen, Bell, & Temkin, 2004). Additionally, the families who play a vital role in progressing the rehabilitation of their relative (Elbaum, 2007) may have to navigate both the health and the criminal justice systems. Complicating this challenge, family members or informal caregivers may not be included in decisions and actions taken by hospitals, with one study suggesting that families are not routinely involved by staff in emergency departments for all patients who are admitted due to violence (Linnarsson, Benzein, & Arestedt, 2014).

The issue of violence-related TBI is of substantial significance. In addition to the extensive range of impacts experienced by the person and their family members, at a macro level, the financial costs to society of violence-related TBI are significant. There are the direct costs of acute medical care and rehabilitation, as well as indirect costs through the ongoing care, support services, loss of an individual's productivity, and the administration of health insurance and disability payments to individuals (Caro, 2011; Finkelstein, Corso, & Miller, 2006; Harrison-Felix et al., 1998). The estimated lifetime cost of a severe TBI in Australia is $4.8 million per person (Picenna, Pattuwage, Gruen, & Bragge, 2014) so accordingly, TBIs may represent one of the most expensive outcomes of assault. In fact, Helps et al. (2008) estimated that the direct hospital cost of assault related TBIs in Australia is $15.7 million per annum.

Despite the importance of the topic, to the best of our knowledge, there is yet to be a systematic review of the research in this area. Given the lack of previous reviews, a scoping approach was selected, as it is a well suited methodology to identify the breadth and depth of

evidence within a defined field, particular in areas where the research evidence may be limited, heterogeneous or fragmented (Levac, Colquhoun, & O'Brien, 2010). The research question was: *What are the risk factors, impacts, outcomes and service implications of violence-related TBI for individuals and informal caregivers?* By answering this research question, researchers and policy makers will be able to develop and implement interventions targeted at this particular sub-population of injured persons.

Method

The scoping review used the five stages originally outlined by Arksey & O'Malley (2005) and later refined by Levac, Colquhoun and O'Brien (2010). The stages comprise i) identifying the research question; ii) identifying relevant studies; iii) study selection; iv) charting the data; v) collating, summarizing, and reporting results.

Identifying the research question

To identify the research question the concept, target population, and health outcome of interest was defined in order to clearly articulate the scope of enquiry (Levac et al., 2010), The construct of violence within research specifically applied to sustaining a TBI in a civilian context as the result of intentional force arising from gunshot or physical assault. Therefore, it did not encompass studies that considered other dimensions of violence such as threatened violence, or violence targeting families, groups or communities. Research regarding TBI that occurred in a military conflict setting was excluded, as personnel from this context were more likely to present with a range comorbidities associated with being involved in warfare; this presents unique rehabilitation and caregiving needs that are likely to influence the psychosocial outcomes of individuals and informal caregivers of this population (Burke, Degeneffe, & Olney, 2009). The review was international in scope.

The target population comprised adults who were the victim of the violence, as well

as their families and informal caregivers. People sustaining violence-related paediatric brain injury were not included in the study. The term 'informal caregiver' was defined as a non-professional provider of care to a person with violence-related TBI; formal caregivers such as nurses and allied health workers were excluded. Health outcomes of interest included predisposing risk factors (i.e., demographic and psychosocial variables); injury-related factors (e.g., severity of TBI, other injuries associated with polytrauma); outcomes (e.g., presence of symptoms, impairments, functional status, social re-integration); service pathways and costs (e.g., accessing inpatient rehabilitation; health costs payer); and family wellbeing/relationship stability.

Identifying relevant studies

A two-step search strategy was employed. First, a systematic search was conducted employing a number of electronic databases and search engines: Web of Science, PubMed, PsycInfo, ProQuest, Medline, Informit. These are common databases used for the conduct of literature reviews within the field of TBI, capturing all the key journals in the health and rehabilitation fields. Search terms were identified by reviewing the literature that discussed individual family and caregiver psychosocial outcomes in a TBI setting and selecting keywords that were relevant to the research question. Search terms were grouped according to population characteristics (family, informal caregivers, TBI, violence) and health outcomes (psychosocial adjustment, family functioning, and navigating systems). Multiple overlapping terms were used to give the best possible scope of studies identified in the search (see Table 1). Limiting functions were applied to select human studies and articles published in English. The second stage involved the hand-searching reference lists from studies identified through the initial electronic search to identify any further works.

(Insert Table 1)

Study selection

Studies were selected if they (i) contained original research on TBI resulting from violence; (ii) where the study variables were compared to people who sustained TBI from other causes; and (iii) the comparisons were tested statistically. Studies were excluded if (i) they were non-peer-reviewed citations (e.g., unpublished dissertations, abstracts, conference proceedings, books, commentary, and editorials); and (ii) if the study population was not clearly defined as including TBI resulting from violence. Given the limited number of papers that only included individuals with violence related TBIs, studies were incorporated if they considered this group as a sub-population within their wider research.

The database search results were entered into an EndNote library database, which was then used to identify and remove duplicates. Screening occurred in two stages. Initially, two authors (SM, LB) examined the titles and abstracts of the citations individually against the inclusion/exclusion criteria and then compared their individual results. The identified studies then underwent a second stage of screening where full text articles were read (SM) to determine if the full inclusion criteria were met. During this stage additional articles were identified by reviewing the reference lists. The articles retained after this stage were then read by all authors (AB, SM, GS, LB) and a final decision about inclusion was made by consensus.

Data charting

Several templates were devised that would allow identification of data that was relevant to the research question. The first involved collecting descriptive data to characterize all the studies identified in the search including first author, year of publication, country where the research was conducted, study design, service setting and source of the data, the definition of violence used, sample size and time since injury, etiology and breakdown, and measures used. A further five templates were devised to collect data on the five review questions, namely premorbid and demographic features, injury and injury-related

factors, outcomes, service pathways and costs, and caregiver outcomes. The specific data fields for each question are specified in the Results.

Collating, summarizing, and reporting results

Given the broad heterogeneity of studies and variables, a qualitative rather than quantitative (i.e., meta-analytic) synthesis was conducted, seeking to identify patterns and commonalities in the research findings across participants (individual and/or formal caregiver), settings, outcomes and service pathways (for a discussion of the difference between quantitative and qualitative synthesis, see Carter, Lubinsky & Domholdt, 2011; for another example of the qualitative synthesis of findings from quantitative studies, see Wheeler, Accord-Vira & Davis, 2016). This approach is different to reviews that undertake thematic synthesis of qualitative research (e.g., Thomas & Harden, 2008).

Citations were grouped into studies focusing on the individual and studies with data relating to families. Six tables were then constructed to tabulate the data from the templates. Given the large number of findings reported for some of the review variables, only findings that exceeded a more stringent p-value of .01 were reported. This also helped address the problem that some studies reported results from multiple univariate statistical tests without controlling for possible Type II error.

Results

The search terms retrieved a total of 569 articles from the database search (see Figure 1). Titles and associated details were compiled into an EndNote database where 214 duplicates were identified and removed. The remaining abstracts were then screened to identify those potential articles that met the inclusion criteria. A total of 44 full-text articles were identified at this stage. Review of these articles' list of references identified further articles for inclusion. The selected articles were then reviewed against the inclusion/

exclusion criteria, with 17 being retained.

Insert Figure 1

Overview of the studies

The majority of the studies focused on the impact on the individual who sustained the violence-related TBI (n=15), with only two studies documenting impacts upon family members (Arango-Lasprilla et al., 2008; Kreutzer, Marwitz, Hsu, Williams, & Riddick, 2007). Of the 17 articles, 12 were from the USA, published between 1998 and 2008, and used a mix of prospective and retrospective designs. There were four Canadian studies, all published between 2010 and 2013, three of which were retrospective, retrieving data from databases, medical records, and registry information. The one study from the United Kingdom, published in 1998, used prospective data.

Insert Table 2

The majority of studies were conducted among cohorts who had received inpatient rehabilitation (8/17 studies). Most of these studies were multi-centre, drawing upon units that were part of the TBI Model Systems (Dijkers, Harrison-Felix, & Marwitz, 2010). The next largest group was studies based in acute care settings, ranging from single centre (e.g. Wagner et al., 2000) to population-based studies based on trauma registries (Kim et al., 2011). The other studies included two that recruited samples from single centre outpatient rehabilitation clinics and one that involved secondary analysis of data collected from three intervention trials.

The prevalence of violence-related TBIs, as a subset of all TBIs, varied between 6% to 26% within the studies (see Table 2). The definitions of violence ranged from single term global descriptors (e.g., violence, assault, gunshot) through to studies that used specific ICD-9CM E-codes (see Table 2). There was a national difference in the use terminology, with the Canadian studies employing the terms ‘intentional’ versus ‘non-intentional’ violence (as

reflected in the WHO definition) while the terminology within the US studies generally did not include the dimension of intentionality.

Several other differences were noticeable in the approaches to definition across the studies that are likely to create unwanted variability in the prevalence reports. Many studies conflated self-inflicted and other-inflicted injuries, although the two types of behavior are quite different in the underlying motivation and circumstances. This concern is reflected in a minority of studies which did exclude self-inflicted injuries (e.g. Esselman et al., 2004; Kim et al., 2011; Schopp et al., 2006). All gunshot-related injuries were assumed to be violence-related (other inflicted and self-inflicted) with the exception of one study which distinguished between intentional and accidental gunshot (Schopp et al., 2006). Similarly, falls were generally treated as a discrete non-violent injury etiology with the exception of one study that recognized that some violence-related TBIs arise from pushing someone over (Bushnik, Hanks, Kreutzer, & Rosenthal, 2003).

The sample size across the studies were generally large in the context of rehabilitation studies. Most reports comprised samples ranging from greater than 100 through to 15,000 in the largest study. Almost all the studies focused on the acute phase and/or inpatient rehabilitation across the first year post-injury.

Five studies provided a breakdown of the different types of violence that led to the TBI. Two provided a simple breakdown of 'other-inflicted' versus 'self-inflicted' violence (Kim et al., 2011; Machamer et al., 2003). The other three provided more detailed breakdowns of the various types of assault (Gerhart et al., 2003; Harrison-Felix et al., 1998; Wagner et al., 2000) but there was little consensus across the findings (see Table 2).

Two studies (Bogner, Corrigan, Mysiw, Clinchot, & Fugate, 2001; Machamer et al., 2003) identified that people with violence-related TBIs had significantly higher drop-out rates, suggesting that this group may have been underrepresented in the both studies.

However, Machamer et al. (2003) conducted a multivariate analysis testing the strength of a range of demographic and psychosocial variables in predicting the likelihood of not being included in the study. Sex, age and race were all significant individual predictors in the model, however violent etiology was not a significant predictor of study adherence.

Demographic and psychosocial profile of violence-related TBI

The review found a number of premorbid and demographic features that were strongly associated with individuals who sustained a violence-related TBI (see Table 3). Of the 15 articles focusing on the individual, ten specifically tested demographic details between violent and non-violent TBI. Despite the high baseline of males compared to females after TBI (often at a ratio of 3 to 1), eight of the 10 studies reported that a significantly higher proportion of males were represented among violent injuries compared to non-violent injuries.

Next, the US-based studies consistently found that the proportion of non-white or minority races was significantly higher compared to people of white racial background in the violence-related TBI group, however this finding was not observed in Canada or the United Kingdom. In the six studies that reported on age, there was no consistent pattern. Two studies found that people in adult age bands, 26-45 years (Harrison-Felix et al., 1998) and 25-34 years (Gerhart et al., 2003), had a higher risk of violence-related TBI compared to people of younger age (i.e., late adolescence/early adulthood). However three other studies (Dagher, Habra, Lamoureux, de Guise, & Feyz, 2010; Esselman et al., 2004; Hanks et al., 2003) found statistically significant between-group differences in mean ages (violence-related TBI younger than TBI from non-violent causes), but as the mean differences only ranged from one to seven years, these differences may not be clinically significant.

There was consistency in findings that people with violence-related TBIs were significantly more likely than the non-violent group to be unemployed at the time of the injury. However, there was little conclusive evidence to date at $p<.01$ of differences in

education levels between the two groups. Prior alcohol and prior drug abuse were significantly more common among violence-related TBIs in five studies, as were a pre-injury history of arrests. Articles reporting on marital status or the proportions of people living alone post-injury suggest that significantly more individuals who sustained violence-related TBIs were single or living alone. Finally, one study also found that people with violence-related TBIs were significantly more likely to have been the victim of violence prior to the TBI (Schopp et al., 2006).

Insert Table 3

Injury and injury-related factors

The three variables examined in this category were injury severity, blood alcohol levels at admission to hospital, and the presence of other traumatic injuries (apart from the TBI). Nine of the 15 studies focused on individuals investigated one or more of these variables. Starting with injury severity, the three strongest severity classification measures are the Glasgow Coma Scale (GCS) (Teasdale & Jennett, 1976), duration of loss of consciousness (LOC) and duration of post-traumatic amnesia, with the latter two measured in days (Teasdale, 1995). These measures are routinely measured in inpatient rehabilitation and outpatient settings.

The studies that examined injury severity (GCS, LOC, PTA) found no significant differences in injury severity between violence and non-violence-related etiologies of TBI (see Table 4). In the absence of these frontline measures, studies in acute settings fall back on the degree of injury to the head region as measured by the Abbreviated Injury Scale, or Length of Stay in hospital as proxies for injury severity, but these two approaches are far from ideal. Studies that relied on these measures were not considered for the injury severity variable in the current review.

In contrast to injury severity, there were consistent findings that people admitted with

violence-related TBIs had significantly higher BALs than people with non-violent etiologies. These differences were clinically important in one study which found significantly greater proportions of people had blood alcohol levels above the legal limit as defined within their specific jurisdiction (Esselman et al., 2004). Finally, two studies found that people with non-violent TBIs had significantly higher rates of trauma to other body systems as measured by the Abbreviated Injury Scale and Injury Severity Score.

Insert Table 4

Outcomes from violence-related TBIs

Outcomes were reported in 11/15 studies. The types of variables included the presence of neurological symptoms (e.g., dizziness, headaches), neuropsychological impairments (e.g., attention, memory, executive functions), and current employment status. Validated measures were also employed to assess functional status or levels of community participation, most commonly at one or more of three set time points (admission to inpatient rehabilitation; discharge from inpatient rehabilitation; some subsequent follow-up time point). Finally, some attempts were made to capture more global aspects of an individuals' overall functioning.

Two studies investigated the presence of ongoing symptoms, with one finding people with violent-related TBIs were more likely to report changes to vision and taste at 1 year post-injury (Gerhart et al., 2003) and have significantly higher overall symptom scores on the Rivermead Post-Concussional Questionnaire (Wenden et al., 1998). Three studies examined the presence of neuropsychological impairments but in most cases the comparisons were non-significant across tests of intelligence, memory, premorbid reading ability (a commonly used proxy for levels of premorbid intelligence) and executive function, with the exception of one finding in the study by Hanlon et al. (1999) that people with violence-related TBI performed more poorly on the Trail Making Test B, a measure of executive function.

Five studies reported on post-injury employment status, and while two smaller studies found significantly higher levels of unemployment among the violence-related TBIs (Bushnik et al., 2003; Schopp et al., 2006), this was not found at the $p<.01$ level in the three larger studies (Gerhart et al., 2003; Harrison-Felix et al., 1998; Machamer et al., 2003). One study (Dagher et al., 2010) reported outcome status at discharge from acute care for a group that mostly did not go onto inpatient or outpatient rehabilitation. People with violence-related TBIs had significantly better outcomes at discharge on the Glasgow-Outcome Scale-Extended compared to the non-violence group, with the mean score (3.57) sitting just over the moderate disability range.

The only measure reported at admission to inpatient rehabilitation was the Functional Independence Measure (FIM) (Linacre, Heinemann, Wright, Granger, & Hamilton, 1994). The FIM is a measure that rates the ability of a person to independently perform their own self-care, bowel and bladder function, personal mobility, cognition and communication, and appropriate social interactions within a social setting. Higher scores indicate greater independence, with the total score ranging from 18-126, with two subscales: FIM Motor (13 items, 13-91) and FIM Cognition (5 items, 5-35). Three studies reported admission FIM (Harrison-Felix et al., 1998; Kim, Bayley, Dawson, Mollayeva, & Colantonio, 2013; Schopp et al., 2006) with two finding that people with violence-related TBIs were significantly more independent than people with non-violent TBIs (Harrison-Felix et al., 1998; Kim, Bayley, et al., 2013). One study also found the violence group had higher FIM Total scores (Kim, Bayley, et al., 2013). There were no significant differences in FIM Cognitive scores. At the point of discharge from inpatient rehabilitation, most of these differences had disappeared, with only one study finding a significant difference in the FIM Motor scores (Kim, Bayley, et al., 2013), with the violence-related TBI group being more independent. Finally, people with

non-violent related TBIs made significantly greater gains in functional status (FIM scores) between Admission and Discharge.

Insert Table 5

At the follow-up time point, people with violence-related TBI demonstrated significantly poorer scores in scales evaluating productivity, economic self-sufficiency, social integration and recreation, (Bushnik et al., 2003; Harrison-Felix et al., 1998; Wagner et al., 2000). These results were found across a range of measures of participation (see Table 5). Follow-up was commonly conducted at one-year post-injury.

Service pathways and financial costs

The final domain examined for individuals with violence-related TBIs were the service pathways and financial costs (reported in 8/15 studies). Variables reported included acute length of stay, discharge disposition from the acute hospital setting, length of stay in inpatient rehabilitation, service-related costs, payer status and other heterogeneous variables (see Table 6). People with violence-related TBIs had significant shorter lengths of stay in both acute (Esselman et al., 2004; Kim, Bayley, et al., 2013) and inpatient rehabilitation settings (Harrison-Felix et al., 1998). They were also more likely to be discharged home instead of referred to rehabilitation (Dagher et al., 2010; Esselman et al., 2004). Four studies reported that violence-related injuries were more likely to be funded from the public purse than from private insurance (Esselman et al., 2004; Gerhart et al., 2003; Harrison-Felix et al., 1998; Schopp et al., 2006). Kim, Colantonio, Bayley & Dawson (2011) found that individuals with 'intentional injuries' had higher rates of discharge against medical advice and they associated this with a younger population who had a pre-morbid history of alcohol and drug abuse.

Insert Table 6

Impact on families or informal caregivers

Two studies were identified that reported on the impact of violence-related TBI on post-injury marital stability (Arango-Lasprilla et al., 2008; Kreutzer et al., 2007). In a multivariate model, Arango-Lasprilla and colleagues (2008) found that over the first 2 years post-injury, people with violence-related TBI were three times more likely to experience marital breakdown compared to people with non-violent TBI (Odds Ratio 2.99, 95% CI 1.55-5.75). Similarly, Kreutzer and colleagues (2007) found that people with violence-related TBI were three times more likely to have experienced marital breakdown up to eight years post-TBI (still married, 7 Violent vs. 93 Non-violent; separated/divorced, 24 Violent vs. 76 Non-violent; (statistically significant, chi-square).

Discussion

Across acute and rehabilitation service settings, the prevalence of violence-related TBI ranged between 3% and 26% as a proportion of all causes of TBI. There was a consistent profile of people at greatest risk of sustaining violence-related TBI and the associated outcomes. People sustaining TBIs through violence were more likely to be male, unemployed at the time of injury, with a pre-injury history of substance abuse and prior arrests, and to be single and/or living alone. In the context of the US, people at risk were also more likely to be from non-white or minority racial groups, however this finding did not generalize to other countries. The violence-etiology group was also more likely to have elevated Blood Alcohol Levels on admission to hospital, but less non-head related polytrauma compared to people sustaining TBI by other etiologies. There were few differences in outcomes based on symptom reports, neuropsychological tests or functional measures. However, the violence-related TBI group generally reported poorer FIM gain during inpatient rehabilitation than non-violent groups, and lower scores in the domain of participation at one year follow-up, particularly in areas of productivity and social integration.

In terms of navigating systems, people with violence-related TBI were more likely to draw on government-related supports (Medicaid) than private insurance and were more likely to be discharged home. Finally, the marriages of people with violence-related TBIs were at greater risk of breaking down post-injury compared to people with TBI from other etiologies.

Overall, the prevalence data may be either over-estimates (due to some studies aggregating self-inflicted violence with other-inflicted violence; aggregating intentional with accidental gunshot) or underestimates (e.g., some studies not taking into account that falls may also be due to violence) of the true rate of violence-related TBI. This problem was reflected particularly in decisions about which ICD (International Classification of Disease) E-codes (external causes of injury) would be included as representing violence (e.g., see Bushnik et al., 2003; Esselman et al., 2004; Harrison-Felix et al., 1998). Further investigation as to whether self-inflicted and other-inflicted etiologies have sufficient commonality to be grouped together will help improve consistency for future investigations into the prevalence of violence-related TBI.

It was clear from the pre-morbid and demographic data that violence-related TBI was strongly associated with a particular socio-economic profile (Bogner et al., 2001; Hanks et al., 2003; Harrison-Felix et al., 1998; Kim, Bayley, et al., 2013). However, the evidence for some variables (e.g. a younger age-group; poorer education levels) was not as strong once the more stringent criterion of $p<.01$ was applied, compared to variables such as sex, race and pre-injury employment status. The findings support the notion that people among poorer socio-economic groups may be more at risk of sustaining violent TBI (Harrison-Felix et al., 1998).

This socio-economic profile provides a confounding factor in determining the impact of violence-related TBI on outcomes including participation in health services and one year functional/participation status. Multivariate analyses in some studies (Bogner et al., 2001;

Gerhart et al., 2003; Harrison-Felix et al., 1998) found that socio-economic characteristics were the significant predictors for service use or scores on participation scales, rather than the injury etiology per se. Higher drop-out rates were also noted in some research studies among participants with violence-related TBI compared to people sustaining their TBI through other etiologies (Bogner et al., 2001; Machamer et al., 2003). This raises the concern that the samples in the studies identified in this review may not be representative of all people who sustain violence-related TBIs.

Pre-morbid alcohol abuse is associated with TBI more generally (Corrigan, 1995 cited in Bogner et al., 2001). The studies in the current review have extended this, finding a specific association between alcohol abuse and violence-related TBI, consistent with research in the general community of the links between alcohol and violence (Homel, Carvolth, Hauritz, McIlwain, & Teague, 2004). The frequent presence of elevated blood alcohol levels at time of injury is also well established in the TBI field (Corrigan, 1995 cited in Bogner et al., 2001), but the significantly higher levels associated with violence-related TBIs compared to other TBI etiologies has not been widely reported.

The review did not find a consistent difference in the pattern of injury severity, despite suggestions that people with violence-related TBIs might report less severe injuries. For example, (Alexander 1995 cited in Hanlon et al., 1999) has suggested that the inertial force generated by a blow to a stationary head is not equivalent to the inertial force generated by instantaneous deceleration typically experienced in road crashes. However, the findings from most studies which reported on this issue were inconclusive. This may be due in part because few studies were able to employ the best indicators of initial injury severity (duration of Post Traumatic Amnesia and/or Loss of Consciousness) and therefore further research is required. There has also been discussion of whether people surviving violence-related TBIs due to penetrating injuries (e.g. gunshot wounds) might have less severe injuries than people

experiencing blunt-force trauma (e.g. punch to the head), however one of the few studies to investigate this found little difference in outcomes between the two sub-groups (Zafonte et al., 1997). The higher level of polytrauma observed among people sustaining non-violent types of TBI (e.g. road-related) has also been observed in other studies (Grosswasser et al cited in Esselman et al., 2004), and is supported by the much higher rates of acute orthopedic surgery reported by this group (Dagher et al., 2010). These findings are consistent with the stronger forces associated with road crashes.

The overall lack of difference between violence and non-violence-related TBIs across most domains of outcomes reported in the studies is consistent with the lack of difference in initial injury severity. The significant differences in the amount of FIM gain observed during the episode of inpatient rehabilitation may reflect the lower levels of polytrauma experienced after violent-related TBIs. One domain rarely investigated among outcomes were the emotional consequences (with the exception of Machamer et al., 2003), and it may be that people who sustain the TBI through violence might experience greater levels of post-traumatic stress or other emotional sequelae associated with exposure to violence. Finally, the majority of studies only reported on outcomes up to the end of the first year post-injury, and so little is known about possible longer-term consequences.

People with violence-related TBI generally had a shorter length of stay when admitted to acute care or inpatient rehabilitation (Esselman et al., 2004; Harrison-Felix et al., 1998; Kim, Bayley, et al., 2013). In the US, there was strong evidence that people with violence-related TBIs were more likely to draw upon Medicaid funding (Esselman et al., 2004; Harrison-Felix et al., 1998; Schopp et al., 2006). This is consistent with the demographic features reported previously that suggest a lower socio-economic status.

The review found no studies that specifically investigated the impact of violence-related TBI on family members or informal caregivers, a paucity of research also observed by

Arango-Lasprilla et al. (2008). However, the two identified studies both found that violence-related TBI had an independent impact on post-injury marital stability. Neither paper was able to suggest a reason for this, apart from the broader impact of associated difficulties in productivity reported by people with violence-related TBI (Kreutzer et al., 2007). The results from the studies is consistent with one of the reports that focused on the individual with TBI (Bushnik et al., 2003).

In terms of the practice-based implications, studies within the review suggested that people with violence-related TBI comprised a distinct clinical sub-group within TBI (Kim, Bayley, et al., 2013). Particular approaches to improving the quality of life for this group need to be a focus for service providers (Hanks et al., 2003). To date, no specialized interventions have been reported (Kim, Bayley, et al., 2013) and this is an important area for future research.

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Table 1. Search Strategy

Population	
Informal caregivers	"carer*" OR "caregiver*" OR "caregiving" OR "family caregiving" OR "family" OR "families" OR "informal caregivers"
AND	
TBI	"traumatic brain injury" OR "TBI" OR "head injury" OR "brain injury" OR "brain injuries" OR "severe brain injury" OR "brain damage" OR "craniocerebral trauma"
AND	
Violence	"violence" OR "assault" OR "physical assault" OR "violent crime" OR "aggression" OR "aggressive behavior" OR "criminal justice system" OR "intentional injury"
AND	
Health Outcomes	
Psychosocial adjustment	"psychosocial adjust*" OR "quality of life" OR "mental health" OR "coping" OR "life satisfaction" OR "stress" OR "depression" OR "anxiety" OR "psychological" OR "burnout" OR "vicarious trauma" OR "depressive symptom*" OR "depressive disorder*" OR "satisfaction with life" OR "SWL" OR "caregiver burden*" OR "psychological distress" OR "caregiver distress" OR "QOL" OR "drugs" OR "alcohol" OR "self medication" OR "self-medication"
OR	
Family functioning	"family functioning" OR "family needs" OR "family adjustment" OR "family system" OR "family breakdown" OR "family engagement" OR "family structure" OR "spouse*" OR "sibling*" OR "parent*"
OR	
Navigating systems	"support system*" OR "services" OR "social support" OR "criminal justice system" OR "health system" OR "legal system" OR "service system" OR "non-government organi*ation" OR "NGO" OR "civil societ*" OR "police" OR "police officers" OR "hospital" OR "emergency" OR "rehabilitation unit" OR "social worker*" OR "psychologist*" OR "allied health" OR "lawyer*" OR "neuropsychiatrist*" OR "neuropsychologist*" OR "psychiatrist*" OR "accessibility" OR "community support" OR "patient caregiver advocate"

Table 2: Studies examining violence-related Traumatic Brain Injury

1st author, year, country	Study design	Service setting and Source of data	Definition of violence	N, Time Since Injury	Etiology and breakdown
Arango-Lasprilla (2008), USA	Retrospective Longitudinal, Multicenter	16 Traumatic Brain Injury Model Systems units (TBIMS) (acute care through to IP rehabilitation) TBIMS national database	Gunshot, blunt assaults, other violence	977 (*n* = 969 where cause of injury known) 2 years	Violent (*n* = 31) (3%) Non-violent (*n* = 714)
Bogner (2001), USA	Retrospective Longitudinal, Single Centre	TBI acute IP rehabilitation unit Patient medical records and telephone surveys	Injury resulting from an assault or a gunshot wound, including unintentional gunshot wounds	351 1 year	Violent (*n*=53) (15%) Non-violent (*n*=298)
Bushnik (2003), USA	Prospective Longitudinal, Multicenter	17 TBIMS units (acute care and inpatient rehabilitation) TBIMS national database	Not defined	1,170 1 year	Violence (*n*=250) (21%) Non violent (Vehicle *n*=629; falls *n*=188; other *n*=107)
Dagher (2010), Canada	Retrospective Cross-section Single centre	TBI Programme of the Montreal General Hospital (tertiary care centre) Patient medical records	Assault Cases excluded if mechanism of injury not clearly specified	415 Acute care phase	Assault (*n*=91) (22%) Motor vehicle collision (MVC) (*n*=324)
Esselman (2004), USA	Cross-section Single centre	Level 1 trauma centre Harborview Medical Center Trauma Registry	Not defined Based on ICD E-codes (not reported) Self-inflicted injury excluded	1,807 Acute care phase	Violent (*n*=286) (16%) Non-violent (*n*=1521)
Gerhart (2003), USA	Retrospective Longitudinal	Colorado hospitals Colorado Traumatic Brain Injury Registry and Follow-up System Follow-up interviews	Interpersonal or self-inflicted violence including gunshot wounds, attacks with other objects, fights and altercations, and the intentional pushing of one person by another	1,802 1 year	Violent (*n*=112) (6%) Non-violent (*n*=1689) Mechanisms for violent injuries (n=112) 91.1% inflicted by others during assaults, attacks, or other acts of aggression (5% firearms; 48% knives, other sharp/cutting instruments, or blunt objects; 47% assaults and/or pushes from high places). 7.9% self-inflicted (all gunshot wounds) 1% unknown

1st author, year, country	Study design	Service setting and Source of data	Definition of violence	N, TSI	Etiology and breakdown
Hanks (2003), USA	Prospective Longitudinal	Acute hospitalization and inpatient rehabilitation at four TBIMS Centres Medical records	All actions, either by self or by others, that caused a TBI (e.g. assault with a blunt or penetrating object, gunshot wound)	1,229 1 and 2 years	Violent (*n*=325) (26%) Non-violent (*n*=904)
Hanlon (1999), USA	Prospective Longitudinal	Outpatient concussion clinic Neuropsychological evaluation	Assault	100 3-40 months	Motor vehicle collisions (61%), Falls (11%), Assaults (10%), Falling object (10%), Sport/ Recreation (5%), Pedestrian (3%)
Harrison-Felix (1998), USA	Prospective Longitudinal	Four TBIMS Centres (acute care and inpatient rehabilitation) TBIMS Database	All self-inflicted and other person-inflicted causes; intentional use of weapons, attacks using vehicles, sports equipment (e.g. baseball bats) and other items.	803 1 year	Violent (*n*=234) Non-violent (*n*=569) Mechanisms for violent injuries (n=234) comprised 56% blunt assaults (e.g., blunt object, unarmed fight, jump); 23% penetrating objects (e.g., firearm injuries); 21% unknown
Kim (2011), Canada	Retrospective cohort	Acute care hospitals in Ontario Ontario Trauma Registry's Minimal Data Set	Intentional injury: self-inflicted, homicide/assault (ICD E-codes E950, E960, E969, E979)	15,684 Acute care phase	Intentional (*n*=1,770) (11%) Unintentional (*n*=13,914) Of intentional injuries: Other inflicted 62%, self-inflicted 38%
Kim, Bayley, et al. (2013), Canada	Prospective cohort	Inpatient rehabilitation Discharge Abstract Database National Rehabilitation Reporting System	Intentional injury: physical assault (self-inflicted not included)	1,564 Acute care & rehabilitation phase	Intentional (*n*=163) (10%) Unintentional (*n*=1401)
Kim, Colantonio, Dawson, and Bayley (2013), Canada	Retrospective cohort	Inpatient rehabilitation Discharge Abstract Database National Rehabilitation Reporting System	Intentional injury: homicide or assault (ICD E-codes E960, E969, E979) self-inflicted not included	243 3 to 6 months	Intentional (*n*=24) (10%) Unintentional (*n*=219)

1st author, year, country	Study design	Service setting and Source of data	Definition of violent	N, TSI	Etiology and breakdown
Kreutzer (2007), USA	Prospective longitudinal	Outpatient rehabilitation clinic Interviews, medical records, questionnaire (General Health and History Questionnaire)	Violence or assault	120 30 to 69 months	Violent (11%) Non-violent
Machamer (2003), USA	Secondary data analysis	Three prospective longitudinal trials Outpatient settings	Suicide attempts and assaults	752 1 year	Violent (*n*=113) (15%) Non-violent (*n*=631) Violent injuries: assault (*n*=101) and suicide attempts (*n*=12) Significantly higher dropout rate at 1 year V vs NV; 31% vs 21% (P<.05); Multivariate analysis found that it was other factors (sex, age and race) that predicted drop out rather than violent etiology.
Schopp (2006), USA	Prospective longitudinal	2 inpatient rehabilitation facilities, one acute rehabilitation hospital, one long-term rehabilitation hospital	Definite assault-related injury (evidence of intention to inflict harm) Probable assault-related injury and self-inflicted injuries were excluded	45 1 year	Violent (*n*=19) (42%) Non-violent (*n*=26)
Wagner (2000), USA	Prospective Cross-section	Level 1 trauma centre Carolinas Medical Center Trauma Registry	Intentional injury defined by an ICD-9 E-codes ranging from E950 to E976	2,637 Acute care setting	Intentional (*n* = 469) (17.8%) Unintentional (*n* = 2168) Intentional etiologies (*n*=469) included gunshot wounds (35%), assault (35%), stabbing (3%), other (explosive, jumping, suicide; 27%)
Wenden (1998), UK	Prospective longitudinal	Hospital trauma service Oxford Head Injury Service	Assault	625 (*n*=478 at follow up) 6 months	Assault (*n* = 90) (14%) Non-assaults (*n* = 417)

Note. IP Inpatient; ICD International Classification of Diseases; E External causes; TBIMS Traumatic Brain Injury Model Systems; V Violent; NV Non-violent

Table 3. Premorbid and demographic features (all findings at p<.01 or Bonferroni corrected)

1st author, year	Sex, % male V vs NV	Race, non-white V vs NV	Age (years) V vs NV	Not married V vs NV	Unemployed at injury V vs NV	Education V vs NV	Prior alcohol abuse V vs NV	Prior drug abuse V vs NV	Other V vs NV
Harrison-Felix (1998)	86% vs 74%	71% vs 42%	26-45 57% vs 41%	91% vs 69%	50% vs 24%	NS trend	NR	NR	Live alone 29% vs 16%
Bognor (2001)	96% vs 76%	32% vs 4%	NS	NS	51% vs 20%	NS trend	NS trend	NR	NR
Hanks (2003)	86% vs 72%	74% vs 46%	37±17 vs 36±13	NR	44% vs 21%	< HS degree 48% vs 39%	NR	NR	NR
Gerhart (2003)	83% vs 67%	40% vs 14%	25 -34 26% vs 18%	84% vs 64%	NS	NR	28% vs 11%	NS	Previous TBI NS
Bushnik (2003)	NS	56% vs NV	NS	86% vs NV	42% vs NV	NS	NS	46% vs NV	H'x of arrest 60% vs NV
Machamer (2003)	89% vs 77%	37% vs 12%	NS	NS	NR	NS	40% vs 23%	NS	Pre-existing conditions, yes 80% vs 61% H'x of arrest, yes 67% vs 40%
Esselman (2004)	91% vs 62%	44% vs 20%	34.8.0±11.5 vs 39.5±18.4	NR	NR	NR	NR	NR	NR
Schopp (2006)	NS	37% vs 0%	NS	NS	53% vs 8%	NS	NS	78% vs 38%	Perpetrator violence 57% vs 16%; Victim of violence 89% vs 21%
Dagher (2010)	92% vs 67%	NS	35.0±13.3 vs 42.0±19.6	NS trend	NS trend	NS at .01	54% vs 21%	43% vs 20%	Prior criminal record NS
Kim, Bayley, et al. (2013)	92% vs 75%	NR	16-24 32% vs 29%	NR	56% vs 35%	NR	NR	NR	Live alone 28% vs 17%

Note. NS Non significant; NR Not reported; TBI Traumatic brain injury; HS High school; H'x History; NV Non-violent;

Table 4 Injury and injury-related factors (all findings at p<.01 or Bonferroni corrected)

1st author, year	Injury severity V vs NV	BAL at admission V vs NV	Other traumatic injuries V vs NV
Harrison-Felix, (1998)	GCS at ED admission 9.6 vs 8.3 Highest GCS in 1st 24 hrs 10.9 vs 9.7	V vs NV, NS	NR
Hanks, (2003)	NS	93 mg/dL vs 67.1 mg/dL	NR
Gerhart, (2003)	GCS scores NS	NR	NR
Bushnik, (2003)	GCS at ED admission and Highest GCS in 1st 24 hrs V>Vehicle Loss of Consciousness, Duration of Post Traumatic Amnesia NS	NR	NR
Machamer, (2003)	GCS NS	142 mg/dL vs 87 mg/dL	NR
Esselman, (2004)	GCS NS	(≥80 mg/dL) legal limit 40% vs 25%	Highest other (non-head) body system AIS≥3 18% v 39%s AIS level 4 (head) 47% vs 34%
Schopp, (2006)	Loss of Consciousness NS	NR	NR
Dagher, (2010)	NS	33.5±28.7 mg/dL vs 10.9±21.4 mg/dL	Polytrauma 37.5% vs 84.5% ISS 23.3±12.2 vs 33.1±12.1
Kim, Bayley, et al. (2013)	NR	NR	Number of comorbidities, NS

Note. GCS Glasgow Coma Scale; NS non significant; NR Not recorded; ED Emergency Department; hrs hours; V Violent; NV Non-violent; AIS Abbreviated Injury Scale; ISS Injury Severity Score; mg/dL milligram per decilitre

Table 5 Outcomes (all findings at p<.01 or Bonferroni corrected)

1st author, year	Symptoms V vs NV	NP impair-ments V vs NV	Current un-employment V vs NV	Measures at acute care dc V vs NV	Measures at IP rehab admission V vs NV	Measures at IP rehab discharge V vs NV	Measures at follow-up V vs NV	Behaviour/ overall function V vs NV
Harrison-Felix, (1998)	NR	NR	NS	NR	FIM Motor 46 vs 40	FIM NS	1 year follow up FIM NS CIQ Social subscale 6.8 vs 8.0; Productivity 2.3 vs 3.2 Total 13.3 vs 16.0	Living alone/not with family 45% vs 32%
Wendon, (1998)	Rivermead Post-Concussion Q 13.7±13.9 vs 6.3±9.6	NR	NR	NR	NR	NR	NR	Rivermead Head Injury Follow-up Questionnaire 7.0±8.4 vs 3.0±5.6
Hanlon, (1999)	NR	Exec function Trail Making B V<NV	NR	NR	NR	NR	NR	NR
Wagner, (2000)	NR	NR	NR	NR	NR	NR	1 year follow up CIQ Total score V<NV	NR
Gerhart, (2003)	1 year follow-up Vision 47% vs 25% Taste 26% vs 16%	NR	NS	NA	NA	NA	1 year follow-up CHART Social integration 80.3 vs 86.4; Economic self-sufficiency 70.1 vs 83.3 Total 501.8 vs 531.4	NR

1st author, year	**Symptoms** **V vs NV**	**NP impair-ments** **V vs NV**	**Current un-employment** **V vs NV**	**Measures at acute care dc** **V vs NV**	**Measures at IP rehab admission** **V vs NV**	**Measures at IP rehab discharge** **V vs NV**	**Measures at follow-up** **V vs NV**	**Behaviour/ overall function** **V vs NV**
Bushnik, (2003)	NR	NR	70% vs NVI	NA	NR	DRS, FIM NS	1 year follow-up DRS 3.8±4.1 vs 2.4±3.1 CIQ Total 12.9±6.2 vs 16.1±5.8	FIM total change (Admission -discharge) 38.6±19.5 vs 44.2±22.2 Total change discharge - 1 yr post-injury DRS 2.3±3.3 vs 3.4±3.0 FIM total 15.4±15.5 vs 19.6±17.3
Machamer, (2003)	NR	Verbal intelligence; Performance intelligence; Trails A and B; Stroop A and B; Recall all NS	NS	NR	NR	NR	NR	Sickness Impact Score NS Brief Symptom Inventory Trend at $p<0.5$
Schopp, (2006)	NR	WAIS-R-7* WRAT3 WMS-R RAVLT Trails A, B All NS * Trend $p<.05$	NS Access Supplementa l Security Income 61% vs 12%	NR	FIM NS	FIM NS	NR	1 year follow-up Access Psychiatric Treatment NS Legal History NS
Dagher, (2010)	NR	NR	NR	Glasgow Outcome Scale-Extended 3.57 vs 4.29 FIM NS	NR	NR	NR	NR

1st author, year	**Symptoms** **V vs NV**	**NP impair-ments** **V vs NV**	**Current un-employment** **V vs NV**	**Measures at acute care dc** **V vs NV**	**Measures at IP rehab admission** **V vs NV**	**Measures at IP rehab discharge** **V vs NV**	**Measures at follow-up** **V vs NV**	**Behaviour/ overall function** **V vs NV**
Kim, Bayley, et al. (2013)	NR	NR	NR	NR	FIM Total 88.9±27.2 vs 79.6±30.2 FIM Motor 68.1±22.3 vs 59.5±25.0	FIM total NS at <.01 FIM Motor 84.9(12.8) vs 80.5(17.3)	NR	FIM total change (Admission – discharge) 22.4±21.1 vs 27.3±23.2
Kim, Colantonio, et al. (2013)	NR	NR	NR	NR	NR	NR	3-6 month follow- up RNLI Total score V<NV Daily functioning subscale V<NV Recreation V<NV Family role V<NV	NR

Note. V Violence; NV Non-violence; NR Not Reported; NS Non Significant; CHART Craig Handicap Assessment and Reporting Technique ; DRS Disability Rating Scale; CIQ Community Integration Questionnaire; DRS Disability Rating Scale; FIM Functional Independence Measure; WAIS-R-7 Weschler Adult Intelligence Scale – Revised – 7; WRAT3 Wide Range Achievement Test-3; WMS-R Weshler Memory Scale-Revised; RAVLT Rey Auditory Verbal Learning Test; RNLI Reintegration to Normal Living Index

Table 6 Costs (all findings at p<.01 or Bonferroni corrected)

1st author, year	Acute Length of Stay (days) V vs NV	DC disposition, Referral to IP rehabilitation? V vs NV	IP rehab LOS (days) V vs NV	Costs V vs NV	Payer status V vs NV	Other V vs NV
Harrison-Felix, (1998)	20 vs 25	NA	33 vs 41	1996 USD Acute LOS $81,000 vs $112,000	Medicaid Acute hospital >50% vs 21% Medicaid IP Rehab >50% vs 21%	NA
Gerhart, (2003)	NR	Discharge disposition NS	NR	NR	Government health care funding NS	V vs NV Rehabilitation/Therapy service use NS
Bushnik, (2003)	NS	NA	NS	NR	NR	NA
Esselman, (2004)	5.5±6.7 vs 9.2±10.6	Rehab vs Home Odds Ratio 0.54	NA	NR	Medicaid Acute hospital 54% vs 28%	NA
Schopp, (2006)	NR	NR	NR	NR	Medicaid Rehab 89% vs 33%	NA
Dagher, (2010)	NS	Discharged home 28.9% vs 11.5%	NA	NR	NR	V vs NV Orthopedic surgery 4.4% vs 34.6%
Kim, (2011)	NR	NR	NA	NR	NR	DAMA vs Regular discharge Other-inflicted 18% vs 7% Self-inflicted 8% vs 4%
Kim, Bayley, et al. (2013)	48.4±86.6 vs 56.8±100.6	NA	NS	NR	NR	Home without services 59% vs 52%

Note.V Violent; NV Non-violent; IP Inpatient; Rehab Rehabilitation; USD United States Dollars; LOS Length of Stay; NR Not Reported; NA Not Applicable; NS Non Significant; DAMA Discharge Against Medical Advice

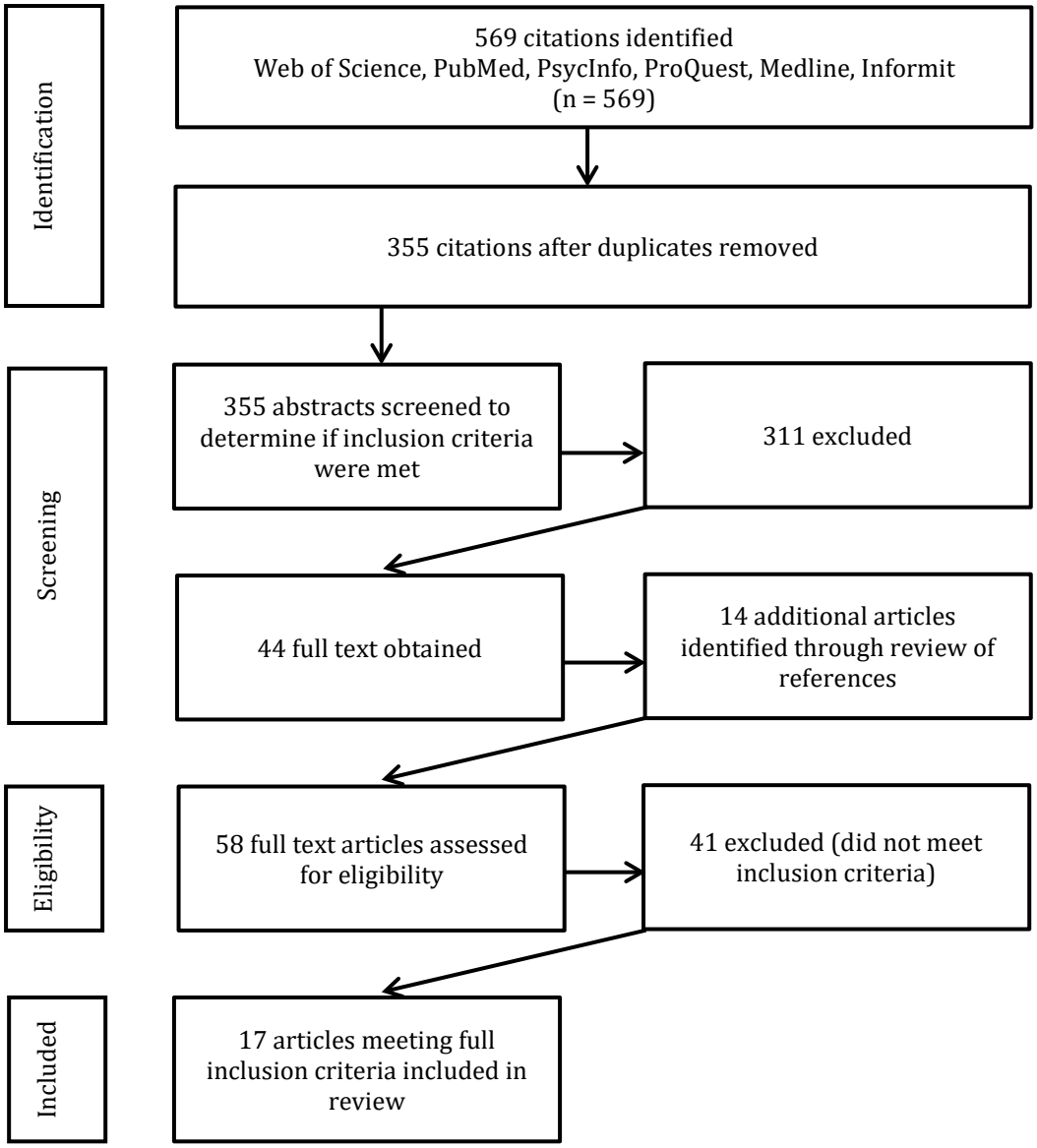

Figure 1. Literature review flowchart