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Factors related to recovery after mild traumatic brain injury

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Abstract

Primary objectives: To study the variables that relate to outcome after mild traumatic brain injury (TBI).
Methods and procedures: Sixty-seven adults with disappointing recoveries after mild TBI most occurring in a compensation or litigation context were studied with regard to pre-injury, neuro-trauma, physical, emotional and cognitive variables on outcome. Validity of physical, emotional and cognitive symptoms was controlled for.
Main outcomes and results: Except for prior psychological traumatization, neither pre-injury, neuro-trauma or cognitive variables were related to outcome. Variables most consistently related to outcome were depression, pain and symptom invalidity on measures of response bias. These factors accounted for the majority of variance in outcome.
Conclusions: In cases of poor recovery after mild TBI where compensation or litigation may be a factor, most of the variance in recovery seems to be explained by depression, pain and symptom invalidity, rather than by the injury variables themselves.

Keywords: *Traumatic brain injury, concussion, recovery, industrial injury, symptom validity testing*

Introduction

Traumatic brain injury (TBI) is a significant public health problem. One study [1] concluded that ~1.5 million new cases of brain injury occur each year in the US, with the majority of these being in the mild severity category. In most cases of mild TBI, a good recovery can usually be anticipated. In those cases of mild TBI with a good outcome, recovery usually occurs over a short period of time; not usually lasting longer than several weeks to 3 months in the majority of cases [2–4]. Other studies found that return to normal may not be complete at 3 months [5] and those with residual symptoms which are still present at 3 months or longer tend to have problems which are often quite persistent [2]. This raises the possibility that different underlying mechanisms may account for those with mild TBI who recover early vs. those whose recovery is much more prolonged or incomplete.

Those patients who apparently have mild TBI but who fail to recover as quickly and completely as expected have been a clinically perplexing group and various explanations have been proposed to account for the atypical recoveries which people in this group experience. These alternative diagnostic formulations include under-estimation of brain injury severity, concurrent dementia, pre-existing psychiatric conditions, pre-existing personality factors and social and demographic factors which interact with injury circumstances. Post-injury explanations for failure to recover as expected include new psychiatric conditions occurring since the injury such as depression, anxiety disorder and conversion disorder; headache and other non-cephalic pain; dizziness; insomnia; medication side effects; and the influence of compensation and litigation factors [6].

Several studies have been interpreted as indicating that failure to recover as expected after mild TBI may be the result of the neuro-trauma itself [7–10]. These studies have tended to rely on specialized neuro-imaging techniques to demonstrate the presence of cerebral abnormalities not in evidence with conventional imaging methods. McAllister et al. [11] have

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written a very comprehensive review of the use of both structural and functional imaging in mild TBI.

The relationship of pre-morbid psychiatric conditions to mild brain injury recovery has also been proposed as another explanation for failure to recover as expected. Qualitative analyses have identified pre-existing personality characteristics such as over-achievement, perfectionism and dependency which can sometimes complicate the recovery process [12]. The relationship of pre-morbid affective disturbance to recovery after mild TBI has also been investigated and in the case of depression, not found to have a significant relationship to the development of chronic post-concussion syndrome after mild TBI [13, 14].

Post-injury motivational factors have been implicated in some cases of failure to recover after mild TBI. A significant number of mild TBIs potentially occur within a compensation or litigation context and the possibility has been raised that symptoms can become reinforced by their financial consequences. A meta-analysis of this topic was carried out on 17 reported studies and concluded that financial incentives actually did have a moderate effect on mild TBI symptoms and disability [15]. Other studies addressing this issue have produced results that may lend support to this conclusion, including post-injury symptom magnification [16] and exaggeration of the quality of pre-injury functioning among individuals who have retained attorney representation after acquired brain injury [17].

Many mild TBIs occur as a result of motor vehicle accidents. Post-injury psychiatric conditions in general have been implicated in cases of failure to recover after accidents and injuries. Especially when accompanied by serious physical injuries, motor vehicle accidents themselves frequently have significant emotional effects and can result in such mental health conditions as adjustment disorder, phobic disorder, panic attacks, acute stress disorder, post-traumatic stress disorder, major depressive disorder or one of the somatoform disorders [18]. Indeed, in a major trauma outcome study, functional outcome after serious trauma, regardless of the cause, was found to be determined as much by the presence of psychological morbidity such as depression as it was determined by physical dysfunction [19]. Regardless of the presence of TBI, accidents in general, especially when accompanied by injuries, seem to be pre-disposing factors for the development of post-accident psychiatric disorders. With regard to injury situations which result in mild TBI, several studies have found that the development of new psychiatric conditions since the injury may also play an important role in the success of the recovery process. One study [20] found a high rate of emotional disorders in patients who had sustained mild TBI's in motor vehicle accidents. The investigator concluded that 'emotional disorders added to persistent cognitive loss and other neuropsychological symptoms greatly impair the capacity to adapt after TBI'. Several other studies have resulted in similar findings. For example, post-injury psychological distress was strongly associated with prolonged post-concussion syndrome [21]. A prospective study found that psychiatric conditions were often present in those who fail to recover after mild TBI and that in those patients with mild TBI without concurrent psychiatric morbidity there usually could be the expectation of a quick and complete recovery [22].

A number of studies have found that the presence of a mild TBI was compatible with the development of injury-related psychological traumatization in the form of acute stress disorder and post-traumatic stress disorder [23–29]. One study even found that post-concussion syndrome symptoms were more prevalent in mild TBI patients with post-traumatic stress disorder than in those without it [30]. The investigators concluded that post-concussion symptoms may be 'mediated by an interaction of neurological and psychological factors'.

Other studies have found depression to be a frequently occurring factor in cases of mild TBI where the outcome is worse than expected. Major depression after mild TBI has been found to be associated with poor functional outcome and high distress levels [31], with disability and cognitive impairment [32] and with higher levels of post-concussion syndrome symptom endorsement [31, 33, 34]. After treatment for depression, cognitive impairments are significantly alleviated [35].

Depersonalization is a feeling of detachment from one's body or sense of self that most people experience as alien. Patients with TBI often describe it as feeling of being mentally foggy or as a sensation of being detached and off at a distance from things. Depersonalization is a form of dissociation or a state in which there is a disturbance in the integration of mind, body and environment. Depersonalization has been reported to be common after head injury and among those with mild TBI, more than 60% complained of depersonalization [36]. In the same mild TBI sample, depersonalization had a high rate of co-morbidity with post-traumatic stress disorder and vertigo. Relatedly, high scores on the Dissociative Experiences Scale, a probe for depersonalization and other dissociative symptoms, have been found in those with mild TBI who had prolonged or complicated recoveries [22].

Depersonalization and other symptoms of dissociation have been shown to have an impact on basic information processing and to be related to deficits of memory [37]. Thus, the development of unusual symptoms such as depersonalization may also be a factor in the long-term maintenance of problems after mild TBI. At this point, it is not yet clear if these unusual symptoms should be considered to be neurological in origin or if they are more appropriately seen in connection with co-morbid psychiatric conditions.

Another factor which has been proposed to explain failure to recover as expected after mild TBI is under-estimation of injury severity. Those cases of injury which, on clinical grounds, would be classified as mild but which are also accompanied by skull fracture or intra-cranial traumatic lesion appear to have a different recovery pattern than simple, mild TBI unaccompanied by such lesions [38–40]. Such cases have sometimes been referred to as complex mild TBI. The expectation for recovery after such injuries is probably different from simple mild TBI.

Mild TBI can frequently be accompanied by a variety of physical symptoms including headache and dizziness. Many instances of mild TBI also occur in the context of additional musculoskeletal injury accompanied by non-cephalic pain. Headache and dizziness are also among the more commonly occurring symptoms of post-concussion syndrome.

Headache and non-cephalic pain might have an effect on mild TBI outcome through several intermediary mechanisms. Persistent, severe pain has psychological consequences and can disorganize psychological functioning at several levels [20]. Headache and other pain are also known to have an adverse effect on important cognitive functions such as attention and memory [41–43]. Specific to those with mild TBI, worse memory performance has been found in those TBI subjects with headache than in those without headache [44]. With regard to other clinical conditions that cause pain, there is a fairly well established relationship between level of pain severity and the person's ability to function [45].

Studies have found co-morbid rates of headache to be quite high in the mild TBI population. One study [46] noted a headache rate of 89% in a sample of mild TBI patients. The investigators emphasized the high rate of chronic pain in the mild TBI group and suggested that caution be exercised in misattributing symptoms to brain injury that could just as likely be due to the co-morbid pain condition. Other studies have presented evidence that symptoms of post-concussion syndrome are by no means unique or specific to mild TBI, but are commonly found in chronic pain conditions. One study found that 81% of a non-brain injured chronic pain sample endorsed three or more post-concussion syndrome symptoms [47]. Another study compared responses on a post-concussion syndrome questionnaire between a mild TBI sample and a chronic pain sample. Although there were some group differences with regard to endorsement of specific items, the two groups were not significantly different in their total scores on the post-concussion syndrome questionnaire [48]. These investigators concluded that post-concussion syndrome is not specific to mild TBI and is also present in other conditions such as chronic pain.

Headache and other physical symptoms are common after mild TBI, but their actual influence on recovery after mild TBI has not been sufficiently studied. An investigation of the effects which these symptoms have on mild TBI recovery would improve understanding of the full range of factors which complicate or prolong the recovery process after mild TBI.

Method

The study was an analysis of patient variables, injury variables, neuro-cognitive status, neuro-emotional status and the relationship among these variables to outcome after mild TBI. The specific focus of the study was to investigate the complexity of factors that influence outcome after mild TBI. The study had been reviewed and approved by the Institutional Review Board at the University of Utah Health Sciences Center.

Subjects

The subjects were 67 adult (37 male, 30 female) outpatients of the mild TBI clinic at the University of Utah Health Sciences Center. Participants were referred from a variety of sources both within and outside of the Health Sciences Center. Most were referred from physicians within the University Health Sciences Center or from local community physicians. Participants were classified according to whether or not they were recovering as expected from their injuries. Recovery as expected was defined as a significant remission of post-concussion symptoms within 3 months after the trauma of interest. Failure to recover as expected consisted of having an actual or suspected mild TBI and having three or more post-concussion syndrome symptoms for a period of 3 months or longer after the accident of interest.

The average age of the participants was 41.36 years (SD = 13.26 years) and the median age was 41 years. Fourteen subjects were over the age of 50 years, which may indicate that this sample is older than typical TBI samples. The possible explanation for this may lie in the fact that many of them (85%) were in the workforce. The average education level of the subjects was 13.01 years (SD = 2.34). Most ($n = 63$, 94%) of the participants were involved in productive activities consisting of either employment or education at the time of their injury. Forty were married, 10 were single and not previously married and 17 were divorced or separated. The majority of the subjects ($n = 35, 52\%$) were injured in traffic accidents. The remainder were injured in other types of industrial accidents as well as falls, sports and assaults. Forty-one (61%) of the injuries occurred within a worker's compensation context. Eighteen (27%) were involved in litigation concerning the injury. Thirteen (19%) were both workers compensation cases and were also involved in litigation. Alcohol did not appear to be a factor in any of the accidents as determined by self-report of subjects and by a review of the clinical records. The median length of time from injury until participation in the study was 15 months.

Procedure

Information about pre-injury history, injury history and post-injury clinical course was obtained from an interview with the subject, as well as a review of each participant's clinical records. Information about pre-existing psychiatric history was obtained from carefully interviewing the participants. In many, although not in all cases, family members were available as collateral informants. Data were not obtained about which cases had information supplemented by collateral informants and which did not.

Participants were classified as to whether they had a mild TBI using the definition of the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine [49]. Participants were also classified as to whether they had a mental health condition using the diagnostic criteria of the American Psychiatric Association (DSM-IV) [50]. Failure to recover as expected was operationally defined as the presence of three or more post-concussion syndrome symptoms at a moderate or severe level of symptom intensity noted on a symptom checklist 3 months or more after the accident of interest. Disability after injury was defined as subjective inability on the part of the subject to no longer perform previous social roles such as employee or student resulting in withdrawal from work or school.

The study included a battery of questionnaires about symptoms and about emotional functioning designed to probe for the presence of those conditions which previous studies had found to be prevalent in the failure to recovery group. The questionnaires consisted of the following: Minnesota Multiphasic Personality Inventory-2, Beck Depression Inventory-II, Dissociative Experiences Scale, Impact of Event Scale [51–54] and the Post-Concussion Syndrome Checklist published in a previous study [22]. In addition to symptom checklists and measures of emotional functioning, the participants were also administered several measures of cognitive functioning which consisted of: Wechsler Adult Intelligence Scale-III, Auditory Verbal Learning Test, Trail Making Test, Part B, Hooper Visual Organization Test, Finger Tapping Test and the Boston Naming Test [55–60]. As needed, the measures of cognitive functioning were accompanied by validity testing consisting of the Computerized Assessment of Response Bias, the Word Memory Test and the Test of Memory Malingering [61–63]. In addition to measures of cognitive test taking validity, Scale F of the MMPI-2 was used as the measure of validity for questionnaires about emotional symptoms and Scale 3 of the MMPI-2 was used as the measure of validity of physical symptom reporting [64].

Information about the participants was then de-identified, coded and stored in analysis-ready form in an electronic database. The data then underwent statistical analysis using SPSS 11.5 for Windows.

Results

Pre-injury variables

Prior to injury, the individuals in the sample were a fairly high-functioning group. Ninety-four per cent ($n = 63$) were engaged in productive social roles either through employment or as students or homemakers. Only 5% ($n = 3$) had a prior history of substance abuse. This low figure possibly is a reflection of the predominant local religion and culture which tends to avoid the use of alcohol and drugs. On the other hand, prior history of TBI was present in 25% ($n = 17$). Thirty-four per cent ($n = 23$) had a prior history of psychological trauma, with 57% ($n = 13$) of these cases consisting of childhood physical or sexual abuse. Fifty-four per cent ($n = 36$) had a life-time history of prior mental health problems, with 58% ($n = 21$) of these consisting of depression and 17% ($n = 6$) consisting of an anxiety disorder. Although they were of a high functioning nature prior to injury, most of those in the failure to recover as expected sample were disabled ($n = 48, 72\%$) after injury.

The relationship of pre-injury variables to outcome after injury was explored. Several variables appeared to have no significant relationship to outcome including level of social support ($\chi^2 = 3.00, \mathrm{df} = 1, n = 67, p = 0.08$), prior level of psychological adaptation ($\chi^2 = 3.50, \mathrm{df} = 2, n = 67, p = 0.17$) and prior history of TBI ($\chi^2 = 0.26, \mathrm{df} = 1, n = 67, p = 0.61$). In contrast to this, a prior history of psychological traumatization did seem to have an important relationship to outcome after mild TBI ($\chi^2 = 6.67$, $df = 1, n = 67, p = 0.01$). A prior history of TBI might not have been significantly related to outcome because of the mild nature of brain injuries in the present sample.

Prior to injury, there was a lifetime rate of mental health problems in 54% ($n = 36$) of the sample. This study was concerned that this was higher than expected in the general population and so the relationship of pre-injury mental health problems and post-injury functioning was analysed. This study first looked at how pre-injury mental health problems and pre-injury depression might affect level of post-injury depression. Pre-injury depression made no difference in post-injury scores on the Beck Depression Inventory-II ($t = 1.03, df = 60$, $n = 62, p = 0.31$). Likewise, pre-injury mental health problems of any type made no difference in post-injury scores on the Beck Depression Inventory-II ($t = 1.26$, $df = 60$, $n = 62$, $p = 0.21$). The relationship between post-injury disability to pre-injury depression, anxiety and mental health problems was also analysed. There did not appear to be a significant relationship between pre-injury depression, pre-injury anxiety or pre-injury mental health problems in general and post-injury disability ($\chi^2 = 0.51$, $df = 1$, $n = 67$, $p = 0.48$; $\chi^2 = 0.36$, $df = 1$, $n = 67$, $p = 0.55$; $\chi^2 = 0.43$, $df = 1$, $n = 67$, $p = 0.51$).

Injury variables

The sample consisted of individuals with actual or suspected mild TBI who had not recovered as expected according to the study's criteria. Diagnostic possibilities of interest to this study consisted of mild TBI, psychiatric diagnosis, pain or various combinations of these diagnoses. Table I lists the final diagnoses for the sample under study. It can be seen that there are very few subjects in the failure to recover as expected sample who had a single diagnosis of mild TBI only ($n = 2, 3\%$). Similarly, there were only a few subjects with a psychiatric diagnosis only ($n = 4, 6\%$) or with pain only ($n = 1, 2\%$). Rather, the majority of patients who don't recover as expected after mild TBI have multiple diagnoses. Indeed, the largest group of patients ($n = 33, 49\%$) were those who had the combined diagnoses of mild TBI, psychiatric diagnosis and pain. Among the sample as a whole, 56 subjects (85%) had a psychiatric diagnosis which is a considerable increase over the 54% pre-injury lifetime occurrence rate of mental health conditions present in the sample prior to injury.

Table I. Final diagnosis.

Diagnosis	n	%
No diagnosis	1	2
Mild TBI only	2	3
Psychiatric diagnosis only	4	6
Pain only	1	2
Mild TBI + psychiatric diagnosis	13	20
Mild TBI + pain	6	9
Psychiatric diagnosis + pain	6	9
Mild TBI + psychiatric diagnosis + pain	33	49

Data were collected on a number of different neuro-trauma variables that might be of interest with regard to recovery after mild TBI. These included prior TBI, skull fracture, traumatic intracranial neuro-imaging abnormalities and abnormal physical signs on neurological exam. The frequency of neuro-trauma findings was low, consistent with the fact that this was a mildly injured group. Only four of the 67 subjects (6%) had loss of consciousness. The remainder had amnesia ($n = 47, 70\%$) or were only dazed or confused at the time of injury ($n = 16, 24\%$). Data about amnesia or confusion at the time of injury were obtained either from medical records or patient report. Objective medical record observations were required to establish actual loss of consciousness. None of the neuro-trauma variables had a significant relationship to disability outcome after injury: prior TBI, $\chi^2 = 0.26$, $df = 1$, $n = 67$, $p = 0.61$; skull fracture, $\chi^2 = 1.52$, $df = 1$, $n = 67$, $p = 0.22$; neuro-imaging abnormality, $\chi^2 = 0.48$, $df = 1$, $n = 67$, $p = 0.49$; and neurological exam abnormality, $\chi^2 = 0.37$, $df = 1$, $n = 67$, $p = 0.54$.

Post-injury symptom variables

Information about subjective symptoms was collected in the sample. This included data about post-concussion syndrome along with more specific symptoms such as depression, headache, non-cephalic pain and dizziness. The relationship of these subjective symptom variables to outcome was also evaluated.

Headache, non-cephalic pain and depression were common in the sample of patients studied. Dizziness was somewhat common. Seventy-two per cent of the patients had moderate-to-severe headache, 64% had moderate-to-severe pain in other locations, 32% had moderate-to-severe dizziness and 15% had moderate-to-severe vertigo. Depression in the form of major depressive disorder or depressive disorder, not otherwise specified, was present in 61% of the failure to recover sample.

The measure of post-concussion syndrome (PCS) was a 25-item questionnaire about PCS symptoms. The intensity of each symptom is rated by the subject on a 1–5 Likert-type scale. The individual scores are summed for a total PCS score. The relationship of PCS to outcome after injury was evaluated in the sample by comparing the PCS scores of the disabled group ($n = 47$) with the scores of the non-disabled group ($n = 19$). There was a significant difference in PCS scores between the two groups ($t = 3.26$, $\mathrm{df} = 64, n = 66, p = 0.002$), with the disabled group having higher scores than the non-disabled group.

The relationship of specific symptoms to overall PCS was also evaluated in the case of depression, headache and non-cephalic pain. There was a significant correlation between headache and PCS ($r = 0.49, n = 66, p < 0.001$), between non-cephalic pain levels and PCS ($r = 0.44, n = 66, p < 0.001$) and between scores on the Beck Depression Inventory-II and PCS ($r = 0.58, n = 62, p < 0.001$). A small part of this relationship is undoubtedly explained by the fact that each of these symptoms is itself an individual PCS symptom. The strong relationship between these symptom variables and overall intensity of post-concussion syndrome continued to hold up even after controlling for possible response bias influences. The MMPI-2 Scale 3 and the MMPI-2 Scale F were used as the measures of physical symptom validity and emotional symptom validity, respectively. A partial correlation was calculated for the relationship between headache level and PCS while controlling for MMPI-2 Scale 3 ($r = 0.33$, $p = 0.02$), for the relationship between non-cephalic pain and PCS while controlling for MMPI-2 Scale 3 ($r = 0.45, p = 0.001$) and for the relationship between Beck Depression Scale-II and PCS while controlling for MMPI-2 Scale F ($r = 0.52, p < 0.001$).

Pain and depression are well known to be highly interactive with one another. Where both were present, one wanted to have a method to study the effect of each of these on outcome in isolation from the another. A series of partial correlations were conducted to accomplish this. The relationship of non-cephalic pain and PCS continued to be significant while controlling for level of depression ($r = 0.37$, $p = 0.003$). The relationship of depression to PCS remained significant while controlling for non-cephalic pain ($r = 0.54, p = 0.000$) and the relationship of headache to PCS was significant while controlling for both level of depression and level of non-cephalic pain ($r = 0.40, p = 0.001$). Thus, non-cephalic pain, headaches and depression appeared to be independent factors in their effect on outcome after injury.

Although these specific symptoms had a significant relationship to overall PCS score, their relationship to outcome in terms of disability was also of interest to the study. Scores on the Beck Depression Inventory-II (BDI-II) as an overall reflection of depression were significantly related to disability ($t = 2.29, \mathrm{df} = 60, n = 62, p = 0.03$). However, none of the other specific symptoms of interest individually had a significant relationship to outcome after injury in terms of disability, for example headache ($t = 0.81, \mathrm{df} = 65, n = 67, p = 0.42$), non-cephalic pain ($t = 0.19, \mathrm{df} = 65, n = 67, p = 0.85$) and dizziness ($t = 1.18, \mathrm{df} = 65, n = 67, p = 0.24$).

Post-injury cognitive variables

The subjects in the sample were administered a battery of cognitive tests. Mean scores were calculated for the subjects in the sample on these measures of cognitive functioning, as shown in Table II. Other than the abnormally long time to completion of Part B of the Trail Making Test, these scores are in the normal range in comparison to normative data derived from the general, non-injured population. This study was also interested in the relationship of the cognitive test variables to outcome after mild TBI in this sample who for the most part exhibited poor recoveries. The relationship of performance on the cognitive tests to total score on the PCS was analysed and is also displayed in Table II. In several cases, a significant relationship was present between cognitive test scores and post-concussion syndrome. However, when this relationship was analysed as a partial correlation while controlling for the influence of a moderating variable such as performance on symptom validity measures (e.g. CARB), the strength of the relationship diminished or became absent. In this sample, cognitive test performance had little, if any, independent relationship to outcome.

Another objective was to understand the relationship of cognitive test variables and outcome after

Table II. Neuro-cognitive test scores and their relationship to post-concussion syndrome while controlling for response bias (CARB).

Test	n	M	SD	r	significance	partial r	significance
WAIS-III full scale IQ	59	91.57	13.46	−0.15	0.27	–	–
AVLT	61	43.50	12.05	−0.12	0.38	–	–
HVOT	61	23.82	4.21	−0.43	0.001	0.20	0.14
BNT	61	52.47	6.32	−0.36	0.005	−0.32	0.02
FTT	64	46.98	12.63	−0.33	0.007	−0.12	0.37
Trails Part B	61	110.39	74.4	0.07	0.57	–	–

Table III. Relationship of cognitive test variables to disability.

Test	n	df	t	p
WAIS-III full scale IQ	60	58	1.11	0.27
AVLT	62	60	0.36	0.27
FTT	65	63	1.33	0.19
BNT	62	60	1.55	0.13
Trails Part B	61	59	0.19	0.85
HVOT	61	59	1.03	0.31

injury in terms of overall disability and this was studied with a series of independent *t*-tests. None of the cognitive variables had a significant relationship to disability after injury, as shown in Table III.

Post-injury emotional variables

The subjects in the sample of patients who failed to recover as expected after mild TBI were administered a battery of questionnaires about emotional functioning. Mean scores were calculated for the sample of subjects on the measures of emotional functioning. The average score on the BDI-II was 22.03 (SD = 12.36). In clinical samples, scores in this range are typically found among individuals with mild-to-moderately severe depression. The mean number of MMPI-2 scales elevated over a *T*-score of 70 was 4.45 (SD = 2.54). The mean raw score on the MMPI-2 Scale 1 was 20.17 (SD = 5.83) and the mean raw score on the MMPI-2 Scale 3 was 35.00 (SD = 5.92). The average score on the DES was 19.22 (SD = 13.57). The mean score on the Intrusive Thoughts factor of the IES was 20.17 (SD = 3.71) and the mean score on the Avoidance factor of the IES was 23.52 (SD = 6.09). All of these mean scores are well above the normal range.

The scores on many of the measures of emotional functioning correlated significantly with one another. For example, the BDI-II and the number of clinical scales of the MMPI-2 that were elevated ($r = 0.77$, $n = 52$, $p = 0.000$) and the BDI-II with the DES ($r = 0.63$, $n = 40$, $p = 0.000$).

Depression has previously been found in a number of studies of outcome after mild TBI to have an important connection to recovery after mild TBI and the relationship of scores on the BDI-II to several outcome variables was analysed. These included some of the pain variables including headache ($r = 0.23$, $n = 62$, $p = 0.07$), non-cephalic pain ($r = 0.26$, $n = 62$, $p = 0.05$) and post concussion syndrome checklist scores ($r = 0.58$, $n = 62$, $p < 0.001$). There was also a significant relationship between scores on the BDI-II and outcome in terms of disability. Non-disabled subjects had a mean BDI-II score of 16.61, while disabled subjects had a mean BDI-II score of 24.24. This difference was significant ($t = 2.29$, df = 60, $n = 62$, $p = 0.03$). These elevated depression scores are believed to be a reflection of post-injury circumstances and not of pre-injury factors as there appeared to be no relationship between the presence of self-reported pre-injury depression and post-injury scores on the BDI-II ($t = 1.03$, df = 60, $n = 62$, $p = 0.31$). Similarly, there was no relationship between scores on the BDI-II and pre-injury psychological traumatization ($t = 1.35$, df = 60, $n = 62$, $p = 0.18$) or the presence of pre-injury mental health conditions ($t = 1.26$, df = 60, $n = 62$, $p = 0.21$). These bi-variate analyses were followed-up with a linear regression analysis of depression, headache and non-cephalic pain on level of post-concussion syndrome. These three variables together explained 44% of the variance in level of concussion syndrome. Several of the other measures of emotional functioning were also found to be related to outcome. For example, there was a significant relationship between disabled status and number of clinical scales elevated on the MMPI-2 ($t = 4.08$, df = 51, $n = 53$, $p < 0.001$) and on Scale 3 of the MMPI-2 ($t = 4.28$, df = 51, $n = 53$, $p < 0.001$).

Table IV. Credibility measure mean scores.

Validity measure	n	*M*, current sample	SD	*M*, normative group
MMPI-2 Scale F raw score	54	9.31	6.44	–
MMPI-2 Scale 3 raw score	53	35.00	5.92	30
CARB	57	88.86%	18.22	97%
WMT IR	34	78.09%	20.73%	96.5%
WMT DR	33	74.03%	22.54%	95.8%
TOMM Trial 2	17	38.65	11.27	49

Post-injury credibility variables

Credibility measures were administered to the subjects in this study. These consisted of the MMPI-2 Scale F to assess emotional symptom over-reporting, the MMPI-2 Scale 3 to assess physical symptom over-reporting and the Computerized Assessment of Response Bias (CARB), the Word Memory Test (WMT) and the Test of Memory Malingering (TOMM) to assess exaggeration of cognitive symptoms. Mean scores on each of these symptom validity measures were calculated for the sample. These are shown in Table IV. For the sake of comparison, mean scores from normative samples of patients with verified TBIs are also shown where available. In most cases, the mean scores for the sample on these validity measures were abnormal. In all cases, the abnormality for the sample was in the direction of invalidity compared to normative data.

Table V. Percentage of subjects below cut-off scores on symptom validity tests.

Test	n	Cut-off	Number below cut-off	Percentage
CARB	57	89%	16	28%
WMT-IR	34	82%	19	44%
WMT-DR	33	82%	19	58%
TOMM	17	46	10	59%

Table VI. Inter-relationships among credibility measures.

	WMT-IR	WMT-DR	TOMM	Scale F	Scale 3
CARB	0.86	0.82	0.83	−0.50	−0.30
WMT-IR		0.90	0.71	−0.47	−0.45
WMT-DR			0.82	−0.64	−0.45
TOMM				−0.66	−0.63
Scale F					0.17

The mean scores for the present sample that are shown in Table IV deviated substantially from the scores found in previous normative groups. This raised concern that many of the subjects in the sample might have invalid response patterns. To investigate this concern further, the number of subjects in the sample with symptom validity scores below cut-off levels established by prior research on the credibility measures was calculated. This is shown in Table V.

The investigators were interested in any relationships that were present among the various symptom validity measures. The measures of cognitive symptom exaggeration were all very highly correlated with one another. The MMPI-2 F Scale, which was the measure of emotional symptom over-reporting, was inversely related to many of the cognitive symptom validity measures. Scores on the F Scale of the MMPI-2 and Scale 3 of the MMPI-2 did not seem to be related, suggesting a lack of relationship between the degree of physical symptom over-reporting and the degree of emotional symptom over-reporting. These relationships are shown in Table VI.

How well each validity measure related to symptoms in its content area was also analysed. For example, scores on Scale F of the MMPI-2 had a significant relationship to scores of the BDI-II ($r=0.49, n=53, p<0.001$)m suggesting that emotional symptom exaggeration may account for some portion of the depression reported by patients in the failure to recover as expected sample. Similarly, scores on validity measures for cognitive symptoms showed a significant relationship to scores on the actual cognitive tests themselves. For example, scores on the CARB were significantly related to scores on the AVLT ($r=0.55, n=55, p<0.001$), the FTT ($r=0.65, n=57, p<0.001$) and Part B of the Trail Making Test ($r=-0.55, n=53, p<0.001$). This suggests that a certain amount of the cognitive impairment in the failure to recover as expected sample may be due to poor test-taking effort and not to actual impairment. The MMPI-2 Scale 3 was selected as the measure of physical symptom over-reporting and the relationship of this measure to physical symptoms was analysed. Scale 3 raw scores did not have a significant relationship to headache level ($r=0.16, n=53, p=0.26$) or to level of non-cephalic pain ($r=0.03, n=53, p=0.84$), but were significantly related to subjective level of dizziness ($r=0.34, n=53, p=0.01$).

Symptom exaggeration as a mediator of outcome after mild TBI was also a focus of the study and the relationship of the validity measures to outcome after injury was analysed. Lower scores on the CARB were related to higher scores on the PCS ($r=-0.44, n=56, p=0.001$). High scores on Scale 3 of the MMPI-2 were strongly related to high levels of symptom reporting on the PCS ($r=0.54, n=53, p<0.001$). The relationship of scores on Scale F, the measure of emotional symptom over-reporting to post-concussion syndrome symptoms on the PCS was significant but less strong ($r=0.29, n=54, p=0.04$). Symptom invalidity had a significant relationship to outcome in terms of scores on the PCS. Indeed, when a linear regression of CARB, the TOMM and WMT-DR on level of PCS was conducted, these variables together explained 37% of the variance in level of post-concussion syndrome. A linear regression analysis of CARB, TOMM, WMT-DR, BDI-II, headache level and level of non-cephalic pain was then conducted all on PCS. This analysis indicated that 63% of the variance in post-concussion syndrome intensity could be explained by pain, depression and level of invalidity on cognitive test taking.

Finally, the relationship of the validity measures to disability after mild TBI was also analysed. Raw scores on Scale 3 of the MMPI-2 were significantly related to disability status ($t=4.28, df=51, n=53, p=0.00$), but no significant relationship was found for raw scores on Scale F of the MMPI-2 ($t=1.46, df=52, n=54, p=0.15$) or for scores on the CARB ($t=1.59, df=55, n=57, p=0.12$).

In the case of some validity measures, there was a relationship between level of invalidity and length of time in months since injury. Such relationships were present for the CARB $r=-0.29, p=0.03$) and for MMPI-2 Scale F ($r=0.41, p=0.002$) but not for any of the other validity measures. This suggests that, in certain cases, invalidity may be an evolving process over time and not something present immediately after injury.

Discussion

This study focused on the minority of people with mild TBI who fail to recover as expected. The study attempted to understand which factors are related to failure to recover and which are not. A strength of this study lies in the fact that it simultaneously studied a fairly large number of factors that might be related to outcome after mild TBI. A potential weakness of this approach is the risk of false positive results when multiple analyses are conducted. This problem is mitigated by the fact that many of the study's statistical analyses had highly significant results that probably corrected for the potential additive error issue.

This study did not involve a consecutive series of patients with mild TBI. Rather, it relied on a sample of patients who were referred to a mild TBI specialty clinic. For this reason, a significant selection bias may have been introduced into the process by which subjects were enrolled into the study. Additionally, 61% of the subjects had injuries that occurred within a worker's compensation context and 27% were involved in litigation. It is, therefore, unlikely that this sample is representative of the general population of patients with mild TBI. On the other hand, the sample quite likely is representative of the minority of mild TBI patients who fail to recover as expected, many of whose injuries occur in a compensation or litigation context. In a number of respects, this sample resembles typical clinical groups described in the mild TBI literature and there is some confidence that the results of the present study can be extended to patients likely to be seen in mild brain injury clinics, particularly those that treat a significant proportion of those injured in industrial settings.

There are several classification systems for mild TBI. The diagnostic criteria for mild TBI used in this study were those of the Mild Brain Injury Special Interest Group of the American Congress of Rehabilitation Medicine (ACRM). This definition has been gaining in recognition over the past decade and is consistent with the diagnostic criteria used in a number of other recent mild TBI studies. The ACRM definition could be criticized for having diagnostic criteria which are overly inclusive and the risk of using these criteria would be that of committing a Type I error and labelling a condition a brain injury when in fact it was not. On the other hand, the consistent use of the same criteria among a large number of studies results in a uniform standard of how mild TBI is defined.

Post-concussion syndrome was operationally defined as agreement with three or more symptoms on a post-concussion syndrome symptom questionnaire 3 months or longer after injury. Significant endorsement of a symptom was further defined as a score of four or higher on a 1–5 rating scale of symptom intensity. Defined in this way, 91% of the sample had post-concussion syndrome. The particular post-concussion syndrome checklist used in this study was selected because of the authors' familiarity with it from a previous study [22] and because it included a numerical rating scale that allowed for quantification of symptom intensity. The questionnaire itself is published as an appendix to that study [22]. The study also collected information on disability after mild TBI. Disability was present in 72% of the sample, which indicates the significant impact on functioning which occurs in the failure to recover group after mild TBI. The significance of this finding is highlighted by the fact that, before injury, 94% of the sample were engaged in productive roles. Level of post-concussion syndrome and presence of disability were significantly associated with one another.

As in a number of previous studies, the present study also found that, for the most part, pre-injury factors had little relationship to post-injury factors or to outcome after mild TBI, even though there was a fairly high pre-injury rate of mental health problems. The exception to this was the prominent association between a pre-injury history of psychological traumatization and outcome after mild TBI. This might be a general injury recovery phenomenon, in that a similar association has been found between early, pre-injury psychological trauma and recovery from surgery for back pain [65].

The sample consisted of individuals with mild TBI who had failed to recover as expected. Data were collected about brain injury diagnosis, post-injury mental health diagnosis and pain. Potentially, these diagnoses could occur singly or in any combination with one another. Interestingly, there were very few people in the failure to recover sample with a single diagnosis of mild TBI only. This suggests that mild TBI itself rarely accounts for the presence of severe or chronic post-concussion syndrome or disability after such injuries. The largest single group in the failure to recover sample (49%) were those with mild TBI, a new mental health condition and pain. This suggests that an overly parsimonious approach to diagnosis that attempts to place patients in only one category is inappropriately restrictive. The next largest sub-group in the failure to recover as expected sample were those with both mild TBI and a new psychiatric condition. These trends suggest that the presence of a new mental health condition since the injury may be a particularly important influence on outcome after mild TBI.

Data were collected on a number of neuro-trauma variables such as prior TBI, skull fracture and imaging abnormality. Consistent with the fact that this was a mildly injured group, such abnormalities were infrequently present and, upon analysis, had no significant relationship to outcome. This is consistent with the previous finding that there were few subjects in the failure to recover sample with a diagnosis of brain injury only [22].

The relationship of symptoms to outcome was of special interest in this study. First of all, symptom level in general, as reflected by severity of post-concussion syndrome, was of importance and those who were disabled after mild TBI has significantly higher scores on the post-concussion syndrome questionnaire. With regard to specific symptoms, however, only level of depression was strongly related to disabled status, making this one of the more important influences on outcome.

A number of cognitive variables were studied with regard to their relationship to outcome after mild TBI. With one exception, the mean scores on these tests for the sample were close to the mean for normative samples derived from the general population. Especially after the cognitive test results were controlled for the effects of symptom exaggeration, they had no significant relationship to outcome, even though cognitive problems are some of the symptoms that patients in this group complain of the most.

This study also looked at a number of variables in the area of emotional functioning as well as at their relationship to outcome after mild TBI. In all cases, the mean scores on these measures for the sample were significantly in the pathological direction compared to the mean scores for normative groups from the general population. Additionally, the indicators of emotional problems in the sample are probably an accurate reflection of the actual level of emotional pathology in that the average MMPI-2 Scale F score does not indicate significant emotional symptom over-reporting. The high level of emotional symptoms also seemed to have a significant relationship to outcome and this is illustrated quite well by the relationship of post-injury depression and outcome. Subjects in the disabled group had a mean score on the Beck Depression Scale-II of 24, a score which would ordinarily be found in those with depression of moderate severity. The importance of this finding is perhaps strengthened by the fact that even when other factors such as pain are simultaneously controlled for, depression still continues to have a significant independent relationship to outcome. Lastly, the importance of depression as an influence on outcome is not simply an extension of pre-injury mental health problems as no such relationship was found between pre-injury depression and post-injury depression. The depression that is important as an influence on outcome is that which develops after the injury.

A strength of this study was that it included an array of credibility measures. This is particularly important in light of the fact that so many of the subjects in the failure to recover as expected sample had injuries which occurred in a compensation or litigation context. Many of the subjects in the sample were in this category and, in many of these cases, the mean scores on the cognitive validity measures were indicative of response bias. Thus, the data support the need for these measures when testing is done under conditions where response bias is possible. Similarly, the mean score for the sample on the MMPI-II Scale 3 which was the measure of physical symptom invalidity was also indicative of response bias. Response bias seemed less of an issue for exaggeration of emotional symptoms as indicated by a more moderate mean score for the sample on the MMPI-II Scale F.

There was a high degree of correlation among many of the validity measures. This was interpreted to mean that, generally, if there was symptom exaggeration in one symptom area it would probably also be found in other areas as well. The high levels of symptom exaggeration found in the sample was felt to be a significant mediator of outcome after mild TBI because the symptom validity scores were all strongly correlated with number and intensity of PCS symptoms and in the case of the MMPI-II Scale 3, with disability itself. There was also an intriguing relationship between the length of time since injury and responses on some of the validity measures. This suggests that symptom exaggeration may be a complex, dynamic process that evolves over time in response to a variety of potential influences. A similar pattern of unexplained late developing cognitive impairment accompanied by worsening somatization after TBI has been reported in a previous paper [66]. The authors do not have an opinion as to why this effect seemed to be present with some of the validity measures, but not with others.

Finally, one of the consequences of having collected data on response bias is that it allowed the effects of cognitive response bias to be controlled for when analysing the actual cognitive test results. In most cases where the cognitive test results correlated with PCS, this relationship disappeared after controlling for response bias.

Conclusions

A previous ($n = 80$) study found that there was a significant relationship between post-injury psychiatric morbidity and recovery after mild TBI [22]. This conclusion from a previous study as well as similar conclusions found by other investigators was again confirmed by the results of the present study.

The study investigated the relationship of pre-injury and neurotrauma variables to outcome after mild TBI. Other than a pre-injury history of psychological traumatization, no other pre-injury factors evaluated by the study appeared to have a relationship to outcome after mild TBI. Similarly, neuro-trauma variables included in this study did not appear to significantly relate to outcome.

A number of post-injury variables were analysed with regard to their association with outcome. Cognitive test variables appeared to have little if any relationship to outcome after mild TBI, after controlling for response bias. This is of significance since subjective cognitive impairment is so frequently reported by those with mild TBI who have prolonged or complicated recoveries. Emotional variables appeared to have a strong relationship to outcome after mild TBI. Among the emotional variables, level of depression appeared to be of the greatest significance in terms of its relationship to outcome. A large number of the sample had headaches and non-cephalic pain. In addition to depression, these physical symptoms also had significant independent relationships to level of post-concussion syndrome, even after controlling for response bias, while only depression had an independent relationship to disability status after mild TBI. Indeed, when combined with cognitive symptom over-reporting, pain and depression accounted for most of the variance in cases of poor outcome after mild TBI. The relationship of multiple variables to outcome is also emphasized by the fact that the largest single group of patients in this failure to recover as expected sample were those with mild TBI plus post-injury depression plus pain occurring simultaneously.

One strength of this study was the use of multiple credibility measures. Separate credibility measures were employed for physical, emotional and cognitive symptoms. Within this sample, a large number of the subjects had credibility scores outside of the cut-off for acceptable validity. When such invalidity was controlled for, it sometimes negated the significance of the symptom associated with it. This finding seems to confirm the importance of validity assessment as an important control measure that should be taken when studying the mild TBI group, particularly in a compensation or litigation context. Associated with this was the intriguing finding of a relationship between length of time since injury and level of invalidity. This observation may have implications for understanding the development of psychological factors and their ability to alter or mitigate recovery from illness and injury.

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