JOURNAL OF NEUROTRAUMA 31:658–669 (April 1, 2014)
© Mary Ann Liebert, Inc.
DOI: 10.1089/neu.2013.3160

Contribution of Psychological Trauma to Outcomes after Traumatic Brain Injury: Assaults versus Sporting Injuries

Jane L. Mathias,[1] Yasmin Harman-Smith,[1] Stephen C. Bowden,[2] Jeffrey V. Rosenfeld,[3,4] and Erin D. Bigler[5,6]

Abstract

Clinical research into outcomes after traumatic brain injury (TBI) frequently combines injuries that have been sustained through different causes (e.g., car accidents, assaults, and falls), the effect of which is not well understood. This study examined the contribution of injury-related psychological trauma—which is more commonly associated with specific types of injuries—to outcomes after nonpenetrating TBI in order to determine whether it may be having a differential effect in samples containing mixed injuries. Data from three groups that were prospectively recruited for two larger studies were compared: one that sustained a TBI as a result of physical assaults (i.e., psychologically traumatizing) and another as a result of sporting injuries (i.e., nonpsychologically traumatizing), as well as an orthopedic control group (OC). Psychosocial and emotional (postconcussion symptoms, injury-related stress, and depression), cognitive (memory, abstract reasoning, problem solving, and verbal fluency), and functional (general outcome; resumption of home, social, and work roles) outcomes were all assessed. The $TBI_{assault}$ group reported significantly poorer psychosocial and emotional outcomes and higher rates of litigation (criminal rather than civil) than both the TBI_{sport} and OC groups approximately 6 months postinjury, but there were no differences in the cognitive or functional outcomes of the three groups. The findings suggest that the cause of a TBI may assist in explaining some of the differences in outcomes of people who have seemingly comparable injuries. Involvement in litigation and the cause of an injury may also be confounded, which may lead to the erroneous conclusion that litigants have poorer outcomes.

Key words: assault; outcome; post-traumatic stress; psychological trauma; sporting injury; traumatic brain injury

Introduction

Nonpenetrating traumatic brain injuries (TBI) cause a variety of cognitive, psychosocial, physical, and functional sequelae.[1] Although the severity of an injury is known to affect outcome after a TBI, it has limited prognostic value.[2–4] With mild TBIs (mTBIs), people typically experience a range of short-term postconcussive symptoms (PCSs) that usually resolve in the first few months after an injury; however, a substantial minority report experiencing long-term problems.[5–7] Moderate-to-severe injuries, on the other hand, are generally associated with poorer outcomes,[8–12] although outcomes can vary appreciably between injuries that are ostensibly similar in severity.[13,14] Consequently, it remains difficult to accurately predict outcomes at an individual, rather than group, level on the basis of injury severity.

A range of other variables have been found to affect outcome and explain some of this variability. In the case of mTBI, it is has been suggested that premorbid variables or psychological reactions may be more important because the sequelae often exceed what would be expected on the basis of the assumed injury.[15–17] Specifically, it is thought that pre-existing problems,[18] inflated recollections of premorbid ability (''good-old-days'' phenomenon),[18,19] diagnosis threat (poor performance resulting from expectations associated with a particular diagnosis),[6,20] stereotype threat (poor performance resulting from the pressure to perform at preinjury levels),[21] and/or disingenuous effort,[22] possibly motivated by financial compensation,[23] may contribute to poor outcomes after mTBI. Moreover, the fact that many symptoms are not specific to TBI has led to the suggestion that they may be better explained by other factors, such as depression and post-traumatic stress,[24] involvement in litigation,[19,25] or the stress associated with litigation.[21] The common link between these explanations is that outcome after mTBI is purportedly more affected by non-neurological factors than by the physical injury.

[1]School of Psychology University of Adelaide, Adelaide, South Australia, Australia.
[2]School of Psychological Sciences, University of Melbourne, Melbourne, Victoria, Australia.
[3]Division of Clinical Sciences and Department of Surgery, Monash University, Melbourne, Victoria, Australia.
[4]Department of Neurosurgery, Alfred Hospital, Melbourne, Victoria, Australia.
[5]Department of Psychology and Neuroscience, Brigham Young University, Provo, Utah.
[6]Department of Psychiatry, University of Utah, Salt Lake City, Utah.

Likewise, a range of variables are thought to contribute to the outcomes of people who have sustained moderate-to-severe injuries. Included among these are demographic variables, such as age,[26] gender,[27] and education,[28] as well as a range of premorbid characteristics, including a history of psychiatric and learning problems,[29,30] a previous TBI,[31–33] and preinjury alcohol and/or drug abuse.[34,35] Marital status, employment status, and high levels of alcohol intoxication at the time of injury,[34,36,37] as well as comorbid physical injuries,[35,39] are also reportedly related to outcome.[39]

Although there is evidence to suggest that there may be a relationship between these variables and outcome after TBI,[23,25,38] these relationships are far from simple and important confounds can easily be overlooked. For example, reports that people who are involved in litigation have higher rates of PCS[17,39] have led to the suggestion that they may be exaggerating their symptoms for the purposes of financial gain.[39,40] However, the cause of the TBI may also be contributing to this relationship. For instance, assault victims are more likely to be involved in criminal (and possibly civil) litigation stemming from the cause of their injury. Outcome after an assault may therefore be affected by both the TBI and the psychologically traumatizing circumstances of the injury,[21,41] even if the person does not meet the diagnostic criteria for post-traumatic stress disorder (PTSD). Thus, the psychological trauma experienced by victims of assault may contribute to poorer outcomes in this group, rather than the fact that they are involved in litigation.

Similarly, in Australia, people are more likely to be involved in civil litigation for the purposes of compensation after motor vehicle accidents (MVAs) than sporting injuries or falls, if only because third-party insurance for personal injuries caused by MVAs is mandatory (linked to car registration). Coincidentally, TBIs caused by MVAs may also differ from other causes because of the greater biomechanical forces associated with high-speed acceleration and deceleration injuries,[42–44] differences that may not be captured by our relatively course-grained measures of injury severity (Glasgow Coma Scale [GCS], loss of consciousness [LOC], post-traumatic amnesia [PTA]), but may be reflected in poorer outcomes (e.g., PCS). MVAs may also involve some degree of psychological trauma, which may additionally affect outcome.[15,21,45] Thus, although litigation status and outcome after TBI may be related, variables related to the cause of an injury (i.e., psychological trauma and/or biomechanical forces) may similarly be contributing to this relationship.

It may therefore be important to consider the *cause* of an injury in addition to its *severity* when examining outcome after TBI, particularly given that psychological trauma may be more common after certain types of injuries (e.g., MVAs or assaults) than others (e.g., sporting injuries or falls).[21,41] Whereas a number of studies have examined outcome after different causes of injury, their findings and methodologies are inconsistent. For example, it has variously been reported that MVAs result in more serious injuries, but better outcomes, than assaults and falls[46,47]; nonviolent TBIs (MVAs and falls) have better outcomes and less disability than violent TBIs (assaults and gunshot wounds)[48,49]; MVAs are more likely to lead to persistent problems than other causes[15]; and the cause of an injury does not independently predict outcome after controlling for age.[50] Importantly, many of these studies[50,51] have combined very different injuries into a single group (e.g., gunshot wounds, assaults, and sporting injuries),[47] examined a specific cause (e.g., assaults) but combined penetrating with nonpenetrating TBIs (e.g., gunshot wounds plus assaults),[46,48,49] excluded participants who were hospitalized but did not receive inpatient rehabilitation (therefore excluding mild and very severe injuries),[46,48] and/or only assessed outcome using rating scales (e.g., Glasgow Outcome Scale [GOS] and Disability Rating Scale)[47,50] or self-report measures (e.g., Symptom Impact Profile).[46,48,49] Still other studies have reported poorer outcomes in those who have sustained their injuries in psychologically traumatizing circumstances (e.g., MVAs or assaults).[45,51–53] However, to our knowledge, no study has undertaken a detailed examination, using both formal cognitive assessments and rating scales, of the effect of injury-related psychological trauma on outcomes subsequent to nonpenetrating TBIs in samples whose injuries arose from specific causes.

The present study examined whether TBIs (nonpenetrating) sustained in circumstances that are more psychologically traumatizing have poorer outcomes than those who sustain equivalent injuries through other causes. To this end, the psychosocial and emotional, cognitive, and functional outcomes of a group who sustained their TBI as a result of physical assaults ($TBI_{assault}$) were compared with those resulting from accidental sporting injuries (TBI_{sport}). An orthopedic control (OC) group was included to control for more general accident- and injury-related stress. Assaults were thought to be more psychologically traumatizing because they involved physical violence with intent to cause injury. Sporting injuries, on the other hand, occur while participating in an activity of the person's own choosing and, although they may involve physical violence or risk-taking, any associated harm is less likely to be malicious or criminal in intent. TBIs caused by MVAs were excluded in order to avoid the potentially confounding effects caused by the greater biomechanical forces involved in high-speed acceleration/deceleration injuries. Mild, moderate, and severe injuries were examined in order to capture a range of injuries and outcomes, and participants were assessed approximately 6 months after their injury in order to focus on any residual problems that arose from these injuries.[5–7] Litigation status was also considered.

Methods

Participants

Data for three groups of participants are reported: a group that had acquired their TBI during an assault that was intended to cause physical harm ($TBI_{assault}$; $N = 27$); another that sustained their TBI through sporting injuries (TBI_{sport}; $N = 26$); and an OC group who had not sustained a TBI (or experienced any LOC), did not have an injury to the head or face, and had not previously had a TBI (OC; $N = 36$; see Table 2 for summary demographic information). TBI severity was determined on the basis of the lowest recorded GCS score (mild, 13–15; moderate, 9–12; severe, ≤ 8), LOC (mild, < 20 min; moderate, ≥ 20 min to 6 h; severe, > 6 h), and/or PTA (mild, < 60 min; moderate, > 60 min to < 24 h; severe, ≥ 24 h). When the GCS, LOC, and PTA scores for a participant did not all fall into a single category, he or she was assigned to the most severe category. mTBIs were reclassified as moderate if hospital records indicated that there was a depressed skull fracture or if computed tomography/magnetic resonance imaging scans performed on the day of injury provided evidence of any form of hemorrhage or focal lesion.

Participants were excluded from any group if they had a preexisting neurological problem, English was a second language, or had serious physical problems that would prevent test completion (e.g., blindness or amputation). Participants who sustained their TBI as a consequence of domestic violence were not recruited into the study because of the risk that it might lead to further violence. All participants were recruited on a prospective basis from consecutive admissions to the Royal Adelaide (Adelaide, South Australia, Australia) and Alfred (Melbourne, Victoria, Australia) hospitals and were assessed approximately 6 months after their injury (see Table 2 for means and standard deviations [SDs]). The two TBI groups were predominately males ($TBI_{assault}$, 100%;

TBI_{sport}, 85%); therefore, only demographically matched males were selected from the pool of participants who were originally recruited into the OC group in order to avoid the potentially confounding effects of gender on outcome.[54–56] The OC group suffered orthopedic injuries to their upper ($N=14$) and lower limbs ($N=13$) or shoulders ($N=5$), lacerations ($N=2$), spinal injuries ($N=1$), and multi-site injuries ($N=1$), which were sustained during sporting ($N=14$) or bicycle accidents ($N=7$), falls ($N=6$), and motor vehicle ($N=2$) or other accidents (e.g., injured by machinery; $N=7$).

Measures

Demographic (age, gender, and education), injury-related (cause of injury, GCS, LOC, PTA, hospitalization, and litigation status), and background information was obtained from hospital records and participant interviews. In addition, the 10-item Alcohol Use Disorders Identification Test (AUDIT)[57] was administered by telephone at the time of recruitment to measure alcohol use over the preceding year (score range, 0–40; 0 = abstainer, 1–7 = low-risk alcohol consumption, 8–12 = risky/harmful alcohol use, and > 13 = dependence). The Modified Rey 15-item Memory Test[58] was used to screen for suboptimal effort (maximum total score, 30), with scores below 20 suggestive of malingering.[58]

Details for the measures of psychosocial and emotional (PCS,[59] injury-related stress,[60, 61] PTSD,[62] and depression[63]), cognitive (verbal memory, vocabulary, verbal and visual abstract reasoning, problem solving, and verbal fluency),[64–67] and functional (global outcome[68] and community integration[69]) outcomes are summarized in Table 1. The Rivermead PCS Questionnaire (RPCSQ)[59] was used to assess PCS on a continuous scale and determine the presence or absence of clinically diagnosable postconcussive syndrome (PCS_{synd}). Specifically, participants who rated three of the eight International Classification of Diseases, Tenth Edition, symptoms[70] as being moderate or severe were classified as having PCS_{synd} (RPCSQ items 1, 2, 5, 6, 7, 8/9, 10, and 11).

Procedure

Data were drawn from two recent studies on outcome after TBI that had ethics approvals from the participating hospitals (Royal Adelaide and Alfred hospitals) and Universities (Universities of Adelaide [Adelaide, South Australia, Australia] and Melbourne [Melbourne, Victoria, Australia]). Participants were recruited on a prospective basis and completed the self-report measures before attending a single test session (2–3 h). Detailed demographic and background information was collected during an initial interview and injury-related information was obtained from medical records.

Results

Comparability of the traumatic brain injury and orthopedic control groups

Overall, the three samples were comparable in terms of age and education and consisted largely of young to middle-aged males who had completed some postsecondary education (see Table 2). Unlike the TBI_{sport} group, the $TBI_{assault}$ and OC groups only included males, resulting in a significant difference in gender. This was not considered problematic because there were only 4 females (15%) in the TBI_{sport} group and, when examined, there were no gender differences on any of the outcome measures.

Mean GCS scores of the $TBI_{assault}$ and TBI_{sport} groups were comparable and there were similar numbers of participants who were classified as having mild and moderate-to-severe TBIs, with the majority classified as mild (Table 2). In addition, mean length of hospitalization (proxy measure of injury severity) was comparable across all three groups. In contrast, there were significant differences in mean time since injury, with the TBI_{sport} group being assessed slightly sooner (approximately 1.5 months) than both the $TBI_{assault}$ and OC groups.

As seen in Table 2, there were significant group differences in mean alcohol usage, which was also reflected in the categorization of drinkers (AUDIT scores). Specifically, the TBI_{sport} group had significantly lower mean AUDIT scores and fewer people in the ''risky'' and ''possible dependence'' categories than the $TBI_{assault}$ and OC groups.

In addition, significantly more participants in the $TBI_{assault}$ group were involved in legal proceedings, although it was not known if this was for criminal or civil purposes (see Table 2). When $TBI_{assault}$ litigants were subsequently approached for clarification, 7 of the 12 were still contactable. All 7 were involved in assault-related criminal proceedings and 3 sought modest financial compensation for out-of-pocket medical expenses (Note: all Australian residents are entitled to high-quality, government-subsidized public health care, which includes in- and out-patient public hospital care and rehabilitation, diagnostic assessments, specialist consultations, and subsidized medications), to replace damaged property, and/or legislated ''victims of crime'' payments for pain and suffering. Importantly, there were no group differences on the Modified Rey 15 Test, which was used to screen for test effort (Table 2); no participant in any group performed at a level suggestive of compromised effort; and all assessments were conducted entirely for research purposes (i.e., the results were not available for medicolegal or clinical purposes). Thus, it was considered unlikely that disingenuous performance contributed to the study findings.

Before examining group differences in outcomes, we examined the relationship between the two variables that differed between the groups—time since injury and alcohol use—and outcome. These analyses revealed that time since injury did not correlate with any outcome measure ($p > 0.01$), and AUDIT scores only correlated with immediate memory (Wechsler Memory Scale [WMS]-III Logical Memory; $r = -0.29$; $p < 0.01$). Thus, it was not considered necessary to statistically control for these variables when examining group differences in outcome.

Group differences in outcome

The current study sought to examine whether TBIs sustained in psychologically traumatizing circumstances are associated with poorer outcomes than injuries of equivalent severity that do not have this same psychological overlay. Three multivariate analyses of variance (MANOVAs) were performed to examine group differences in the measures of 1) psychosocial and emotional (RPCSQ scores, Impact of Event Scale/Impact of Event Scale-Revised [IES/IES-R] Intrusion and Avoidance subscale scores, and Beck Depression Inventory [BDI]-II scores), 2) cognitive (Wechsler Abbreviated Scale of Intelligence/Wechsler Adult Intelligence Scale [WASI/WAIS] Vocabulary, Block Design, Similarities, and Matrix Reasoning scaled scores, WMS Logical Memory-immediate and delayed recall, and Controlled Oral Word Association [COWA] total), and 3) functional (Extended GOS [GOS-E] and Community Integration Questionnaire [CIQ]) outcomes. Group (TBI_{sport}, $TBI_{assault}$, and OC) was the fixed factor.

Before conducting these analyses, Pearson's r correlations were calculated between measures of outcome to ensure that they were grouped appropriately[71] (see Table 3). With the exception of the CIQ home integration subscale, which did not correlate with any other measure of functional outcome, the measures correlated

Table 1. Summary Details for the Study Measures

Domain measure	Acronym	Variable	Description	Reference
Psychosocial and emotional outcome				
Rivermead Post Concussion Symptoms Questionnaire	RPCSQ	Postconcussion symptoms (PCSs)	Self-report measure asking how severely people were affected by 16 postconcussion symptoms (0 = not at all, 1 = no more of a problem, 2 = a mild problem, 3 = a moderate problem, 4 = a severe problem). Max score = 64	59
Impact of Events Scale/Impact of Events Scale-Revised	IES or IES-R	Injury-related psychological distress/trauma	Self-report scale designed to measure injury-related psychological distress. Scores for the Intrusion and Avoidance subscales (common to IES and IES-R) were used for present purposes. Subscale scores were converted to percentages because the response scales for the IES and IES-R varied slightly, enabling them to be analyzed together.	60, 61
Mini International Psychiatric Interview (Version 5), Post Traumatic Stress Disorder (PTSD) section	MINI	Post-traumatic stress disorder	Structured interview designed to screen for the presence/absence of PTSD	62
Beck Depression Inventory	BDI-II	Depression	21-item self-report scale designed to measure depression over the past week. Scores range between 0 and 63 (scores: 0–13 = minimal depression; 14–19 = mild depression; 20–28 = moderate depression; ≥29 severe depression)	63
Cognitive outcome				
Wechsler Memory Scale-III, Logical Memory Subtest	WMS-III LM	Verbal memory	LM immediate and delayed free recall of two stories; age-scaled scores used (M = 10; SD = 3)	64
Wechsler Adult Intelligence Scale-III or Wechsler Abbreviated Scale of Intelligence	WAIS-III WASI	Vocabulary, verbal, and visual abstract reasoning, problem solving	Vocabulary, Similarities, Block Design, and Matrix Reasoning subtests common to both tests. Age-scaled scores used (M = 10; SD = 3). The WASI consists of parallel versions of these four WAIS subtests. Scores on the WASI and WAIS III are highly correlated, making them suitable to combine.	65, 66
Controlled Oral Word Association test	COWA	Verbal fluency	Participants provide words beginning with the letters F, A, and S within three 1-min periods. Score: total number of correct responses.	67
Functional outcome				
Extended Glasgow Outcome Scale	GOS-E	General outcome	Structured interview designed to assess the overall effect of a TBI on a person's level of functioning using an 8-point scale (1 = deceased to 8 = upper good recovery)	68
Community Integration Questionnaire	CIQ	Community roles and activities	Self-report scale measuring the extent to which participants returned to their preinjury domestic, social, and occupational activities. Higher scores = better outcome (total score range, 0–29; CIQ-home, 0–10; CIQ-social, 0–12; CIQ-work, 0–7)	69

M, mean; SD, standard deviation.

TABLE 2. SUMMARY DEMOGRAPHIC AND BACKGROUND DATA FOR THE TBI_{SPORT}, $TBI_{ASSAULT}$, AND OC GROUPS

	Group								
	TBI_{sport} (n = 26)		*$TBI_{assault}$* (n = 27)		*OC* (n = 36)				
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	f	df	p *value*
Age (years)	28.5	9.6	34.3	16.8	34.4	12.4	1.91	2, 87	0.15
Education (years)	13.4	1.8	13.1	2.6	14.3	2.8	2.02	2, 87	0.14
GCS	14.4	1.4	14.0	2.6			0.41	1, 42	0.52
Time in hospital (days)	2.4	3.2	3.9	7.6	2.0	2.0	1.33	2, 87	0.27
Time since injury (months)	5.4	1.1	7.1	2.3	7.0	1.5	8.7[a]	2, 87	< 0.001
Alcohol use (AUDIT score)	4.8	3.1	9.1	5.8	7.5	4.1	7.24[b]	2, 87	< 0.01
Effort (Modified Rey 15)	29.3	1.5	28.5	2.3	29.3	1.4	1.99	2, 87	0.14
	N	%	N	%	N	%	χ^2	df	p *value*
Gender (male)	22	85	27	100	36	100	10.30	2, 90	< 0.01
Injury severity							0.23	1, 53	0.63
Mild	18	69	17	63					
Moderate/severe	8	31	10	37					
Alcohol use (AUDIT category)							45.79	6, 90	< 0.001
Abstainers	14	54	1	4	1	3			
Low-risk consumption	9	35	12	44	19	53			
Risky or harmful consumption	3	11	5	19	13	36			
Possible alcohol dependence	0	0	9	33	3	8			
Involved in legal proceedings (yes)	2	8	12	43	4	11	13.38	2, 90	< 0.01

[a]Least significant difference post-hoc comparison: TBI_{sport} assessed significantly sooner than $TBI_{assault}$ ($p < 0.01$) and OC ($p < 0.001$).
[b]Tamhane's post-hoc comparison: TBI_{sport} significantly lower AUDIT scores than $TBI_{assault}$ ($p < 0.01$) and OC ($p < 0.05$).
GCS, Glasgow Coma Scale; AUDIT, Alcohol Use Disorder Identification Test; TBI, traumatic brain injury; OC, orthopedic control; SD, standard deviation.

TABLE 3. PEARSON'S r CORRELATIONS BETWEEN THE OUTCOME MEASURES, WITHIN AND ACROSS DOMAINS

	Emotional				*Cognitive*							*Functional*			
Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Emotional															
1. RPCSQ	—	0.68†	0.67†	0.70†	−0.23*	−0.19	−0.24*	−0.23*	−0.16	−0.27*	−0.17	−0.64†	−0.02	−0.25*	−0.38†
2. IES-Intrusion		—	0.79†	0.52†	−0.17	−0.09	−0.26*	−0.28†	−0.20	−0.36†	−0.27*	−0.58†	−0.09	−0.23*	−0.30†
3. IES-Avoidance			—	0.47†	−0.06	−0.01	−0.21*	−0.26*	−0.21*	−0.36†	−0.22*	−0.43†	−0.11	−0.21	−0.25*
4. BDI-II				—	−0.26*	−0.13	−0.33†	−0.22*	−0.23*	−0.25*	−0.08	−0.54†	−0.18	−0.32†	−0.28†
Cognitive															
5. LM-Immediate					—	0.85†	0.42†	0.12	0.20	0.16	0.30†	0.45†	0.07	0.26*	0.11
6. LM-Delayed						—	0.39†	0.19	0.17	0.23*	0.29†	0.34*	0.05	0.19	0.02
7. Vocabulary							—	0.30†	0.67†	0.40†	0.47†	0.35*	0.26*	0.19	0.01
8. Block Design								—	0.38†	0.45†	0.20	0.31*	0.06	0.07	−0.06
9. Similarities									—	0.42†	0.39†	0.26	0.13	0.19	0.15
10. Matrix Reasoning										—	0.33†	0.29*	0.22*	0.04	0.09
11. COWA											—	0.28*	0.13	0.26*	0.17
Functional															
12. GOS-E												—	0.26	0.32*	0.46†
13. CIQ-Home													—	0.20	−0.15
14. CIQ-Social														—	0.28†
15. CIQ-Work															—

$N = 89$ for correlations in Emotional domain; $N = 52$ for correlations involving GOS-E.
$^{*}p < 0.05$; $^{\dagger}p < 0.01$.
RPCSQ, Rivermead Post Concussion Symptoms Questionnaire; IES-Intrusion, Intrusion subscale score of the Impact of Events Scale (IES or IES-R); IES-Avoidance, Avoidance subscale score of the Impact of Events Scale (IES or IES); LM-Immediate, Weschler Memory Scale (WMS)-III Logical memory Immediate recall; LM-Delayed, WMS-III Logical Memory Delayed recall; Vocabulary, Block Design, Similarities, and Matrix Reasoning—scaled scores from the Wechsler Abbreviated Scale of Intelligence or Wechsler Adult Intelligence Scale-III; GOS-E, Glasgow Outcome Scale, Extended version; CIQ, Community Integration Questionnaire.

within, but not across, outcome domains. Closer examination of the CIQ-home scores revealed a strong correlation with age (r[99], 0.43; $p<001$), reflecting the fact that younger participants were living with their parents and not actively involved in home duties. This subscale was therefore excluded from further analysis.

Psychosocial and emotional outcomes

Descriptively, all three groups reported low levels of ongoing PCS (RPCSQ; maximum score, 64), although the $TBI_{assault}$ group was experiencing more problems than the other two groups and showed greater within-group variability (see Table 4). This same pattern was evident for the measures of injury-related stress (IES; maximum score, 100) and depression (BDI; maximum score, 63), with all groups reporting low means and the $TBI_{assault}$ similarly reporting more symptoms and greater variability.

The MANOVA performed on the three measures of psychosocial and emotional outcomes revealed that there was a significant main effect for group (Wilk's $\Lambda=0.81$; $F(8,166)=2.33$; partial $eta^2=0.10$; $p<0.05$; Table 4). Specifically, groups differed in terms of their PCSs (RPCSQ; $TBI_{assault}$ more symptoms than TBI_{sport} and OC), injury-related psychological distress (IES/IES-R; $TBI_{assault}$ more intrusive thoughts than OC as well as more avoidance than TBI_{sport} and OC), and depression (BDI-II; $TBI_{assault}$ more depressed than TBI_{sport} and OC; Table 4). Although the assumption of homoscedasticity was violated (Box's $M=68.94$; $p<0.001$), this was a result of positive skew, rather than the presence of outliers, in which case the MANOVA remains robust.[72] Overall, group (cause of injury) accounted for 10% of the variance in psychosocial and emotional outcomes, which equates to a high-moderate effect size,[73] suggesting that the circumstances in which a TBI was sustained does appear to contribute to psychosocial and emotional outcomes.

In addition, we examined rates of PCS_{synd} (RPCSQ), PTSD (MINI), and clinical levels of depression (moderate to severe; BDI) within each sample as well as the number of participants who qualified for multiple diagnoses. Although mean scores for all groups were low, a subset of individuals reported experiencing problems at a level that met the criteria for a clinical diagnosis of PCS_{synd}, PTSD, or depression. As seen in Table 4, there were significant group differences in the number of cases of PCS_{synd}, PTSD, and clinically significant depression. Specifically, the $TBI_{assault}$ group had more people who met the diagnostic criteria for PCS_{synd}, PTSD, and moderate-to-severe depression ($TBI_{assault}=25\%$; $TBI_{sport}=8\%$; $OC=11\%$), indicating higher rates of psychopathology in this group. When multiple diagnoses were examined (Table 5), it was found that neither TBI_{sport} participant who showed evidence of PCS_{synd} suffered from PTSD, but 1 did have moderate levels of depression. Of the 8 participants who had PCS_{synd} in the $TBI_{assault}$ group, 3 additionally met the diagnostic criteria for PTSD, but were equally spread over the depression categories (minimal, mild, moderate, and severe), suggesting that PCS_{synd} and depression were relatively independent of one another. In addition, the 3 $TBI_{assault}$ participants with PCS_{synd} and PTSD showed moderate-to-severe symptoms of depression. Finally, only 1 individual from the OC group had symptoms equating to those observed in people with PCS_{synd}, together with minimal depressive symptoms, and no one had PTSD.

Cognitive outcomes. Overall, mean scaled scores for the WMS and WAIS/WASI subtests were mostly in the average to high-average range for all three groups (scaled scores are standardized to have mean = 10 and SD = 3; see Table 6), consistent with the relatively high educational levels of these samples. Normatively, cognitive performance of the three groups was generally good. The one exception was for the $TBI_{assault}$ group, which included participants who performed below average on the Logical Memory-Immediate test (< 7).

A MANOVA preformed on cognitive measures found that the dependent variables were normally distributed and the assumption of homoscedasticity was supported (Box's M, 83.95; $p=0.059$), but

Table 4. Summary Data for the Psychosocial and Emotional Outcome Measures

	TBI_{sport} (n = 26)		$TBI_{assault}$ (n = 27)		OC (n = 36)		ANOVA		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	F	df	p *value*
RPCSQ score	5.4	7.6	13.3	15.8	2.5	6.1	8.79[b]	2, 89	< 0.001
IES Intrusion (% score)	13.9	17.7	20.8	25.9	7.5	11.6	3.95[c]	2, 89	< 0.05
IES Avoidance (% score)	11.6	19.0	22.9	24.3	8.4	13.7	4.74[d]	2, 89	< 0.05
BDI-II	6.8	7.3	11.7	10.7	5.9	8.9	3.84[d]	2, 89	< 0.05
Clinical diagnoses	N	%	N	%	N	%	χ^2	*df*	p *value*
PCS_{synd} (RPCSQ)	2	8	8	29	1	3	11.0	2, 89	< 0.001
PTSD (MINI)	0	0	3	11	0	0	7.1	2, 89	< 0.05
Depression (BDI)							13.5	6, 89	< 0.05
Minimal	24	92	17	61	32	89			
Mild	0	0	4	14	0	0			
Moderate[a]	1	4	5	18	3	8			
Severe[a]	1	4	2	7	1	3			

[a]Clinically significant levels of depression.
[b]Least significant difference post-doc comparison: $TBI_{assault}$ significantly higher than TBI_{sport} ($p<0.01$) and OC ($p<0.001$).
[c]Least significant difference post-doc comparison: $TBI_{assault}$ significantly higher than OC ($p<0.01$).
[d]Least significant difference post-doc comparison: $TBI_{assault}$ significantly higher than TBI_{sport} ($p<0.05$) and OC ($p<0.01$).
RPCSQ, Rivermead Post Concussion Symptoms Questionnaire; IES, Impact of Events Scale (IES or IES-R); PCS_{synd}, postconcussion syndrome; PTSD, post-traumatic stress disorder; MINI, Mini International Psychiatric Interview; BDI, Beck Depression Inventory; TBI, traumatic brain injury; OC, orthopedic control; SD, standard deviation; ANOVA, analysis of variance.

Table 5. Number of Participants in Each Group Meeting the Diagnostic Criteria for Postconcussion Syndrome (PCS_{synd}), PTSD, and Depression

	PCS_{synd}	
	No N *(%)*	*Yes* N *(%)*
PTSD		
TBI_{sport}		
No	24 (92)	2 (8)
Yes	0	0
$TBI_{assault}$		
No	19 (70)	5 (19)
Yes	0	3 (11)[a]
OC		
No	35 (97)	1 (3)
Yes	0	0
Depression		
TBI_{sport}		
Minimal	23 (88)	1 (4)
Mild	0	0
Moderate	0	1 (4)
Severe	1 (4)	0
$TBI_{assault}$		
Minimal	15 (55)	2 (7)
Mild	2 (7)	2 (7)
Moderate	3 (10)	2 (7)
Severe	0	2 (7)
OC		
Minimal	31 (86)	1 (3)
Mild	0	0
Moderate	3 (8)	0
Severe	1 (3)	0

[a]One participant met the criteria for moderate depression and 2 for severe depression.

PTSD = post traumatic stress disorder; PCS_{synd} = postconcussion syndrome; TBI, traumatic brain injury; OC, orthopedic control.

failed to find a main effect for group (TBI_{sport}, $TBI_{assault}$, and OC) (Wilk's $\Lambda = 0.85$; $F(14,154) = 0.93$; partial $eta^2 = 0.078$; $p = 0.52$; see Table 6). Moreover, there were no group differences in any of the individual measures (Table 6), indicating that they had comparable cognitive outcomes. Interestingly, the cognitive performance of the TBI groups did not differ from that of the OC group, suggesting that the injuries sustained (predominantly mild) were not sufficient to cause lasting cognitive effects approximately 6 months postinjury.

Functional outcomes. Based on the summary descriptive data provided in Table 6, most of the TBI_{sport} group were classified as having a general functional recovery (GOS-E) that fell within the lower-good to upper-good recovery range (92%), as did most of the $TBI_{assault}$ group (75%). Thus, both groups reported having good global functional outcomes. In terms of community integration, all three groups reported social and work activity levels (mean + 1 SD) that fell within the upper range for this measure.

Two MANOVAs were performed on the functional measures to compare outcomes—one that analyzed the GOS-E and CIQ scores of the two TBI groups and one that excluded the GOS-E (measure is specific to TBI), but was based on the CIQ data for all three groups (see Table 6). The main effect for group was not significant in either analysis (TBI groups, GOS-E included: Wilk's $\Lambda = 0.90$; $F(3, 48) = 1.74$; partial $eta^2 = 0.098$; $p = 0.17$; three groups, GOS-E excluded: Wilk's $\Lambda = 0.92$; $F(4, 170) = 1.71$; partial $eta^2 = 0.039$; $p = 0.15$). Once again, the assumption of homoscedasticity was violated for these MANVOAs (Box's M, 18.41; $p < 0.01$ and Box's M, 17.53; $p < 0.05$, respectively), but this, too, reflected the fact that the distributions were negatively skewed (rather than the presence of outliers), suggesting that the MANOVA remains robust.[72] Similarly, there were no group differences for any of the individual measures, although the resumption of work activities approached significance. Thus, functional outcome was unrelated to the circumstances in which a TBI was sustained.

Discussion

The current study examined the contribution of injury-related psychological trauma to outcomes after nonpenetrating TBI in an attempt to improve our understanding of how the cause of an injury may contribute to the variability observed in patients who sustain similar injuries. Existing research has tended to focus on the contribution of premorbid and postinjury factors to outcome (e.g., disingenuous effort, postinjury stress, and depression),[16,17,74] and on demographic characteristics,[14,75] but has yet to adequately consider some of the variables that are more closely tied to the *cause* of an injury, such as the effect of any associated psychological trauma, on outcome.

For this reason, the psychosocial and emotional, cognitive, and functional outcomes of two TBI groups and an OC group that were recruited specifically for research purposes (the assessments were not performed for clinical or medicolegal purposes) on a prospective basis in a hospital setting were compared. The $TBI_{assault}$ group comprised people who had sustained mild, moderate, or severe TBIs as a result of physical assaults and who were assumed to have experienced high levels of injury-related psychological trauma. The TBI_{sport} group sustained injuries of equivalent severity while playing sport, which were not thought to be as traumatizing because they did not involve criminal physical threats to a person's safety or life. Last, the OC group served as an injury control group against which to compare outcomes while controlling for the general stressors associated with physical injuries (e.g., pain and hospitalization).

The three groups were assessed approximately 6 months postinjury and were well matched in terms of age (young to middle-aged adults), gender (predominantly males), education (late high school and above), length of hospitalization, and TBI severity (majority mild). Similarly, all groups performed comparably and at high levels on a screening measure of effort and performed within normal limits on the cognitive tests. This, combined with the fact that the data were collected entirely for research purposes and could not be used for litigation, suggests that participants were likely to be responding genuinely. In contrast, the groups differed in terms of their mean time since injury (TBI_{sport} group assessed slightly earlier), alcohol use (TBI_{sport} group had lower AUDIT scores), and involvement in legal proceedings (more $TBI_{assault}$ participants involved in litigation). Alcohol is often involved in assaults and accidental injuries,[76–78] so the higher AUDIT scores of these groups was not unexpected. However, when these variables were examined further, it was found that time since injury and alcohol use only correlated with one outcome measure (LM-immediate recall), for which there was no group difference. It was therefore concluded that time since injury and alcohol use were unlikely to substantially or differentially affect the outcomes of the three groups. Although the $TBI_{assault}$ group was more likely to be involved in litigation, this largely involved criminal proceedings or limited financial

Table 6. Summary Data for the Cognitive and Functional Measures

	TBI_{sport} (n=26)		$TBI_{assault}$ (n=27)		OC (n=36)		ANOVA		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	F	df	p *value*
Cognitive outcome									
WMS-III–Scaled score									
LM-Immediate	11.3	2.5	9.4	3.4	10.0	2.7	2.90	2, 83	0.061
LM-Delayed	11.5	3.0	9.9	2.9	10.3	2.6	2.41	2, 83	0.096
WAIS/WASI–Scaled score									
Vocabulary	12.7	2.2	12.0	3.9	12.8	3.1	0.58	2, 83	0.57
Block Design	13.4	2.2	12.6	2.5	12.6	2.3	1.02	2, 83	0.37
Similarities	12.2	2.1	11.3	3.2	11.4	3.3	0.84	2, 83	0.44
Matrix Reasoning	12.5	2.8	12.1	2.7	12.3	1.9	0.24	2, 83	0.79
COWA total correct	40.7	9.1	39.2	11.9	42.2	10.7	0.91	2, 83	0.41
Functional outcome									
GOS-Extended	7.4	1.3	6.7	1.9	N/A	N/A	2.43	1, 52	0.13
CIQ-Social	9.4	1.8	9.0	2.0	8.9	2.1	0.35	2, 86	0.71
CIQ-Work	6.0	0.8	5.1	1.7	5.6	1.4	3.07	2, 86	0.052
	N	%	N	%			χ^2	df	p *value*
GOS-E							3.1	4, 52	0.53
Upper good recovery=8	17	68	15	56					
Lower good recovery=7	6	24	5	19					
Upper moderate disability=6	0	0	0	0					
Lower moderate disability=5	0	0	1	4					
Upper severe disability=4	1	4	3	11					
Lower severe disability=3	1	4	3	11					

WMS-III, Wechlser Memory Scale, third edition; LM-Immediate, Logical Memory Immediate recall; LM-Delayed, Logical Memory Delayed recall; WAIS, Wechsler Adults Intelligence Scale, third edition; WASI, Wechsler Abbreviated Scale of Intelligence; COWA, Controlled Oral Word Association test; GOS-E, Glasgow Outcome Scale, Extended version; CIQ, Community Integration Questionnaire; TBI, traumatic brain injury; OC, orthopedic control; SD, standard deviation; ANOVA, analysis of variance; N/A, not applicable.

recompense (minor medical expenses, replacement of damaged property, or small victim of crime payment), rather than substantial monetary gain, suggesting that secondary gain was unlikely to contribute to the findings. Nevertheless, it is still possible that the stress associated with litigation, whether it was for criminal or civil purposes, may have affected the outcomes of this group.

When the groups were compared on measures designed to assess the consequences of a TBI, the $TBI_{assault}$ group was found to have significantly poorer psychosocial and emotional outcomes. Specifically, they reported more PCSs (RPCSQ) and injury-related stress (IES/IES-R), involving both intrusive thoughts and attempts to avoid reminders of the injury, as well more symptoms of depression (BDI). Indeed, our original assumption that the $TBI_{assault}$ group experienced more psychological trauma than the TBI_{sport} and OC groups was supported by our measures of injury-related psychological stress. Though the PCS and stress levels evident in the $TBI_{assault}$ group were largely subclinical, more participants in this group met the criteria for clinically diagnosable PCS_{synd}, PTSD, and depression. In contrast, the cognitive and functional outcomes of the three groups were generally good and comparable across all three samples. Indeed, neither TBI group had poorer cognitive or functional outcomes than the OC group.

These findings serve to highlight the fact that sustaining a TBI in psychologically traumatizing circumstances can have significant and independent effects on specific aspects of a person's recovery. Psychosocial and emotional outcomes may therefore be compromised, even when other aspects of a person's life are unaffected, although this does not exclude the possibility that cognitive and functional outcomes may also be detrimentally affected by such an injury. Indeed, the current failure to find evidence of cognitive and functional problems may have been influenced by the fact that the samples were well-educated, which may provide greater cognitive ''reserve'' and act as a buffer that lessens the effect of an injury[79–81]; the majority of injuries were mild, and most people could be expected to have recovered within this period;[16,17,82] within-group variability in outcomes may have masked some between-group differences; and sufficient time may have elapsed for subtle problems to have resolved, had they been present earlier.[83–85]

Interestingly, had the current study also found cognitive and/or functional problems in the $TBI_{assault}$ group, it would have left unanswered the question of causality—whether the psychosocial/emotional problems were contributing to the cognitive/functional problems of this group or whether the latter were contributing to the poor psychosocial/emotional outcomes (e.g., depression secondary to altered functioning). Instead, our results suggest that people who sustain their TBI in psychologically traumatizing circumstances have a poorer prognosis than those who do not have this additional complication, even if the effects are specific (psychosocial/emotional outcomes). Moreover, this difference may be overlooked when different, and potentially heterogeneous, types of injury (assaults, sports, motor vehicles, or falls) are combined and differentiated only by injury severity. Alternatively, the poorer outcomes associated with this group could mistakenly be attributed to their involvement in litigation because this group was more likely to be involved in litigation, albeit largely criminal proceedings. It is therefore likely that some within-group variability in outcomes after TBI is explained by the cause of the injury. In the current study, we examined TBI samples that differed in terms of psychological trauma, but it is also conceivable that other injury-related variables, such as differences in the biomechanical forces that are associated with different causes or in the regions of the brain that are injured, could also be important.

Overall, the current findings are consistent with research that reports a link between certain noninjury variables and outcome after TBI; however, it also offers an alternative explanation for some of these relationships. As with other research linking poorer outcomes with litigation,[25,38,86] the $TBI_{assault}$ group had poorer psychosocial and emotional outcomes than the TBI_{sport} and OC groups and was also more likely to be involved in litigation. However, upon closer examination, this group was largely involved in criminal proceedings, and, at most, the financial benefits were very modest. Thus, it is possible that the cause of an injury and involvement in litigation have previously been confounded, which could lead to the erroneous conclusion that the poorer outcomes of litigants reflects disingenuous performance. Poorer outcomes have also been linked with depression[24,87] and PTSD. [87] In this study, we examined a broad range of outcomes to capture the variety of areas that can be affected by a TBI. Our $TBI_{assault}$ group had poorer psychosocial and emotional outcomes, which was reflected in significantly higher levels of PCS, emotional distress, and depression, as well as more cases of PCS_{synd}, PTSD, and clinical levels of depression, than the TBI_{sport} and OC groups. However, this group did not experience poorer cognitive and functional outcomes, suggesting that these areas can be independently affected and that poor outcomes may be more related to the cause of an injury than previously thought.

Limitations and recommendations

There are a number of limitations with this study that should be used to temper the conclusions and inform future research. First, psychosocial/emotional and functional outcomes were only assessed using self-report measures. Although common practice, collateral reports from family and/or clinical interviews would be useful to corroborate these reports. In addition, the GOS-E does not adequately capture subtle differences in global outcomes, particularly after mTBIs, and should be replaced with a more sensitive measure. Second, the study would benefit from having a measure of psychological trauma that was administered around the time of the TBI to strengthen the link between trauma and outcome. At present, it is not possible to determine whether the injury-related psychological trauma was exacerbated by the protracted involvement of assault victims in criminal litigation. It would also be helpful to document the premorbid psychological histories of participants (e.g., history of anxiety, depression, and personality disorders as well as psychiatric treatments) to evaluate whether these factors affected outcomes.

Third, although participants were recruited prospectively (i.e., were not symptomatic referrals or insurance/medicolegal cases), we only recorded whether participants were involved in litigation or not. They were not originally questioned about specific types of litigation (criminal vs. civil) or, in the case of the financial compensation, the actual or potential amount. This proved problematic for the $TBI_{assault}$ group, 43% of whom were involved in litigation, potentially for criminal and/or financial reasons (compared to 8% and 11% in the TBI_{sport} and OC groups, respectively). We attempted to contact the $TBI_{assault}$ litigants to obtain this information; however, only 58% were contactable—all were involved in criminal proceedings and only a few sought modest financial compensation. Detailed information regarding litigation should therefore be routinely collected, including whether a person is involved in litigation (yes/no), type of litigation (criminal/civil), potential for financial compensation (yes/no), and the type (e.g., medical expenses, victim of crime, and pain/suffering) and amount of financial compensation. This limitation applies equally to many other studies that report on litigation status, but do not provide more details.

Fourth, although our TBI samples are likely to be representative because they were recruited prospectively, they were relatively small in size due to the specific cause of their injuries. Ideally, this study should be replicated using well-matched, but larger, samples that either examine a narrower severity range (mild, moderate, or severe) or include sufficient numbers of each to enable subgroup analyses of injury severity. Moreover, the mTBI category itself includes a broad range of injuries (i.e., LOC ranging between 0 and 20 min), which may have differing outcomes. Researchers should attempt to address this problem by additionally differentiating between concussion and mTBI.[88–90]

Fifth, the Modified Rey 15-item Memory Test was used to screen for suboptimal effort because the motivation to perform disingenuously was considered low in the current setting. This was based on the fact that participants were recruited through hospitals on a prospective basis, assessments were performed for research purposes only and not for clinical or medicolegal purposes, no feedback was provided to participants regarding their performance, and publicly funded health care was available to all participants, whether or not they had insurance or received compensation. All of this suggests minimal external incentives for poor or feigned performance. However, a more sensitive measure of effort is recommended in circumstances where the potential for financial gain is greater and/or the sample is more selected (e.g., insurance claimants or symptomatic referrals). Next, detailed imaging data were not available for our study participants. This information would add significantly to any future research on this topic. Finally, additional research is needed to examine the contribution of other injury-related variables to outcome, such as variation in the biomechanical forces that are associated with the different causes of TBI, and how and where neuropathological changes occur after TBI.

Conclusions

People who sustained their TBI in psychologically traumatizing circumstances (assaults) had poorer psychosocial and emotional outcomes, but comparable cognitive and functional outcomes, than those who acquired injuries of equivalent severity in less-traumatic circumstances (e.g., playing sport). Although not unexpected, our findings have very important implications because they suggest that outcome after TBI may differ according to the cause of an injury, and that involvement in litigation (criminal or civil) may be confounded with the cause of an injury (assault victims may be more likely to be involved in litigation), which could lead to the erroneous conclusion that litigants have poorer outcomes if the cause of an injury and the type of litigation is not also considered. The cause of a TBI therefore needs to be given greater consideration in clinical settings when considering prognosis and treatment, because emotional outcomes may be improved with targeted interventions for at-risk individuals who have sustained their TBI in psychologically traumatizing circumstances. This may extend beyond assault victims to other TBIs in which there is a serious threat to a person's life and/or safety (e.g., MVA). Similarly, researchers need to be aware that the cause of a TBI may be contributing to the variability in outcomes, and that both the cause and severity should be considered.

Acknowledgments

This research was funded by project grant nos. 207711 and 519220 from the National Health and Medical Research Foundation of Australia.

Author Disclosure Statement

E.D.B. is codirector of the Neuropsychological Assessment and Research Clinic at Brigham Young University (Provo, UT), which provides forensic assessments (please note that none of the participants in this study were recruited at this site).

References

1. Bagiella, E., Novack, T.A., Ansel, B., Diaz-Arrastia, R., Dikmen, S., Hart, T., and Temkin, N. (2010). Measuring outcome in traumatic brain injury treatment trials: recommendations from the traumatic brain injury clinical trials network. J. Head Trauma Rehabil. 25, 375–382.
2. Hoffman, J.M., Lucas, S., Dikmen, S., Braden, C.A., Brown, A.W., Brunner, R., Diaz-Arrastia, R., Walker, W.C., Watanabe, T.K., and Bell, K.R. (2011). Natural history of headache after traumatic brain injury. J. Neurotrauma 28, 1719–1725.
3. Rickels, E., von Wild, K., and Wenzlaff, P. (2010). Head injury in Germany: a population-based prospective study on epidemiology, causes, treatment and outcome of all degrees of head-injury severity in two distinct areas. Brain Inj. 24, 1491–1504.
4. Podell, K., Gifford, K., Bougakov, D., and Goldberg, E. (2010). Neuropsychological assessment in traumatic brain injury. Psychiatr. Clin. North Am. 33, 855–876.
5. Williams, W.H., Potter, S., and Ryland, H. (2010). Mild traumatic brain injury and postconcussion syndrome: a neuropsychological perspective. J. Neurol. Neurosurg. Psychiatry 81, 1116–1122.
6. Suhr, J.A., and Gunstad, J. (2005). Further exploration of the effect of ''diagnosis threat'' on cognitive performance in individuals with mild head injury. J. Int. Neuropsychol. Soc. 11, 23–29.
7. Arciniegas, D.B., Anderson, C.A., Topkoff, J., and McAllister, T.W. (2005). Mild traumatic brain injury: a neuropsychiatric approach to diagnosis, evaluation, and treatment. Neuropsychiatr. Dis. Treat. 1, 311–327.
8. Garnett, M., Blamire, A., Rajagopalan, B., Styles, P., and Cadoux-Hudson, T. (2000). Evidence of cellular damage in normal-appearing white matter correlates with injury severity in patients following traumatic brain injury: a magnetic resonance spectroscopy study. Brain 123, 1403–1409.
9. Lee, S.-Y., Kim, S., Kim, C.-H., Park, S.-W., Park, J.H., and Yeo, M. (2012). Prediction of outcome after traumatic brain injury using clinical and neuroimaging variables. J. Clin. Neurol. 8, 224–229.
10. Hoofien, D., Vakil, E., Gilboa, A., Donovick, P., and Barak, O. (2002). Comparison of the predictive power of socio-economic variables, severity of injury and age on long-term outcome of traumatic brain injury: sample-specific variables versus facjtors as predictors. Brain Inj. 16, 9–27.
11. MRC CRASH Trial Collaborators. (2008). Predicting outcome after traumatic brain injury: practical prognostic models based on large cohort of international patients. Br. Med. J. 336, 425–429.
12. Dikmen, S.S., Corrigan, J.D., Levin, H.S., Machamer, J., Stiers, W., and Weisskopf, M.G. (2009). Cognitive outcome following traumatic brain injury. J. Head Trauma Rehabil. 24, 430–438.
13. Reynolds, S. (2011). Predicting outcome after traumatic brain injury. J. Intensive Care Soc. 12, 196–200.
14. de Oliveira Thais, M., Cavallazzi, G., Formola, D., Castro, L., Schmoeller, R., Guarnieri, R., Schwarzbold, M., Diaz, A., Hohl, A., Prediger, R., Mader, M., Linhares, M., Staniloiu, A., Markowitsch, H., and Walz, R. (2012). Limited predictive power of hospitalization variables for long-term cognitive prognosis in adult patients with severe traumatic brain injury. J. Neuropsychol. Nov 20. doi: 10.1111/jnp.12000. [Epub ahead of print]
15. Ponsford, J., Willmott, C., Rothwell, A., Cameron, P., Kelly, A.-M., Nelms, R., Curran, C., and Ng, K. (2000). Factors influencing outcome following mild traumatic brain injury in adults. J. Int. Neuropsychol. Soc. 6, 568–579.
16. Ponsford, J., Grant, M., Cameron, P., Fitzgerald, M., Mikocka-Walus, A., and Schonberger, M. (2012). Predictors of postconcussive symptoms 3 months after mild traumatic brain injury. Neuropsychology 26, 304–313.
17. Mooney, G., Speed, J., and Sheppard, S. (2005). Factors related to recovery after mild traumatic brain injury. Brain Inj. 19, 975–987.
18. Iverson, G.L., Lange, R.T., Brooks, B.L., and Rennison, V.L. (2010). ''Good old days'' bias following mild traumatic brain injury. Clin. Neuropsychol. 24, 17–37.
19. Lange, R.T., Iverson, G.L., and Rose, A. (2010). Post-concussion symptom reporting and the ''good-old-days'' bias following mild traumatic brain injury. Arch. Clin. Neuropsychol. 25, 442–450.
20. Silverberg, N.D., and Iverson, G.L. (2011). Etiology of the post-concussion syndrome: Physiogenesis and psychogenesis revisited. NeuroRehabilitation 29, 317–329.
21. Silver, J.M. (2012). Effort, exaggeration and malingering after concussion. J. Neurol. Neurosurg. Psychiatry 83, 836–841.
22. Ord, J.S., Greve, K.W., Bianchini, K.J., and Aguerrevere, L.E. (2010). Executive dysfunction in traumatic brain injury: the effects of injury severity and effort on the Wisconsin Card Sorting Test. J. Clin. Exp. Neuropsychol. 32, 132–140.
23. Iverson, G.L., and Binder, L.M. (2000). Detecting exaggeration and malingering in neuropsychological assessment. J. Head Trauma Rehabil. 15, 829–858.
24. Iverson, G.L., and Lange, R.T. (2003). Examination of ''postconcussion-like'' symptoms in a healthy sample. Appl. Neuropsychol. 10, 137–144.
25. Belanger, H.G., Curtiss, G., Demery, J.A., Lebowitz, B.K., and Vanderploeg, R.D. (2005). Factors moderating neuropsychological outcomes following mild traumatic brain injury: a meta-analysis. J. Int. Neuropsychol. Soc. 11, 215–227.
26. Maas, A.I., Stocchetti, N., and Bullock, R. (2008). Moderate and severe traumatic brain injury in adults. Lancet Neurol. 7, 728–741.
27. Ponsford, J., Myles, P., Cooper, D., Mcdermott, F., Murray, L., Laidlaw, J., Cooper, G., Tremayne, A., and Bernard, S. (2008). Gender differences in outcome in patients with hypotension and severe traumatic brain injury. Injury 39, 67–76.
28. Mushkudiani, N.A., Engel, D.C., Steyerberg, E.W., Butcher, I., Lu, J., Marmarou, A., Slieker, F., McHugh, G.S., Murray, G.D., and Maas, A.I. (2007). Prognostic value of demographic characteristics in traumatic brain injury: results from the IMPACT study. J. Neurotrauma 24, 259–269.
29. Whelan-Goodinson, R., Ponsford, J., Johnston, L., and Grant, F. (2009). Psychiatric disorders following traumatic brain injury: their nature and frequency. J. Head Trauma Rehabil. 24, 324–332.
30. Fann, J., Burington, B., Leonetti, A., Jaffe, K., Katon, W., and Thompson, R. (2004). Psychiatric illness following traumatic brain injury in an adult health maintenance organization population. Arch. Gen. Psychiatry 61, 53–61.
31. Cameron, C.M., Purdie, D.M., Kliewer, E.V., and McClure, R.J. (2008). Ten-year outcomes following traumatic brain injury: a population-based cohort. Brain Inj. 22, 437–449.
32. Whitnall, L., McMillan, T., Murray, G., and Teasdale, G. (2006). Disability in young people and adults after head injury: 5–7 year follow up of a prospective cohort study. J. Neurol. Neurosurg. Psychiatry 77, 640–645.
33. Ownsworth, T., and McKenna, K. (2004). Investigation of factors related to employment outcome following traumatic brain injury: a critical review and conceptual model. Disabil. Rehabil. 26, 765–784.
34. Harrison-Felix, C., Kreider, S., Arango-Lasprilla, J., Brown, A., Dijkers, M., Hammond, F., Kolakowsky-Hayner, S., Hirshson, C., Whiteneck, G., and Zasler, N. (2012). Life expectancy following rehabilitation: A NIDRR traumatic brain Injury model systems study. J. Head Trauma Rehabil. 27, E69–E80.
35. Baguley, I., Nott, M., Howle, A., Simpson, G., Browne, S., King, A., Cotter, R., and Hodgkinson, A. (2012). Late mortality after severe traumatic brain injury in New South Wales: a multicentre study. Med. J. Aust. 196, 40–45.
36. Opreanu, R., Kuhn, D., and Basson, M. (2010). Influence of alcohol on mortality in traumatic brain injury. J. Am. Coll. Surg. 210, 997–1007.

37. Davis, L., Sherer, M., Sander, A., Bogner, J., Corrigan, J., Dijkers, M., Hanks, R., Bergquist, T., and Seel, R. (2012). Preinjury predictors of life satisfaction at 1 year after traumatic brain injury. Arch. Phys. Med. Rehabil. 93, 1324–1330.
38. Carroll, L.J., Cassidy, J.D., Peloso, P.M., Borg, J., von Holst, H., Holm, L., Paniak, C., and Pépin, M. (2004). Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J. Rehabil. Med. Suppl. 43, 84–105.
39. Paniak, C., Reynolds, S., Toller-Lobe, G., Melnyk, A., Nagy, J., and Schmidt, D. (2002). A longitudinal study of the relationship between financial compensation and symptoms after treated mild traumatic brain injury. J. Clin. Exp. Neuropsychol. 24, 187–193.
40. Ryan, L., and Warden, D. (2003). Post concussion syndrome. Int. Rev. Psychiatry 15, 310–316.
41. Stein, M.B., and McAllister, T.W. (2009). Exploring the convergence of posttraumatic stress disorder and mild traumatic brain injury. Am. J. Psychiatry 166, 768–776.
42. Bayly, P.V., Clayton, E.H., and Genin, G.M. (2012). Quantitative imaging methods for the development and validation of brain biomechanics models. Annu. Rev. Biomed. Eng. 14, 369–396.
43. Yoganandan, N., Baisden, J., Maiman, D., Gennarelli, T., Guan, Y., Pintar, F., Laud, P., and Ridella, S. (2010). Severe-to-fatal head injuries in motor vehicle impacts. Accid. Anal. Prev. 42, 1370–1378.
44. Eid, H., and Abu-Zidan, F. (2007). Biomechanics of road traffic collision injuries: a clincian's perspective. Singapore Med. J. 48, 693–700.
45. McCauley, S.R., Boake, C., Levin, H.S., Contant, C.F. and Song, J.X. (2001). Postconcussional disorder following mild to moderate traumatic brain injury: anxiety, depression, and social support as risk factors and comorbidities. J. Clin. Exp. Neuropsychol. 23, 792–808.
46. Bushnik, T., Hanks, K.R., Kreutzer, J., and Rosenthal, M. (2003). Etiology of traumatic brain injury: characterization of differential outcomes up to 1 year postinjury. Arch. Phys. Med. Rehabil. 84, 255–262.
47. Majdan, M., Mauritz, W., Brazinova, A., Rusnak, M., Leitgeb, J., Janciak, I., and Wilbacher, I. (2011). Severity and outcome of traumatic brain injuries (TBI) with different causes of injury. Brain Inj. 25, 797–805.
48. Hanks, R.A., Wood, D.L., Millis, S.R., Harrison-Felix, C., Pierce, C.A., Rosenthal, M., Bushnik, T., High, W.M., Jr., and Kreutzer, J. (2003). Violent traumatic brain injury: occurrence, patient characteristics, and risk factors from the Traumatic Brain Injury Model Systems Project. Arch. Phys. Med. Rehabil. 84, 249–254.
49. Gerhart, K.A., Mellick, D.C., and Weintraub, A.H. (2003). Violence-related traumatic brain injury: a population-based study. J. Trauma 55, 1045–1053.
50. Butcher, I., McHugh, G.S., Lu, J., Steyerberg, E.W., Hernandez, A.V., Mushkudiani, N., Maas, A.I., Marmarou, A., and Murray, G.D. (2007). Prognostic value of cause of injury in traumatic brain injury: results from the IMPACT study. J. Neurotrauma 24, 281–286.
51. Blanchard, E.B., and Hickling, E.J. (2003). *After the Crash: Psychological Assessment and Treatment of Survivors of Motor Vehicle Accidents*. Second ed. American Psychological Association: Washington, DC.
52. Butler, D.J., Moffc, H.S., and Turkal, N.W. (1999). Post-traumatic stress reactions following motor vehicle accidents. Am. Fam. Physician 60, 524–530.
53. Hours, M., Chossegros, L., Charnay, P., Tardy, H., Nhac-Vu, H.-T., Boisson, D., Luauté, J., and Laumon, B. (2013). Outcomes one year after a road accident: results from the ESPARR cohort. Accid. Anal. Prev. 50, 92–102.
54. Rosenfield, S. (1980). Sex differences in depression: do women always have higher rates? J. Health Soc. Behav. 21, 33–42.
55. Fullerton, C.S., Ursano, R.J., Epstein, R.S., Crowley, B., Vance, K., Kao, T.-C., Dougall, A., and Baum, A. (2001). Gender differences in posttraumatic stress disorder after motor vehicle accidents. Am. J. Psychiatry 158, 1486–1491.
56. Kessler, R.C., Berglund, P., Demler, O., Jin, R., Koretz, D., Merikangas, K.R., Rush, A.J., Walters, E.E., and Wang, P.S. (2003). The epidemiology of major depressive disorder: results from the National Comorbidity Survey Replication (NCS-R). JAMA 289, 3095–3105.
57. Babor, T.F., de la Fuente, J. R., Saunders, J. B., and Grant, M. (1989). AUDIT: the Alcohol Disorders Identification Test. World Health Organization: Geneva.
58. Boone, K.B., Salazar, X., Lu, P., Warner-Chacon, K., and Razani, J. (2002). The Rey 15-Item Recognition Trial: a technique to enhance sensitivity of the Rey 15-Item Memorization Test. J. Clin. Exp. Neuropsychol. 24, 561–573.
59. King, N.S., Crawford, S., Wenden, F.J., Moss, N.E.G., and Wade, D.T. (1995). The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. J. Neurol. 242, 587–592.
60. Horowitz, M., Wilner, N., and Alvarez, W. (1979). Impact of Events Scale: a measure of subjective stress. Psychom. Med. 41, 209–218.
61. Weiss, D.S., and Marmar, C.R. (1996). Impact of Event Scale-Revised (IES-R), in: *Assessing Psychological Trauma and PTSD*. J.P. Wilson and T.M. Keane (eds). Guilford Press: New York, pps. 399–411.
62. Sheehan, D.V., Lecrubier, Y., Harnett-Sheehan, K., Amorim, P., Janavs, J., Weiller, E., Hergueta, T., Barker, R., and Dundar, G. (1998). The Mini International Neuropsychiatric Interview (MINI): the development and validation of a structured diagnostic psychiatric interview. J. Clin. Psychiatry 59, 22–30.
63. Beck, A.T., Steer, R.A., and Brown, G.K. (1996). *Beck Depression Inventory*. Second ed. Psychological Corporation: San Antonio, TX.
64. Wechsler, D. (1997). *Wechsler Memory Scale*—Third Edition. Psychological Corporation: San Antonio, TX.
65. Wechsler, D. (1997). *Wechsler Adult Intelligence Scale*—Third Edition. Psychological Corporation: New York.
66. Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence*. Harcourt Brace & Company: San Antonio, TX.
67. Spreen, O., and Straus, E. (1998). *Compendium of Neuropsychological Tests.* Vol. 2. Oxford University Press: New York.
68. Wilson, J.T.L., Pettigrew, L.E.L., and Teasdale, G.M. (1998). Structured interviews for the Glasgow Outcome Scale and the Extended Glasgow Outcome Scale: guidelines for their use. J. Neurotrauma 15, 573–585.
69. Willer, B., Rosenthal, M., Kreutzer, J.S., Gordon, W.A., and Rempel, R. (1994). Assessment of community integration following rehabilitation for traumatic brain injury. J. Head Trauma Rehabil. 8, 75–87.
70. World Health Organisation (1992). The ICD-10 Classification of Mental and Behavioural Disorders: Clinical descriptions and diagnostic guidelines. International Statistical Classification of Diseases and Related Health Problems (10th ed.): Geneva.
71. Meyers, L.S., Gamst, G. and Guarino, A. (2006). *Applied Multivariate Research: Design and Interpretation*. Sage: Thousand Oaks, CA.
72. Tabachnick, B.G. and Fidell, L.S. (2007). *Using Multivariate Statistics*, 5th ed. Pearson Education: Boston, MA.
73. Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*, Second ed. Psychology Press: New York.
74. Hou, R., Moss-Morris, R., Peveler, R., Mogg, K., Bradley, B., and Belli, A. (2012). When a minor head injury results in enduring symptoms: a prospective investigation of risk factors for post-concussional syndrome after mild traumatic brain injury. J. Neurol. Neurosurg. Psychiatry 83, 217–223.
75. Jeon, I.-C., Kim, O.-L., Kim, M.-S., Kim, S.-H., Chang, C.-H., and Bai, D.-S. (2008). The effect of premorbid demographic factors on the recovery of neurocognitive function in traumatic brain injury patients. J. Korean Neurosurg. Soc. 44, 295–302.
76. World Health Organization. (2007). Alcohol and injury in emergency departments: summary of the report from the WHO Collaborative Study on Alcohol And Injuries. World Health Organization: Geneva.
77. World Health Organization. (2011). Global status report on alcohol and health. World Health Organization: Geneva.
78. Macdonald, S., Wells, S., Giesbrecht, N., and Cherpitel, C.J. (1999). Demographic and substance use factors related to violent and accidental injuries: results from an emergency room study. Drug Alcohol Depend. 55, 53–61.
79. Kesler, S., Adams, H., Blasey, C., and Bigler, E. (2003). Premorbid intellectual functioning, education, and brain size in traumatic brain injury: an investigation of the cognitive reserve hypothesis. Appl. Neuropsychol. 10, 153–162.
80. Salmond, C., Menon, D., Chatfield, D., Pickard, J., and Sahakian, B. (2006). Cognitive reserve as a resilience factor against depression after moderate/severe head injury. J. Neurotrauma 23, 1049–1058.
81. Spitz, G., Ponsford, J., Rudzki, D., and Maller, J. (2012). Association between cognitive performance and functional outcome following traumatic brain injury: a longitudinal multilevel examination. Neuropsychology 26, 604–612.

82. Carroll, L., Cassidy, D., Holm, L., Kraus, J., and Coronado, V. (2004). Methodological issues and research recommendations for mild traumatic brain injury: The WHO Collaborating Center Task Force on Mild Traumatic Brain Injury. J. Rehabil. Med. Suppl. 113–125.
83. Ponsford, J., Cameron, P., Fitzgerald, M., Grant, M., and Mikocka-Walus, A. (2011). Long-term outcomes after uncomplicated mild traumatic brain injury: a comparison with trauma controls. J. Neurotrauma 28, 937–946.
84. León-Carrión, J., and Machuca-Murga, F. (2001). Spontaneous recovery of cognitive functions after severe brain injury: when are neurocognitive sequelae established? Rev. Esp. Neuropsicol. 3, 58–67.
85. Dikmen, S., Corrigan, J., Levin, H., Machamer, J., Stiers, W., and Weisskopf, M. (2009). Cognitive outcome following traumatic brain injury. J. Head Trauma Rehabil. 24, 430–438.
86. Bay, E., and Donders, J. (2008). Risk factors for depressive symptoms after mild-to-moderate traumatic brain injury. Brain Inj. 22, 233–241.
87. Hoge, C.W., McGurk, D., Thomas, J.L., Cox, A.L., Engel, C.C., and Castro, C.A. (2008). Mild Traumatic Brain Injury in U.S. Soldiers Returning from Iraq. N. Engl. J. Med. 358, 453–463.
88. Harmon, K.G., Drezner, J., Gammons, M., Guskiewicz, K., Halstead, M., Herring, S., Kutcher, J., Pana, A., Putukian, M., and Roberts, W. (2013). American Medical Society for Sports Medicine position statement: concussion in sport. Clin. J. Sport Med. 23, 1–18
89. Giza, C.C., Kutcher, J.S., Ashwal, S., Barth, J., Getchius, T.S.D., Gioia, G.A., Gronseth, G.S., Guskiewicz, K., Mandel, S., Manley, G., McKeag, D.B., Thurman, D.J., and Zafonte, R. (2013). Summary of evidence-based guideline update: evaluation and management of concussion in sports: report of the Guideline Development Subcommittee of the American Academy of Neurology. Neurology 80, 2250–2257.
90. McCrory, P., Meeuwisse, W.H., Aubry, M., Cantu, B., Dvořák, J., Echemendia, R.J., Engebretsen, L., Johnston, K., Kutcher, J.S., Raftery, M., Sills, A., Benson, B.W., Davis, G.A., Ellenbogen, R.G., Guskiewicz, K., Herring, S.A., Iverson, G.L., Jordan, B.D., Kissick, J., McCrea, M., McIntosh, A.S., Maddocks, D., Makdissi, M., Purcell, L., Putukian, M., Schneider, K., Tator, C.H., and Turner, M. (2013). Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. Br. J. Sports Med. 47, 250–258.

Address correspondence to:
Jane L. Mathias, PhD
School of Psychology
University of Adelaide
North Terrace
Adelaide, South Australia
Australia 5005

E-mail: jane.mathias@adelaide.edu.au