JOURNAL OF NEUROTRAUMA 28:937–946 (June 2011)

DOI: 10.1089/neu.2010.1516

Long-Term Outcomes after Uncomplicated Mild Traumatic Brain Injury: A Comparison with Trauma Controls

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Abstract

The question as to whether mild traumatic brain injury (mTBI) results in persisting sequelae over and above those experienced by individuals sustaining general trauma remains controversial. This prospective study aimed to document outcomes 1 week and 3 months post-injury following mTBI assessed in the emergency department (ED) of a major adult trauma center. One hundred and twenty-three patients presenting with uncomplicated mTBI and 100 matched trauma controls completed measures of post-concussive symptoms and cognitive performance (Immediate Post-Concussion Assessment and Cognitive Testing battery; ImPACT) and pre-injury health-related quality of life (SF-36) in the ED. These measures together with measures of psychiatric status (the Mini-International Neuropsychiatric Interview [MINI]) pre- and post-injury, the Hospital Anxiety and Depression Scale, Visual Analogue Scale for Pain, Functional Assessment Questionnaire, and PTSD Checklist-Specific, were re-administered at follow-up. Participants with mTBI showed significantly more severe post-concussive symptoms in the ED and at 1 week post-injury. They performed more poorly than controls on the Visual Memory subtest of the ImPACT at 1 week and 3 months post-injury. Both the mTBI and control groups recovered well physically, and most were employed 3 months post-injury. There were no significant group differences in psychiatric function. However, the group with mild TBI was more likely to report ongoing memory and concentration problems in daily activities. Further investigation of factors associated with these ongoing problems is warranted.

Key words: mild traumatic brain injury outcomes

Introduction

Traumatic brain injury is the leading cause of disability in young people. Mild traumatic brain injuries (mTBI) constitute at least 80% of these injuries (Kraus and McArthur, 1999). Despite this, there is continuing debate over the existence and nature of mTBI impairment. Studies have documented a range of persisting post-concussive symptoms and cognitive impairments, particularly in the domains of attention, speed of information processing, and memory, in individuals with mTBI (Carroll et al., 2004; Kraus et al., 2005; Lundin et al., 2006; Vanderploeg et al., 2005; Yang et al., 2007).

However, study findings have been variable depending on the context, sampling methods, and timing of assessment. Studies based on clinic presentations and/or including participants in litigation are associated with higher rates of cognitive sequelae and worsening cognitive functioning over time (Belanger et al., 2005a). Few studies have recruited and assessed patients in the emergency department (ED) and monitored them prospectively over an extended period while documenting both cognitive function and post-concussive symptoms.

Recent articles have suggested that factors such as pain, narcotic medications, other bodily injuries, and acute stress disorder may contribute both to reported post-concussional symptoms and impaired neuropsychological test performance, particularly in the acute stages of recovery (Carroll et al., 2004; McLean et al., 2009; Meares et al., 2006, 2008; Ponsford, 2005). However, few studies have controlled for the influence of these factors.

Shores and colleagues (2008) and Peterson and colleagues (2009) found poorer cognitive performance in groups of 82 and 23 mTBI patients, respectively, as assessed in the ED with subtests of the Immediate Post-Concussion Assessment and Cognitive Testing battery (ImPACT). Sheedy and colleagues (2006) found impairments of immediate memory and balance

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in 29 mTBI patients relative to controls with minor trauma. Landre and colleagues (2006) found poorer cognitive performance but no difference in reporting of post-concussive symptoms in 37 hospitalized mTBI patients with other significant injuries and 39 hospitalized trauma controls assessed an average of 4.5 days post-injury. However, these studies lacked subsequent patient reassessment.

Ponsford and colleagues (2000) assessed post-concussive symptoms and cognitive performance at 1 week and 3 months post-injury in 84 mTBI cases and 53 trauma controls. The mTBI group exhibited more post-concussive symptoms and impairment on measures of information processing speed than controls at 1 week post-injury, but there were no group differences by 3 months post-injury. This study highlighted the potential influence of other life stressors and psychological factors on outcome. However, pre- and post-injury psychiatric states were not formally assessed in this study and consequently their influence was not reliably assessed.

More recent studies have also demonstrated the significance of psychological factors as potential contributors to poorer outcomes following mTBI. Meares and colleagues (2006, 2008) and McLean and associates (2009) have argued that post-concussive symptoms are no more likely to occur in people with mTBI than in those with general trauma. In a study involving patients admitted to hospital with major trauma assessed at an average of 4.9 days post-injury, Meares and colleagues (2006) defined the post-concussive syndrome (according to the ICD-10 PCS classification [World Health Organization, 1993]) as three or more of the ICD-10 symptoms (fatigue, dizziness, poor concentration, memory problems, headache, insomnia, and irritability) rated as occurring at least "Often," (scoring 3 or more on the 5-point scale) on an adapted Post-Concussion Syndrome Checklist. Using these criteria, they found a closer relationship between the presence of the post-concussive symptoms and pre-injury psychological state, particularly pre-injury anxiety disorder, than with neuropsychological test performance or the presence of mTBI. They also highlighted the potential association of impaired memory with use of narcotic analgesia, and as well as with anxiety, depression, and stress. However, their study focused only on patients admitted to hospital, including those with major trauma and subsequent surgical interventions, which potentially confounded reporting of symptoms. Arguably the influence of these factors is more accurately assessed in the absence of such confounding influences. The study by McLean and co-workers (2009) included trauma patients with and without mTBI who were not admitted to hospital. They found that baseline mental and physical health status, but not the presence of head injury, predicted persistent symptoms at 1, 3, and 12 months post-injury, and called for studies with more detailed assessment of pre-injury symptoms and health. They did not assess participants prior to 1 month post-injury.

In the present study we aimed to prospectively document post-concussive symptoms and related cognitive, psychological, and functional outcomes in a group of patients with uncomplicated mTBI, who required no anesthesia during their initial hospital presentation. These data were compared to a demographically similar group of trauma controls (TCs). Pre-injury psychiatric history and health status, post-injury post-concussive symptoms, cognitive performance and functional outcomes, as well as pain, post-traumatic stress, and psychological state were all documented. On the basis of previous studies, it was hypothesized that mTBI participants would experience more post-concussion symptoms and perform more poorly on cognitive measures than trauma controls in the ED and at 1 week post-injury, but not at 3 months post-injury.

Methods

This study was approved by the Alfred Hospital and Monash University Ethics Committees.

Participants

Participants were recruited consecutively from the Alfred Emergency & Trauma Centre (E&TC) in Melbourne, Australia. Inclusion criteria for the mTBI group included: (1) recent (<24 h) history of trauma or acceleration-deceleration movement applied to the head resulting in loss of consciousness (LOC) <30 min, post-traumatic amnesia (PTA) <24 h, and a Glasgow Coma Scale (GCS) score of 13–15 on presentation to the ED; (2) age 18 years or over; and (3) English-speaking. Participants were excluded if they: (1) were intubated or required general anesthesia following injury; (2) had a breath alcohol reading >0.05 mg/L at the time of recruitment; (3) were under the influence of illicit substances at the time of injury; (4) had focal neurological signs, seizures, and/or intracerebral abnormalities on CT; (5) had a dominant upper limb injury that precluded them from using a computer mouse; (6) were under spinal precautions and not able to sit upright; (7) had a history of previous cognitive impairment, neurological illness, significant alcohol or drug abuse, or other psychiatric impairment currently affecting daily functioning; or (8) were unavailable for follow-up. The trauma control (TC) group comprised patients presenting with minor injuries not involving the head and no LOC or PTA following their injury. Other inclusion and exclusion criteria were the same as for the mTBI group. Individuals with a medical history of non-neurological illness (such as cardiac disease, hypertension, cancer, and diabetes), psychiatric history (excluding psychosis), prior mTBI, and reported alcohol and/or cannabis use were included in the study if they did not report any significant pre-injury cognitive difficulties.

Measures

Glasgow Coma Scale (GCS). This scale (Teasdale and Jennett, 1976) assesses conscious state utilizing the injured person's best eye-opening and verbal and motor responses, yielding a total score between 3 (a person showing no response) and 15 (a person who is alert and well oriented).

Post-traumatic amnesia. PTA duration was determined by asking the patient to describe their first memory after the injury until they could provide a detailed and continuous recall of events. This information was verified by examination of ambulance and hospital admission notes and discussion with accompanying persons. Patients were also screened using the revised Westmead PTA Scale (Ponsford et al., 2004), and if still in PTA on admission to the ED, the scale was administered prospectively at hourly intervals until a perfect score was obtained.

ImPACT and Post-Concussion Symptom Scale. ImPACT is a validated (Iverson et al., 2005) computer-administered neuropsychological test battery consisting of five test modules, which test attention, verbal and visual memory, processing speed, and reaction time, with a summary measure for each. In addition to the cognitive measures, ImPACT also contains a Post-Concussion Symptom Inventory (Lovell and Collins, 1998) comprising 22 common concussion symptoms (e.g., headache and dizziness), with the severity ranging from 0 = none to 6 = severe. The list is more expansive than the criteria included in ICD-10. The symptoms can be added to obtain a total post-concussive symptoms summary score, reflecting the number and severity of symptoms.

Hospital Anxiety and Depression Scale. The Hospital Anxiety and Depression Scale (HADS) is a 14-item self-assessment of anxiety and depression, grading current symptoms on a 4-point Likert scale (0–3),with a total possible score from 0–21 for each. The physical symptoms of mood disorders also associated with medical illness are excluded from the scale (Snaith and Zigmond, 1986). The HADS has been validated on patients with TBI (Whelan-Goodinson et al., 2009).

The Post-Traumatic Stress Disorder (PTSD) Checklist-Specific. The PTSD Checklist-Specific (PCLS) is a self-report rating scale for assessing the 17 *Diagnostic and Statistical Manual of Mental Disorders IV* symptoms of PTSD on a five-point scale from "not at all" to "extremely." The scale has been comprehensively validated (Blanchard et al., 1996; Forbes et al., 2001).

SF-36 Health Survey. The SF-36 Health Survey (SF-36; Jenkinson et al., 1993; Ware and Sherbourne, 1992) was used to document pre- and post-injury health-related quality of life from the perspective of the injured person. It comprises a 36-item questionnaire, yielding an 8-scale health profile (Physical Functioning, Role Limitations because of physical health problems, Bodily Pain, Social Functioning, General Mental Health, Role Limitations because of emotional problems, Vitality [energy/fatigue], and General Health Perceptions), and two summary measures (Physical Component Summary [PCS] and Mental Component Summary [MCS]).

The Mini-International Neuropsychiatric Interview. The Mini-International Neuropsychiatric Interview (MINI; Sheehan et al., 1998) was used to document pre- and post-injury psychiatric status. It is a brief, reliable, and valid structured diagnostic interview comprising 130 questions, screening for 16 axis I DSM-IV disorders and one personality disorder.

Visual Analogue Scale. The Visual Analogue Scale (VAS) is a brief scale ranging from 0 ("no pain") to 10 ("extreme pain") used to measure pain. The VAS has been commonly used as a brief and convenient measure of pain for more than 30 years (Huskisson, 1974).

Functional Assessment Questionnaire. The Functional Assessment Questionnaire (FAQ) is a 15-item measure of the impact of head injury symptoms on everyday activities (e.g., banking, cooking, and cleaning). The FAQ is graded on a 3-point scale ranging from 1 ("Yes, limited a lot") to 3 ("No, not limited at all"), with total scores from 15–45, the latter indicating no limitations.

Procedures

Potential mTBI and TC participants were identified on the computerized E&TC patient list. Patients with mTBI were recruited after they had emerged from PTA, as assessed using the Revised Westmead PTA Scale. After providing informed consent and background information, participants completed the baseline assessment at the hospital prior to discharge, or in a few cases at home, but within 48 h of injury. The baseline assessment comprised the ImPACT battery, including the Post-Concussion Symptom Inventory, and the SF-36 as it pertained to the participants' general health and well being prior to injury. At 1 week follow-up, participants in both groups completed the ImPACT cognitive battery and the Post-Concussive Symptom Inventory, SF-36, HADS, VAS, and FAQ as they pertained to current functioning. Information relating to current capacity for work or study was also collected. The MINI diagnostic interview was completed with respect to prevalence of lifetime pre-injury psychiatric disorders. At the 3-month follow-up, participants repeated the same assessments. However, the SF-36 examined the participants' general health and well being over the preceding 4-week period, and the MINI examined psychiatric status within the 3 months since injury. Participants were also asked about employment status and completed the PCLS questionnaire to measure PTSD symptoms.

Statistical analysis

Data analysis was undertaken with SPSS 17 (SPSS, Inc., Chicago, IL), and statistical significance at the 0.05 level with exact p values are reported. Categorical variables were presented as percentages and continuous variables as medians and minimum-maximum. Assumptions regarding normality of distributions were examined using qq and box plots, as well as the Kolmogorov-Smirnov and Shapiro-Wilk tests. Scores for the mTBI and TC groups on the various outcome measures were compared at the three measurement time points using univariate, multivariate, and repeated-measures analyses, where appropriate. Chi-square testing was used for categorical variables, and the Mann-Whitney U test for continuous variables that were not normally distributed. Within-subject changes over time were calculated with the Wilcoxon Signed Ranks test and Friedman test, depending on the number of time points being compared. Probability values for the group comparisons are presented in the last column of the results tables, while the within-subject comparison results are provided in superscript below the tables.

Results

Participants were recruited between January 2007 and January 2009. During this period 882 potential mTBI participants were admitted to the E&TC while it was staffed by an mTBI researcher. Of these, 196 were eligible and 123 were recruited into the study (Fig. 1). Ninety percent of TBI participants had had CT scans. Of 1404 potential TC participants, 338 were eligible and 100 were recruited and completed the baseline assessments. Demographics for all participants are presented in Table 1. Regarding ethnicity, 82.2% of participants were born in Australia or New Zealand, 4.4% in the United Kingdom, 2.2% in other European countries, 3.3% in India, and one case each in South Africa, Lebanon, Egypt,

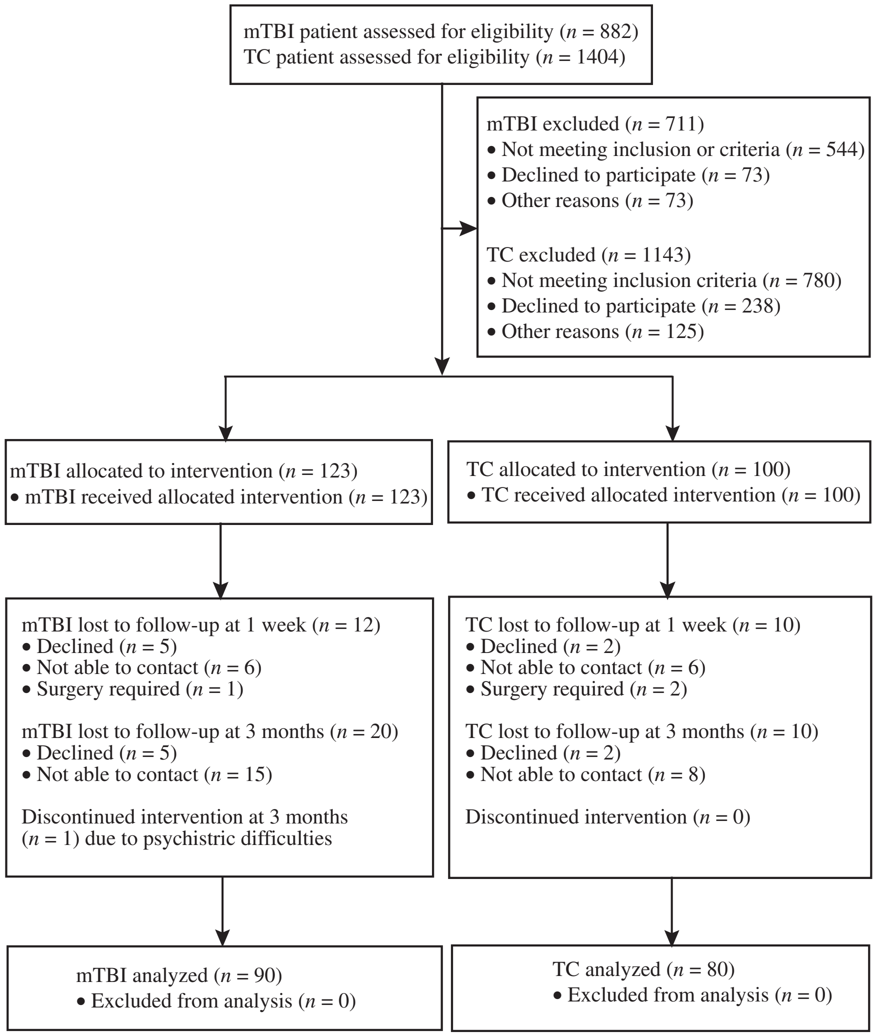

FIG. 1. Summary of participant recruitment (mTBI, mild traumatic brain injury; TC, trauma control).

Indonesia, Singapore, and Brazil. There were no significant differences between groups in terms of gender, age, education, and marital or employment status. The mTBI group more commonly sustained assault-related injuries than controls. More mTBI participants than controls had soft-tissue injuries or lacerations.

Of the 120 mTBI participants with a known LOC status, 111 (92.5%) had a LOC with the median LOC being 7 sec, a mean of 61.44 (SD = 110) sec, and the range being 0–10 min. Overall, 118 (96.7%) TBI participants had a reported period of PTA, with the median PTA being 15 min, a mean of 103 (SD = 191) min, and the range being 0–24 h.

At baseline in the ED, 77 (62.6%) mTBI patients and 44 (44%) TCs reported taking narcotic analgesics ($p = 0.06$). At 1 week, these numbers dropped to 20 (18.2%) in the TBI group, and 19 (21.1%) in TCs, without any significant group difference ($p = 0.603$). At 3 months the use of narcotic analgesics dropped to 2 patients in each group ($p = 0.905$).

Of the 123 mTBI participants recruited, 111 (90.24%) completed the 1-week assessment, and 90 (73.17%) completed the 3-month follow-up. Of the 100 TCs, 90 (90%) completed the 1-week follow-up, and 80 (80%) the 3-month follow-up. There was no significant difference in gender between participants who consented to participate in the study and those who declined ($p = 0.369$). However, those who consented to participate were significantly older, with a median age of 32 years, compared to 29 years for decliners ($p = 0.008$). The subsequent results are presented for those participants completing the 3-month follow-up only.

Post-concussion symptoms

The groups differed significantly in terms of reported post-concussive symptoms, both on baseline assessment in the ED and at 1 week post-injury, with the mTBI group having more than double the Post-Concussive Symptom Inventory score of the control group at both time points. Percentages of symptoms reported in each group at each time point are presented in Table 2.

In the ED mTBI participants reported more headaches ($p < 0.001$), nausea ($p = 0.008$), vomiting ($p < 0.001$), balance problems ($p = 0.014$), dizziness ($p < 0.001$), fatigue ($p < 0.001$), sleeping more ($p = 0.024$), drowsiness ($p < 0.001$), sensitivity to light ($p = 0.003$), irritability ($p = 0.039$), feeling slowed ($p < 0.001$), and foggy ($p < 0.001$), problems concentrating ($p < 0.001$), and remembering ($p < 0.001$), and visual problems

Table 1. Profile of the Patients by Group

Demographics		*mTBI* (n = *123*)	*TC* (n = *100*)
		M / median (SD)	
Age (years)		34.98/31 (13.13)	35.40/66 (10.72)
Education (years)		13.58/13 (2.81)	14.23/14 (2.59)
		n (%)	
Gender (male)		91 (74)	64 (64)
Married/de facto		47 (38.2)	41 (40)
Employment status	Full-time	96 (78)	84 (84)
	Part-time	9 (7.3)	2 (2)
	Casual	4 (3.3)	9 (9)
	Student	3 (2.4)	2 (2)
	Not working	11 (8.9)	3 (3)
Cause of injury	Assault	16 (13.3)**	2 (2)
	Motor vehicle collision[a]	49 (40.9)	28 (28)
	Bicycle collision	24 (20)	18 (18)
	Fall	15 (12.5)	23 (23)
	Sport injury	10 (8.3)	11 (11)
	Other	9 (7.3)	18 (18)
Type of injury	Soft tissue/laceration	97 (78.9)***	59 (59)
	Fracture	21 (17.1)	21 (21)
	Ligamentous	5 (4.1)	19 (19)
	Dislocation	0 (0)	1 (1)

[a]This category includes motor vehicle, motorcycle, accidents and pedestrians hit by vehicles.
**$p = 0.001$ and ***$p < 0.001$ by χ^2 test.
mTBI, mild traumatic brain injury; TC, trauma control.

Table 2. Percentages of Participants with Post-Concussive Symptoms (PCS) at Each Time Point by Group and Total PCS by Group

	Baseline		*1 Week*		*3 Months*	
Symptom	*mTBI*	*TC*	*mTBI*	*TC*	*mTBI*	*TC*
Headache	78.9	35.0	57.8	27.5	25.8	27.5
Drowsiness	78.9	48.8	47.8	26.3	23.6	23.8
Fatigue	73.3	47.5	61.1	42.5	37.1	22.5
Dizziness	67.8	41.3	31.1	18.8	7.9	13.8
Slowed	67.8	45.0	58.9	51.3	22.5	22.5
Foggy	60.0	30.0	40.0	20.0	15.7	7.5
Concentrating	47.8	18.8	41.1	25.0	13.5	11.3
Remembering	46.7	7.5	26.7	16.3	15.7	11.3
Nausea	45.6	32.5	16.7	11.3	3.4	7.5
Balance	44.4	30.0	26.7	23.8	6.7	6.3
Light sensitivity	40.0	20.0	10.0	11.3	4.5	7.5
Emotional	34.4	28.8	31.1	22.5	18.0	12.5
Difficulty falling asleep	33.3	33.8	28.9	33.8	22.5	17.5
Sleeping less	33.3	42.5	16.7	25.0	18.0	13.8
Sleeping more	31.1	17.5	43.3	13.8	10.1	11.3
Visual difficulties	31.1	15.0	17.8	6.3	7.9	6.3
Tingling	30.0	37.5	22.2	26.3	15.7	7.5
Nervousness	28.9	20.0	17.8	11.3	13.5	13.8
Irritability	27.8	15.0	30.0	23.8	23.6	17.5
Sadness	26.7	20.0	25.6	15.0	15.7	6.3
Vomiting	18.9	1.3	1.1	1.3	1.1	1.3
Noise sensitivity	18.9	10.0	22.2	10.0	5.6	5.0
Total PCS						
Mean	37.9	19.1	22.1	15.8	10.4*	9.7*
Median	32.5	13.5	16.0	7.5	4.0	4.0
Standard deviation	22.7	19.3	20.8	19.8	15.5	17.2
P	<0.001		0.019		0.424	

*$p < 0.0001$ by Friedman test for within-subject comparisons over time.
mTBI, mild traumatic brain injury; TC, trauma control.

Table 3. ImPACT Composites at Baseline, 1 Week, and 3 Months by Group

ImPACT composite		*mTBI* n = *90*	*TC* n = *80*	p
		M/Median (SD)		
Verbal memory composite	Baseline	77.21/77.00 (11.46)	78.95/79.00 (10.94)	0.200
	1 Week	78.65/80.00 (12.22)	81.65/82.50 (11.13)	0.103
	3 Months	81.44/83.00 (13.48)*	84.15/86.00 (10.91)**	0.270
Visual memory composite	Baseline	62.61/62.50 (12.61)	64.66/64.50 (15.77)	0.389
	1 Week	63.70/63.50 (15.86)	69.12/70.00 (15.20)	0.030
	3 Months	67.89/69.00 (13.59)***	72.91/75.00 (12.80)****	0.015
Motor speed composite	Baseline	32.41/32.89 (8.40)	34.12/33.23 (8.02)	0.416
	1 Week	34.31/35.34 (9.86)	36.10/35.03 (8.57)	0.371
	3 Months	35.14/34.38 (9.21)****	36.17/36.00 (8.67)****	0.421
Reaction time composite	Baseline	.68/.65 (.16)	.65/.63 (.11)	0.280
	1 Week	.69/.61 (.39)	.62/.60 (.10)	0.589
	3 Months	.63/.60 (.10)****	.80/.60 (1.57)****	0.653

*$p = 0.007$, **$p = 0.006$, ***$p = 0.001$, ****$p < 0.001$ by Friedman test for within-subject comparisons over time.
ImPACT Immediate Post-Concussion Assessment and Cognitive Testing battery; mTBI, mild traumatic brain injury; TC, trauma control.

($p = 0.027$; Table 2). Overall, 98.9% of TBI participants versus 91.3% of controls reported at least one symptom at baseline ($p = 0.019$). Applying the ICD-10 criteria used by Meares and associates (2008), 45.5% of mTBI participants and 14.0% of TCs reported a score of 4 or more on 3 or more of the ICD-10 symptoms ($p < 0.001$).

At 1 week post-injury mTBI participants reported experiencing significantly more severe headaches ($p < 0.001$), fatigue ($p = 0.012$), drowsiness ($p = 0.018$), tending to sleep more ($p < 0.001$), and concentration difficulties ($p = 0.022$) than TCs. They also reported greater sensitivity to noise ($p = 0.038$), feeling foggy ($p = 0.016$), and having visual difficulties ($p = 0.026$). However, there were no significant group differences in the number of participants reporting one or more symptoms or meeting ICD-10 criteria. At 1 week, 81 (90%) TBI participants and 67 (83.8%) controls reported at least one symptom ($p = 0.226$), and 17.9% of mTBI participants and 12.0% of TCs reported a score of 4 or more on more than 2 of the ICD-10 symptoms ($p = 0.224$; Table 2).

There was a significant drop in reported post-concussive symptoms over time (Table 2). Whereas 30.7% of mTBI participants and 26.6% of TCs reported symptoms at 1 week but none at 3 months post-injury, only 3.4% of mTBI cases and 3.8% of TCs reported symptoms at 3 months but not at 1 week. However, 17% of mTBI participants and 25.3% of TCs reported more symptoms at 3 months than at 1 week post-injury. There were no significant differences in overall reporting of post-concussive symptoms at 3 months post-injury, nor did any particular symptom differentiate the groups. However, there was a trend toward greater sadness ($p = 0.057$) and greater fatigue reported by more mTBI participants ($p = 0.083$). At 3 months, 56 (63.6%) TBI participants and 48 (60.8%) controls reported at least one symptom ($p = 0.702$), while only 5.7% of mTBI participants and 7.0% of TCs reported a rating of 4 or more for 3 or more post-concussive symptoms ($p = 0.689$; Table 2).

Cognitive functioning (ImPACT)

Participants were tested at a mean of 24 h post-injury (SD = 31 h). There were no statistically significant differences between the groups in performance on any of the ImPACT scales at baseline assessment in the ED. However, the mTBI group attained significantly poorer scores on the Visual Memory composite at both 1 week and 3 months post-injury relative to TCs (Table 3). In both groups, there was a significant improvement over time in verbal and visual memory, motor speed, and reaction time composite scores.

MINI psychiatric status

The groups differed significantly in the frequency of total lifetime reported psychiatric or substance abuse problems measured at 1 week, with 43 (51.2%) of mTBI participants and 47 (68.1%) of TCs reporting having experienced such problems at some time in their life ($p = 0.034$). However, when the frequencies of classes of disorders (anxiety disorders, depressive disorders, and substance abuse disorders) were compared separately, as shown in Table 4, the differences disappeared ($p = 0.158$, 0.885, and 0.242, respectively). In addition, there was no statistically significant difference in the frequency of psychiatric and substance abuse problems during the 3 months post-injury, with 23 (26.4%) mTBI patients and 12 (15.6%) TCs reporting having experienced these problems ($p = 0.090$). However, as can be seen in Table 4, mTBI participants were somewhat more likely to experience psychiatric problems across all categories after injury, relative to TCs.

Hospital Anxiety and Depression Scale

The groups did not differ on the HADS at baseline, 1 week, or 3 months post-injury (Table 5). There was a significant reduction in anxiety and depression symptoms in both groups over time.

PCLS and PTSD

The mTBI group had significantly higher median scores on the PCLS ($p = 0.003$) at 3 months (Table 5). However, there was no group difference in the frequency of a PTSD diagnosis ($p = 0.338$).

SF-36 health-related quality of life

The groups differed significantly in mental quality of life at pre-injury (measured at baseline), 1 week, and 3 months, with

Table 4. Lifetime Pre-Injury and 3-Month Post-Injury Psychiatric Diagnoses of mTBI and TC Participants on the MINI

MINI disorder class	*mTBI* n=90	*TC* n=80	p
	n (%)		
Lifetime anxiety[1]	14 (16.1)	19 (25)	0.158
Lifetime depression[2]	24 (27)	20 (26)	0.885
Lifetime substance abuse[3]	28 (31.1)	31 (39.7)	0.242
Last 3 months anxiety[4]	11 (12.5)	6 (7.7)	0.308
Last 3 months depression[4]	12 (13.5)	6 (7.5)	0.208
Last 3 months substance abuse[4]	6 (6.7)	3 (3.8)	0.505

[1]Lifetime anxiety encompasses any lifetime panic attacks, panic disorder, agoraphobia with and without panic disorder, social phobia, obsessive-compulsive disorder, post-traumatic stress disorder, and generalized anxiety disorder.
[2]Lifetime depression encompasses any lifetime major depression episode, recurrent major depression, dysthymia and suicidality.
[3]Lifetime substances encompass any lifetime alcohol abuse and dependence and abuse of illicit substances.
[4]Includes the same subcategories as the respective lifetime categories, but limited to occurrence in the last 3 months, including the current state.
mTBI, mild traumatic brain injury; TC, trauma control; MINI, Mini-International Neuropsychiatric Interview.

the mTBI group having a significantly poorer mental quality of life (Table 5). With respect to particular subscales, controls had significantly better median pre-injury scores on General Health ($z = -2.07$, $p = 0.038$), Vitality ($z = -3.11$, $p = 0.002$), and Mental Health ($z = -3.29$, $p = 0.001$) than mTBI participants. At 1 week, TCs had lower median scores on Physical Functioning ($z = -.244$, $p = 0.015$), but better median scores on General Health ($z = -2.53$, $p = 0.011$), Vitality ($z = -2.69$, $p = 0.007$), and Mental Health ($z = -2.38$, $p = 0.018$) than mTBI participants. At 3 months, mTBI participants again had poorer mean scores than controls on General Health ($z = -2.07$, $p = 0.038$), Vitality ($z = -2.33$, $p = 0.020$), and Mental Health ($z = -2.91$, $p = 0.004$).

There was a significant change over time in the Physical Component Score in both mTBI patients and controls. In both groups, the score dropped dramatically at 1 week, and then returned to a level similar to pre-injury levels. In contrast, there was a significant change over time in the Mental Component Score in the mTBI group only. As for the Physical Component Score, the drop in the Mental Component Score was most significant at 1 week and returned to pre-injury levels at 3 months.

Pain (VAS)

There were no group differences in the median pain score at 1 week or 3 months post-injury (Table 5). Over time, both groups significantly improved on the VAS (both $p < 0.001$).

Functioning in everyday life activities (FAQ)

At 1 week post-injury controls were found to have greater limitations with respect to cleaning ($p = 0.022$) and doing laundry ($p = 0.007$), while the mTBI participants more commonly had problems with concentration ($p = 0.003$) and memory ($p = 0.016$), and tended to take naps ($p = 0.053$). At 3 months post-injury, mTBI participants still reported

Table 5. Mean and Median Scores on the HADS, SF-36, VAS, and PCLS, and Percentages with PTSD Symptoms by Group

Measure		*mTBI* n=90	*TC* n=80	p
		M/median (SD)		
HADS anxiety	1 Week	5.28/5 (3.94)	5.04/4 (3.99)	.527
	3 Months	4.02/3 (3.72)*	3.38/2 (3.59)**	.407
HADS depression	1 Week	4.35/3 (3.81)	3.75/3 (3.25)	.267
	3 Months	2.40/1 (1.00)**	1.59/1 (2.34)**	.058
SF-36 physical health	Baseline	54.43/55.90 (6.41)	54.05/55.99 (6.06)	.578
	1 Week	38.47/37.65 (10.05)	36.00/34.99 (9.57)	.108
	3 Months	51.96/54.95 (8.73)**	50.22/53.13 (8.91)**	.143
SF-36 mental health	Baseline	49.10/52.03 (8.42)	53.02/54.17 (6.50)	.001
	1 Week	43.75/44.77 (11.02)	49.08/51.82 (10.49)	.001
	3 Months	47.90/51.40 (10.44)***	53.27/55.13 (7.25)	<.001
VAS pain	1 Week	20.63/13 (21.58)	22.49/15 (21.90)	.366
	3 Months	7.44/2 (13.08)**	7.49/1 (14.73)**	.643
PCLS	3 Months	25.19/22 (9.90)	21.64/19 (7.75)	.003
		Frequency (%)		
PTSD	Cut-off 45	7 (7.8)	3 (3.8)	.338

*$p = 0.002$, **$p < 0.001$, ***$p = 0.001$ by Wilcoxon signed-rank test and Friedman test for within-subject comparisons over time.
PCLS, PTSD Checklist-Specific; PTSD, post-traumatic stress disorder; HADS, Hospital Anxiety and Depression Scale; VAS, Visual Analogue Scale; SD, standard deviation; mTBI, mild traumatic brain injury; TC, trauma control.

experiencing more problems with concentration ($p = 0.010$) and memory ($p = 0.029$) than controls, with 27.8% reporting ongoing concentration difficulties and 30% ongoing memory difficulties affecting daily activities. Over time, both the mTBI and control groups significantly improved in their functional outcomes on each of the FAQ 15 subscales (all $p < 0.05$).

Return to work

By 1 week post-injury, 46.5% of mTBI participants and 61% of controls had returned to work ($p = 0.063$). By 3 months, 80 (93%) mTBI participants and 73 (92.4%) controls were in employment ($p = 0.879$).

Litigation

Very few participants in either group were involved in litigation. In the mTBI group, 15 (17.2%) participants were involved in litigation versus 7 (8.9%) patients in controls ($p = 0.112$). The mTBI group less commonly sought compensation, but more frequently claims were laid against mTBI participants ($p = 0.013$ and 0.030, respectively).

Discussion

This group of individuals with uncomplicated mTBI experienced significantly more frequent and severe post-concussive symptoms acutely and at 1 week after injury relative to a demographically similar trauma control group. This was particularly evident for headaches, fatigue, drowsiness, tending to sleep more, concentration difficulties, feeling foggy, greater sensitivity to noise, and visual difficulties. Indeed the total post-concussive symptom score was the measure that most strongly differentiated the groups within the first week after injury. However, using the ICD-10 criteria of obtaining a score of 4 or more on more than 2 subsets of post-concussion symptoms, similar to that used by Meares and colleagues (2008), the groups were differentiated only on initial assessment in the ED and not at 1 week. This highlights the significance of the manner in which post-concussive symptoms are documented. Had the post-concussive symptoms been measured according to ICD-10 criteria, then we also would have concluded that mTBI patients did not differ from TCs in their reporting of post-concussive symptoms 1 week after injury. It appears that individuals with mTBI experience a broader range of symptoms relative to TCs than those included in the ICD-10 classification, namely sensitivity to noise, visual disturbance, drowsiness, sleeping more, and feeling foggy, and the presence of these should be assessed. As suggested by Boake and colleagues (2005), there is a need to review the criteria for defining PCS following TBI in order to enhance diagnostic specificity.

In terms of cognitive function, the mTBI group did not perform more poorly than controls on any ImPACT subscales in the ED, with the TCs also showing impaired performance, presumably reflecting the effects of general trauma, pain, and/or medication. This finding differs from those of Shores and associates (2008), who found impairment on all ImPACT subtests, and Peterson and colleagues (2009), who found impairment on the Visual Motor Speed and Reaction Time subscales of the ImPACT in mTBI patients assessed in the ED. This underscores the importance of using appropriate comparison groups when assessing mTBI patients early after injury.

However, at 1 week and 3 months post-injury the mTBI group did perform more poorly than trauma controls on the ImPACT Visual Memory Index. This subscale assesses memory for a series of non-verbalizable designs and for the position of Xs and Os on a grid. It arguably requires the most mental effort of the ImPACT subscales because it is difficult to apply a strategy to aid memorization of the designs. Previous studies have found impairments in attention and information processing speed on tests including visual reaction time, Digit Symbol Coding, the Symbol Digit Modalities test, the Speed of Comprehension Task, and the Paced Auditory Serial Addition Task, in the early days or weeks after injury, with some studies also showing impairments on tests of visual and/or verbal memory (Carroll et al., 2004; Echemendia et al., 2001; Halterman et al., 2006; Kwok et al., 2008; Malojcic et al., 2008; Peterson et al., 2009; Ponsford et al., 2000; Vanderploeg et al., 2005). The meta-analysis by Belanger and associates (2005b) found deficits in the domains of fluency and delayed memory to be most common in the first 90 days post-injury. The current finding of impairment in the domain of visual memory at 1 week and 3 months post-injury is not inconsistent with this. Verbal fluency was not assessed in the present study.

In terms of physical function, both groups reported pain and physical limitations within the first week after injury, but these changes had resolved by 3 months post-injury. Most participants in both groups had also returned to work at 3 months post-injury, and there were few ongoing functional limitations in either group. On the SF-36, the mTBI group reported significantly poorer General Health, Vitality, and Mental Health, but this was also the case for their pre-injury ratings on these scales, highlighting the importance of documenting pre-injury status in such studies. However, the mTBI group also reported experiencing more ongoing concentration and memory problems in their daily activities than controls at both 1 week and 3 months post-injury. Kraus and colleagues (2005) also found that after adjusting for pre-injury characteristics, memory and learning difficulties, as well as headaches, dizziness, vision difficulties, and alcohol intolerance were reported significantly more frequently by a group of 235 patients who had been hospitalized for mTBI relative to 235 trauma controls interviewed 6 months after injury. Mickeviciene and associates (2004) also documented self-reported continuing memory and concentration problems, and dizziness and tiredness, as well as worry about the brain injury at 3 and 12 months post-injury relative to trauma controls.

In terms of mental health, overall there were no statistically significant group differences in psychiatric diagnoses or HADS anxiety and depression scores in the 3 months after injury, although there was a trend for mTBI participants to show more psychiatric symptoms on the MINI following injury. Few participants in either group were engaged in litigation. As no symptom validity testing was carried out, one cannot entirely rule out the possibility of biased responding, but litigation was not a factor that appeared to influence outcomes in this study. The high rates of return to employment would support this.

Given the significant number of statistical comparisons performed in this study, the possibility of Type 1 error cannot be ruled out. Nevertheless it is noteworthy that most significant findings were in the same direction. Overall this study, which is one of only a few comprehensive prospective studies controlling for the effects of general trauma, has confirmed the earlier findings by Ponsford and colleagues (2000), that uncomplicated mTBI does result in significantly more postconcussive symptoms and some cognitive dysfunction during the early days post-injury, but found little evidence of ongoing functional limitations relative to those experienced by individuals who have sustained general trauma by 3 months after injury. However, there was evidence of ongoing impairment of cognitive function (on the ImPACT Visual Memory subtest), and a significant proportion of these individuals (27–30%) were reporting reduced concentration and memory difficulties that affected their daily activities. This finding suggests that at least a proportion of these mTBI participants did have subtle residual cognitive sequelae 3 months post-injury. This is consistent with findings from recent sophisticated imaging studies that have identified cerebral changes which were not evident on CT scans in at least a proportion of mild TBI cases (Bigler, 2008; Cohen et al., 2007; Togal et al., 2008; Wilde et al., 2008; Zhang et al., 2006). However, as these patients did not have such scans we cannot comment on the nature or extent of any brain lesions in this mTBI group. Further investigation is required to examine the factors associated with the ongoing symptoms seen in these individuals with mTBI.

Acknowledgments

This research was funded by a grant from the Victorian Neurotrauma Initiative. The authors also gratefully acknowledge the assistance of staff in the Alfred Hospital Emergency and Trauma Care Department.

Author Disclosure Statement

No competing financial interests exist.

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